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ARCOM Declaration:

The papers in these proceedings were double-blind refereed by members of the scientific committee in a process that involved, detailed reading of the papers, reporting of comments to authors, modifications of papers by authors and re-evaluation of re-submitted papers to ensure quality of content.

Foreword

Welcome from the Chair of ARCOM 2020

Professor Lloyd Scott, Technological University Dublin

As we began to roll out the early stage planning for the 36th Annual ARCOM Conference, the world came face to face with the unprecedented challenges of the COVID-19 pandemic. While the immediate global priority remains to tackle this public health emergency, society's long-term response must also address the underlying causes of such a pandemic and certainly the ARCOM community can make a strong contribution to this.

So, with the COVID-19 restrictions and the speed with which the pandemic took hold, the conference organising committee were left with a decision, back in early April, whether or not to hold the conference and if so what type of conference might it be. The shared consensus was that some form of conference needed to be had. After all, it might be said, spread around the world, the ARCOM community should come together and move forward with 'the common good'. We hope, indeed expect, that an effective vaccine will be developed quickly but, in the meantime, we are left to our own resources and virtual it is for this year. So, I am humbled to welcome you to the first ever virtual ARCOM conference.

This year's conference attracted 294 submissions in January 2020. Following three rounds of double-blind peer-review, a total of 110 papers were eventually accepted for presentation at the conference. In a field that is now saturated with so many international conferences, this success rate demonstrates the rigour applied to the ARCOM peer-review process. Of course, this cannot be achieved without the support of 110 reviewers drawn from across the world, including 21 ARCOM Committee members and 78 members of the extended Scientific Committee. Thank you to all involved in the peer-review process.

This is the fourth year in which the ARCOM Conference has been themed. There were also eight thematic tracks proposed for the conference, covering a range of issues from community engagement to the tyranny of metrics and including sustainable entrepreneurship in construction and building for the common good. These thematic tracks now form an important part of shaping the papers received and accepted and, we hope, of steering the discourse at the conference. Another significant area in this year's conference is the focus on sustainability in the built environment, where authors address questions around low energy and low carbon construction along with governance and the common good in construction.

It is also very encouraging to see authors becoming more engaged about the position and research that addresses construction education. The construction management community of researchers can be seen to mature and expand their research activity within the fast changing environment in which society finds itself and particularly the emerging aspects/ impacts of COVID-19. The opening plenary session appropriately focuses on addressing the common good in the context of sustainable cities where two keynote addresses - the first by Professor Ann Bradley from the Construction Leadership Council and the second from our own Dr. Alex Opoku - will be provoking us to think about the role of the AECO in addressing the climate change agenda.

The second plenary session chaired by Dr Craig Thomson with keynote addresses by Professor Martin Loosemore and Dr. Ani Raiden addresses the topic of "The rise of

Social Value within the Construction Industry: the Challenges and Opportunities presented by COVID-19”. The session will include a contribution from Mr. Dave Higgon from Multiplex Australia as a discussant. It gives me great pleasure to introduce this year’s Langford Spotlight where the topic of “The Politics of Construction” is explored by Ms. Chrissi McCarthy, chaired by Dr Vivien Chow. It promises to be a lively session and one that David Langford would be very proud of.

The virtual setting allows for the exploration of three one hour workshops where three distinct topics cater for the divergent needs of the ARCOM community. Construction 4.0 is explored by Professor Paul Chan while Dr. Nicola Callaghan leads the session on research methodology exploring what Grounded Theory is or even is not. The third workshops looks at mental health and wellbeing in the COVID-19 world in which we are now all living. ARCOM chairman, Professor Chris Gorse explores this important topic with some personal reflections. I am delighted to also add to the discourse in this workshop.

ARCOM continues to attract an international audience, and we have delegates joining us this year from, inter alia, Europe (with colleagues from the Netherlands and across Scandinavia), the United States of America, South Africa, Sri Lanka, India, China, Malaysia, Australia and New Zealand. It is good to welcome colleagues from both developed and emerging economies alike. Following the successful ‘Meet the Editors’ session back in ARCOM 2017, we will run this session again at the virtual ARCOM 2020 Conference. Gemma Hemming from Emerald and Ed Needle from Taylor and Francis have teamed up and planned a very interactive session on day two. They will discuss what post COVID-19 in the field of construction management research may look like.

Lastly, but not least, I also wish to express my sincere appreciation to a number of key individuals for their support and help over this past year; the ARCOM Committee, Cath O’Connell, Rosalind Oxley and Katie Clements, all the folk who helped us at iVent, and of course, this conference would not have been possible without the relentless and unwavering efforts of our conference secretary, Chris Neilson. I would like to finally thank ARCOM chairman, Professor Chris Gorse, who has been a rock of support to me in navigating my new experience.

Welcome to ARCOM 2020 and to the virtual experience. Enjoy!



Lloyd Scott
Conference Chair, ARCOM 2020

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The success of the Annual ARCOM Conference depends on the voluntary efforts of the members of both the ARCOM Committee and our international Scientific Committee. We are indebted to the members of both committees who together provided rigour and constructive feedback in the peer-review process.

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THE TYRANNY OF METRICS

THE VALUE OF ‘NON-VALUE ADDING’ ACTIVITY

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Lean Construction seeks to make construction more efficient through the elimination of so called ‘non-value adding’ activity. The act of labelling activity and time as ‘non-value adding’ is a value judgement which to date has been largely unexamined. Stuart Green challenged the concept of lean construction and examined the human cost of lean production in the 1990s and 2000s but did not specifically focus on non-value adding activity. This study aims to start to fill this gap in knowledge through a review of the literature and analysis of three long, unstructured interviews - extended conversations - with construction site managers to explore the activity that has been described as ‘non-value adding’. The findings indicate that during ‘non-value adding’ time (for instance driving to and from site, taking breaks, walking around site to pick up material) the interviewees plan upcoming tasks and evaluate completed work. In addition, ‘non-value adding’ time allows for team building and friendship formation which helps to build mental resilience, which is of genuine value when we consider the mental health crisis amongst construction workers. There is clearly room for improvement in the site efficiency of construction workers; however, the impact on those workers of efficiency measures should be clearly understood before being imposed to avoid unforeseen adverse consequences. This paper contends that ‘non-value adding’ activity is not without value, and that a more appropriate term should be found.

Keywords: Lean Construction, mental health, productivity, resilience

INTRODUCTION

Womack *et al.* (1990) in their book “The machine that changed the world” first coined the term ‘lean thinking.’ Widely recognised as the ‘midwives of lean production,’ they prescribed the ‘systematic elimination of waste by all members of an organisation from all areas of the value stream’ as a means of improving the efficiency of industry. Advocates of lean construction suggest that these lean processes should be adopted in the construction industry, thus non-value adding activity and waste should be eliminated, positioning this as “a way to accomplish more with less and less - less human resources, fewer tools, less time and less physical space” (Avelar *et al.*, 2020:365). Green (1999) was the first to raise concerns about the lean construction approach in terms of the observation and control of workers and the lack of consideration of the impact of such ‘modernisation’ measures on the construction workforce. This was well before the construction industry’s issue with poor mental health came to prominence. In the UK, construction workers experience mental ill health at twice the national average rate (Alderson 2017). Construction workers are subject to stress due to long working hours and tight deadlines (Chan *et al.*, 2020),

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which can contribute to mental and physical health problems (Wang *et al.*, 2018). When construction labour efficiency is prioritised, when schedules are compressed, the opportunity for teambuilding and social support on site may be reduced. This paper therefore examines what non-value adding activity might be, and to whom does the activity not add value? It tries to establish if activity can be categorised thus, and if there is a shared understanding of these terms. It looks at how socially supportive relationships are developed on site and how the definition, and reduction, of 'non-value adding' activity might impact construction workers.

Lean Construction and Non-Value Adding Activity

Glenn Ballard and Greg Howell founded the International Lean Construction institute in 1997 to disseminate lean construction principles. However, it was the Egan report in 1998 that elevated lean construction to the status of construction 'best practice' (Green and May 2005). 'Rethinking construction' (Egan 1998:22) recommended lean construction as a "powerful and coherent synthesis of the most effective techniques for eliminating waste and delivering significant sustained improvements in efficiency and quality." To implement lean construction, Avelar and Meiriño (2019:366) advise a "rigorous and systematic approach focused on waste reduction." Ohno (1988), the author of 'The Toyota production system', identified seven sources of waste: defects in products, overproduction of goods, excess inventories, unnecessary processing, unnecessary movement of people, unnecessary transport of goods and waiting time. This categorisation of waste was largely adopted by lean construction adherents; Kadarova and Demecko (2016) added 'non-utilized talents' to the list; whereas Womack and Jones (2003) include the 'design of goods and services that fail to meet the user's needs,' using client requirements to determine what adds value. One way to conceptualise non-value adding activity (process waste) in construction is to use the terms 'conversion' and 'flow.' Koskela (1992) described the activity of turning one thing into another as 'conversion.' The time spent planning, waiting, moving material about he describes as 'flow.' Conversion activity is value adding, whereas flow is non-value adding. Some flow is necessary; project planning, health and safety, environmental and quality control are all flow but are required for optimal project delivery; however non-value adding flow activity (which uses resource but does not add value to a process) should be reduced to a minimum. Womack and Jones (2003) suggested that good flow has the minimum possible non-value adding actions.

Initially, lean construction literature allocated activity according to a binary definition of value adding or non-value adding. Love and Gunsakeraran (1997:160) defined non-value adding as "any activity that does not contribute to the common organisational goal of reducing costs." Ismail and Yusof (2016:15) find that "Non-value-adding activities are pure waste during the construction process," adding that most construction activity adds no value, including waiting, delay, unnecessary movement and non-utilised talent. Han *et al.* (2012) describe non-value adding effort as that which could have been avoided with better project planning and control. They include fatigue and loss of morale as factors that contribute to productivity loss. Over time other categories of activity have developed. Some lean advocates have introduced an additional activity category: necessary, but non-value adding. Avelar and Meiriño (2019) use the example of moving materials around a site for this term. Mao and Zhang (2008) do not use value adding and non-value adding, but instead main and supportive activity. They argue that activity, such as inspection, transportation, waiting and motion, are necessary and therefore add value. On occasion, the categorisation of non-value adding activity can seem unhinged from the

reality of the construction site. Hannah (2010) includes morning start-up / discussion, restroom visits, morning coffee break, and travelling to and from lunch in the 'non-value adding' category. Green (1999) stated that Lean construction techniques were being advocated by a group of proselytisers who had not considered its drawbacks. Although lean construction is often dressed as a 'sustainable' initiative in that it reduces construction waste, it does not address the concerns of social and economic sustainability for the construction industry (Green, 2011). Green and May (2005:501) contend that the language of lean construction lacks coherence - it shifts and adopts different meaning, according to who is using it. They suggest "language is ... mobilised as a source of power" and find amongst interviewees, a disparity of interpretations and implementation of lean construction. Green has taken issue with the techniques and tools to measure and control construction workers in the pursuit of lean construction. This study focuses specifically on the categorisation of 'non - value adding' activity and the impact that this might have on the mental resilience of construction workers.

Organisational concepts have drifted away from their original conception as they are adopted and diffused; greater clarity could be established on what is implied by the terms 'lean construction' and 'customer value' (Jorgensen and Emmitt, 2008). Chan (2013) cautions against complacency in the use of language, using taken for granted terms in construction research without first examining whether they are still accurate or relevant, and whether there is a common understanding of what they mean. Johanssen and Osterman (2017:6903) find a "lack of conceptual consistency" amongst proponents of lean construction, suggesting that the intention of Lean manufacturing systems may be very different from the implementation of these systems in operation. They compared lean trainers' conceptions of 'value' and 'waste' in four case study locations. Some trainers interviewed took a reflective view of waste and value, classifying some work as 'non-value adding but important,' interpreting these terms according to context and operation. Some trainers adopted a mechanistic, rule-based interpretation, which was found to be appropriate only for repetitive, simple tasks. The terms 'waste' and 'non-value adding' can mean different things, depending on their interpretation. The concepts of 'waste' and 'value' do not have an agreed, shared definition amongst Lean Construction practitioners or researchers, leaving a lot of power in the hands of those who decide the meaning of these terms and how they are used to implement lean processes.

Construction and Mental Health

Construction workers in the UK experience mental ill health at twice the national average rate (Alderson 2017). In recent years, there has been more of an industry focus on mental health promotion, with a number of high-profile awareness campaigns (Kelly, 2019) and mental health first aid becoming more common on construction sites. Construction commonly uses a transient workforce, with constantly changing sites and teams, which has a higher turnover of colleagues than most industries and consequently less opportunity to form close bonds. This can lead to feelings of isolation and a lack of belonging amongst the workforce (Geter, 2019). Construction News' 2019 mind matters survey found that working long hours, job uncertainty, tight deadlines, financial pressures and working away from home were among the top factors that adversely affected mental wellbeing (Kelly, 2019). Travelling distances can lead to time away from families and support networks (Lingard and Turner, 2015) rendering the support available from colleagues and co-workers even more crucial. Lingard and Turner (2015:30) found that long working

hours hindered the adoption of a healthy lifestyle for construction workers in Australia. They suggest “health promotion programmes should...address physical and psychosocial risk factors in the construction work environment.”

Love *et al.* (2010:654) observed that poor mental health was more prevalent amongst contractors than consultants, with contractors significantly more likely to believe that “the people where I work do not care about me”. They found that support in the workplace was very important to the mental health of those working for contractors. Chan *et al.* (2020) examine the risk factors for poor mental health in construction through a systematic review. They identify risk factors including hours worked per day (excess of 60 h per week), work overload/quantity of work, and increased work speed/pressure, little social support from colleagues/immediate supervisors, little relationship with colleagues/co-workers and little opportunity/ability to participate in decision making. These factors can be summarised as increased work pressure, a lack of social support, and a lack of autonomy. Poor work life balance in construction with a long working hours culture is a major contributor to mental ill health (Kotera *et al.*, 2020). Kotera *et al.*, suggest that psychological safety can be enhanced by fostering trust and facilitating communication on site. Chan *et al.* (2020) identified the factors which can help protect against mental ill health to include caring, appreciation, encouraging, building teamwork, and communication skills; creating a sense of involvement among employees; and encouraging quality relationships among colleagues; Love *et al.* (2010) characterised these type of mechanisms as ‘work support.’ Marital status was cited by Kamardeen and Sunindijo (2017) as a protective factor to mental ill health - they suggest that the need for scheduled coffee breaks and casual gatherings is greater amongst unmarried operatives.

Karasek and Theorell (1990:69) state, “Social support at work refers to overall levels of helpful social interaction available on the job from both co-workers and supervisors,” and suggest that physiological demands at work can be mediated by coping mechanisms. Few studies that specifically look at the contribution of social support to good mental health in construction could be found, however Hansson *et al.* (2016) examined this factor in relation to Swedish police officers. They found that high levels of psychological strain were correlated to low levels of workplace social support, and that low levels of social support were more likely to be found amongst male than female officers. They suggest that social support can help buffer between sources of stress at work and poor psychological outcomes. When examining resilience amongst nurses, Cusack *et al.* (2016) found that relational factors were important, including fostering collaborative relationships, open lines of communication with opportunities to feedback to line managers and an input to decision making. Wang *et al.*'s (2018) systematic review of loneliness and social support as a factor for mental ill health found a significant relationship, although this review was in the context of mental health in general, not specific to the workplace or construction in particular. Bovier *et al.*'s 2004 study suggests three ways that social support might help mediate stress - as a direct positive effect on mental health, as an indirect effect, promoting coping strategies, and as a buffer effect, reducing the negative effects of stress on mental health. They find that “social support exerts its beneficial effect by strengthening internal resources and/or diminishing perceived stress” (2004:169).

Construction workers spend a lot of time in each other's company (Geter 2019) - sometimes more time than they get to spend with their families. This combined with the industry's emphasis on teamwork can lead to a feeling of ‘brotherhood’ and

connectedness. Geter also cites the ‘informal support and communication systems’ on site as a key protective factor to poor mental health in construction. Construction News’ 2019 mind matters survey found that more respondents (32.6%) felt comfortable talking about their mental health with co-workers on site than with any other source of support (Kelly, 2019). Ajayi *et al.* (2019) find that improving teamwork and collaboration is an effective strategy to alleviate stress in construction. In 2006, Lingard and Francis examined the role of social support - from supervisors and colleagues - as a moderating force on burnout and stress in construction. They found that employees with supervisory and co-worker emotional support were less prone to emotional exhaustion. They concluded “Interventions designed to alleviate or prevent employee burnout in the construction industry should focus, at least in part, on the creation of a supportive work environment” (Lingard and Francis 2006:194).

RESEARCH METHOD

A desk based narrative review of recent peer reviewed research into lean construction, construction efficiency measures, mental health in construction and the importance of social support to good mental health was undertaken. This established a gap in knowledge and identified themes that are explored in the following investigation. Lean Construction research tends to take a rationalist perspective, missing much of the unique, lived experiences of individuals who work in construction. In contrast, this study adopts an interpretivist perspective, examining the meaning of terms held by site managers in the context of their experience of working on a construction site. In common with the approach adopted by Green and May (2005) and Johanssen and Osterman (2017), the study holds that concepts emerge over time and take on a different meaning according to an individual’s experience and environment. Site managers are interviewed; as Chan (2013) suggests, lay people are “probably much more knowledgeable (aware) about what [is] going on around them than the experts (including policy-makers and academics)”. As a preliminary sample of convenience, three site managers were chosen for interview, and long unstructured conversations based around their typical working day were recorded, transcribed and analysed. In the analysis that follows, patterns were identified, and themes actively generated by the researchers using thematic analysis as described by Braun and Clarke (2006). Direct quotations are used where possible to illustrate themes and allow the respondents to speak for themselves.

FINDINGS

Traveling to and from Work

All three interviewees have to travel some distance from home to work, leaving home early (5:30 am for interviewee 1, 6:10am for Interviewee 2 and 5:50 for interviewee 3); and getting home late (leaving site at 4pm and getting home for between 6 and 7pm). This long working day means that there is less time to socialise, see family and engage in activities outside work. By the time he gets home, interviewee 1 is “wrecked and starved.” Two of the interviewees gave others lifts to and from the site. They both agreed that there was less talking in the morning - “its pitch-black dark there so there wouldn't be a pile of chatter in the van”, but “there's a bit of banter on the way home now; there'd be a bit more chat.” On the way into work, interviewee 3 plans his working day. “When I've been driving, I've been thinking right I have such and such a person to meet, I have such a thing to order... You know... you kind of mentally get yourself ready for the day. You're thinking ... what's ahead of you.”

Clocking in and Out of Site

Once on site, two of the interviewees used new face recognition clock in / clock out machines for themselves and their workforce. They report that most of the operatives didn't mind using this new technology (once initial teething problems had been fixed), although some of the operatives either forget to, or deliberately don't, clock out at the end of the day. Interviewee 1 thought that "In the future...everybody is going to be biometrically tracked and traced, you know, it's going that way." Interviewee 2 referred to some subcontracted workers who had criminal records, who were reluctant to give their fingerprints to use the system. The site manager knew about their criminal records but observed that these workers in particular distrusted the system.

Morning Tea Break and Lunch

After starting work on site at 7am, the first break of the day for all interviewees is a morning tea break at 10am, lasting 20 minutes. Interviewee 3 found it hard to switch off in this break, finding himself instead catching up with paperwork most days. When asked if this break could be eliminated, to shorten the working day, interviewee 1 replied "the men are on their feet all day...You couldn't take it away, for you leave the house at half five in the morning, and you get nothing to eat until ten o'clock here. You couldn't lose that tea break...you're gunning for food." This illustrates the importance of food in the day; as interviewee 3 says, "it gives you that wee bit of a boost of energy you know getting a wee bit of sitting down time - keeps you going for the rest of the day." Lunch on all the sites is between 1:00 and 1:30. During the tea and lunch breaks, the operatives sit in their welfare units, eat, and talk. The site managers agreed that on their sites the operatives got on well. All three site managers found themselves planning tasks, catching up with emails and planning the next stage of work during their tea and lunch breaks. This can create distance between the site manager and operatives. One of the site managers makes a point of bringing hot food for the operatives on a Friday and sitting to eat with them, he thought it is important to engage with the men on his site, and sees getting to know and socialise with his crew on site as a key element of team building. This site manager is also a mental health first aider and he sees this as a key part of his role.

At the end of the lunch and tea breaks, some of the men take 5 minutes more than others getting back to work; others go for a smoke break. According to interviewee 1, smokers did get more breaks than non-smokers - "after tea, he's standing down the smoking area for another 10 minutes or so - you get more productivity out of the men that doesn't smoke." All interviewees took the same approach to this - they felt that it was better to indulge five minutes or so of extra time as that way "you'd get more out of the men" than "go down and shout and gulder." They all felt that "you have to try to get the best out of people" rather than being "constantly on their backs"; if the men were antagonised needlessly, "they would be pulling against you."

Non-Value-Added Activity

Interviewee 2 said that waiting for information from the design team could be disruptive to the 'flow' of work on site and could be stressful. Asking for information from the designers and being 'drip fed' was one of the more frustrating aspects of managing his current site. The importance of setting the right levels on site to avoid excessive excavations, a site setup where materials were stored securely, but close to the work area, and appropriate use of plant on site were cited by interviewee 3 as a way to avoid non-value adding activity - he summarised this as having "a well-managed site." Interviewees 2 and 3 referred to defects and correcting mistakes as the most regularly occurring non-value-added activity in their experience. They both said

that attention to detail, and regular supervision was important to reduce defects, and to catch mistakes and poor workmanship before they had a chance to get out of hand on site. Although it doesn't physically contribute to the completed building, every interviewee emphasised the importance of oversight, of getting out of the office, walking round the site and briefing the operatives, to maintaining a good flow of work, and the successful running of their sites.

Characteristics of Productive People

It can be difficult to tell from a single visit to site who is being productive.

Interviewee 2 illustrated this by saying, "I've come from a carpentry background, and I worked very hard. And - we used to laugh about it - but the moment you would stop for a minute to have a chat about something or whatever - most of the time you were chatting about what you're actually doing - the boss would walk round and you're standing there doing nothing." However, all the site managers said that they were able to build up a good picture of who were the most productive members of their team over time. When asked to describe characteristics that the more productive people on site share, Interviewee 1 said non-smokers tended to be able to work to a higher rate and take less breaks. Interviewee 2 said that people who played sport were fitter and had more "zest...and probably a better mental outlook as well."

Pressure

All three interviewees felt the pressure of their role, and all admitted that, at times they would feel stressed about work when not at site. Interviewee 1 has recently been promoted to the site manager role and admits that he struggled at the start. He says, "that was stressful ... getting my head round it all ...doing new tasks where you're kind of thrown in at the deep end." He continues "for a couple of weeks to start I found myself waking up in the middle of the night you know, thinking about things that you should do - what you're going to do the next day." The more experienced site managers have got better at dealing with stress over time, but still worry about work. They try not to bring worries about work home with them, as interviewee 2 puts it "I can usually go home and forget about the job unless there's something really, really negative on my neck, but there would still be the odd time when you would." All three interviewees felt the responsibility of their role as site manager.

Mental Health First Aid

The companies that the interviewees work for have all introduced mental health awareness campaigns, and all the companies have trained mental health first aiders. Interviewee 2, a mental health first aider, sees "chatting to everybody" and "getting personal with people" as an important part of this job. All three site managers claim to have noticed a difference in their companies in response to the campaigns, although two of the respondents still themselves find it difficult to admit when they are stressed or say that they are 'too proud' to ask for help. As interviewee 3 put it: "I suppose being proud you wouldn't be saying you're worried about [a problem on site] ... I probably wouldn't let them know that I'm worried about it."

Interviewee 2 does martial arts and suggested that the men on site would benefit from breathing and stretching exercises at the start of the working day. "Literally 5 or 10 minutes in the morning, and you're just getting everybody to loosen up their necks their shoulders their arms, you know. I don't know how it would be received. I might start that just myself; you know, it could be part of the considerate constructors as well." He thought this would prepare the men for the day, physically and mentally.

Importance of Relationships on Site

Good working relationships, between the site managers and the operatives on site, and between the site managers and the contract managers and company directors, were emphasised repeatedly as the best way to buffer against stress. Each of the interviewees explained how they relied on another person or group of people to help them resolve issues and deal with the daily stress of their jobs - "the only thing that could lift the stress on you is having a good team." Interviewee 1 says of his contracts manager, "he is a friend. Yeah, definitely. We get on the best from the same frame of mind you know and everything. It makes a big difference, yes. When you're in a job like this... If I hadn't got AB as a contract manager, I wouldn't be sleeping any night, that would stress me out, now." Interviewee 3 also said that he would confide in and talk problems on site through with his Contracts Manager. Interviewee 2 has a team of two labourers that have been with him over a number of jobs, and who he has come to rely on. One in particular has become a friend and confidante, "oh yeah it's a friendship there ...if he would ever say he was leaving me you know, I'd be really at a loss." Interviewee 1 said, "I have CD here - we started four or five weeks ago and then his friend request came on Facebook...and we've been chatting about football and stuff like that there..." Interviewee 3 said that these friendships have developed "just with working with each other for over a period...just like, chatting during breaks, that kind of thing." Time spent on site, during breaks, and travelling to and from site, is where friendships can be formed, and team bonds built.

CONCLUSION

'Successful' lean implementation threatens to remove opportunities for building relationships - swapping stories and talking about football - and forming occasions where struggling operatives can ask workmates for help. The 'water cooler moment' in the office environment has become shorthand for a place to undertake informal learning, swap gossip and build relationships. The welfare unit, the walk across site to pick up materials, or the van on the way to work, fulfils the same function for construction workers. If all activity that does not directly contribute to the construction process is eliminated, where is the 'down time' for the operatives? This study has shown that resting, breaks and interstitial time on site may seem non-value adding using mechanistic project planning, but this is not the case from the perspective of the operatives; these activities are hugely valuable.

Without thoughtful consideration of what constitutes so called 'non-value adding' activity, and to whom the activity adds value, lean construction runs the risk of exacerbating the mental health problems that are prevalent in the construction industry. It is easy to sit at a keyboard and make a judgement as to what adds value or what does not add value to a process. To analyse statistics, to look at movement tracking of operatives and write up time and motion studies. To divide a working day into pie charts and put labels onto activity. For academics to argue about the most efficient way to complete a task. In order to be able to allocate value to a person's activity, the authors hold that first you must have some understanding of the person and their daily routine, at a personal level, not as a movement, or resource, or statistic. Not as an instrument of policy or process. Clearly, this is only a preliminary study into this area; however, it has demonstrated a need for more research into work pressure, social support, and the mental health resilience of site operatives. However, in a world where language is power, the conferred legitimacy of the lean construction label can enable unscrupulous, or unthinking, adoption of waste reduction policies that make the working day more 'efficient,' reducing breaks and downtime for operatives,

and eroding their resilience. Non-value adding activity is often not without value to construction workers, this term should be retired.

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SOCIAL VALUE

ASSESSING THE POTENTIALS OF HERITAGE BUILDING INFORMATION MODELLING (HBIM) IN DAMAGED HERITAGE RECONSTRUCTION

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Recent catastrophic events that destroyed valuable monuments, like Isis attacks on ancient cities in Syria and Iraq in addition to Notre Dame's fire in France, did not only cause a significant cultural loss but also immense economical damage. Moreover, the rapid growth of urban development projects across the globe further raises questions about damaged heritage management. As a result, there is a need for a sophisticated framework that can facilitate accurate virtual reconstruction of lost structures and support their cultural management to initiate cultural healing. Using Heritage Building Information Modelling (HBIM) could provide enriched platforms that store and exchange knowledge crucial to reconstruct and operate damaged structures. Yet, there is little research about adoption and implementation of HBIM in lost or damaged heritage. Thus, this study seeks to investigate HBIM adoption in reconstructing damaged historical assets using published case studies as a source of secondary data. The aim is to critically review approaches in post-destruction HBIM, analyse their methodologies, identify common challenges and finally formulate recommendations. A phenomenological research approach was adopted through systematic literature search to identify cases that responded to such events, ten case studies with various building morphology and HBIM methods were identified. Thematic data analysis was used to analyse how cases adopted HBIM in creating supplemented digital data and exchanging heritage sites knowledge. Initial findings show that HBIM has potentials to enhance virtual reconstruction and restoration of heritage monuments; but its implementation indicate gross lack of procedure and workflow concerning transition from data collection to modelling. The research also highlighted key specific issues confronting adoption of HBIM's in the recovering of damaged historic buildings.

Keywords: case studies, digital data, HBIM, heritage reconstruction

INTRODUCTION

Natural occurrences or human-influenced catastrophes often damage archaeological and historical sites. Heritage that represents a crucial part of communities' identity is often destroyed by development pressures, untenable tourism, poor management, robbery, and political conflicts (Global Heritage Fund 2010). Cultural heritage “stands at the frontline of conflicts”, losing heritage often results in powerful social and economic consequences due to their irreplaceable value (UNESCO 2013). It could be seen as an act of depriving people of their collective memories, identities,

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and belongings which could be seen in ISIS attacks on Nimrud and Palmyra. How could destroyed sites be recovered to initiate cultural healing within affected communities and restore their economic resources? Reconstruction procedures could be very demanding due to the complexity of lost historical recovery. Such demands could be found in Building Information Modelling (BIM): A multi-disciplinary process that conceptualizes projects by using parametric objects which contain geometrical and non-geometrical information (Baik *et al.*, 2014). However, BIM is often developed towards new projects with simplistic libraries containing primary elements (Bryde *et al.*, 2013). Hence, Murphy *et al.* (2009) identified Heritage Building Information Modelling (HBIM): A process that combines data acquisition technologies, such as photogrammetry and 3D scanning, with BIM platforms to produce accurate heritage models. Spatial data concerning historical assets is collected through scanning technologies to produce point clouds, those clouds are processed and filtered to be incorporated and developed within BIM environments. Despite HBIM being researched often, there seems to be a little examination of how it could be used in reconstructing lost heritage. Hence, this research seeks to identify the methodologies currently used in post-destruction HBIM by reviewing practical case studies references, distinguishing common issues, and forming recommendations. For a better understanding of the study's variables, a detailed literature review is needed.

LITERATURE REVIEW

Key definitions

Reconstructing damaged assets often refers to the process of rebuilding what was lost or destroyed due to natural disasters, such as earthquakes, or human-induced events such as armed conflict (Jokilehto 2013). In such events, recreating the physical asset may not always be the goal, but the regenerating the social-economic value of the location. Heritage has long been on the frontline of disasters, the 1976 UNESCO Recommendation concerning the Safeguarding and Contemporary Role of Historic Areas illustrated the urgency of such matter in assessing the Second World War severe damage on global sites. It also highlights how destroying heritage sites leave their social fabric with deep economic and cultural loss. Furthermore, the Global Heritage Fund (2010) asserts that events such as the Bamyán's Buddha's destruction, Notre Dame Cathedral fire, and Palmyra attacks, to mention but a few, represent a substantial economic and cultural loss to their societies. A loss that current research seeks to recover through Heritage Building information modelling (HBIM).

HBIM was first mentioned by Murphy *et al.* (2009) as a process where parametric objects are built from historic information to represent architectural elements of the historical asset. These objects are mapped using data acquisition technologies onto a point cloud survey and then imported to a BIM environment. The term has since been broadened to mean the libraries, 3D models and digital databases representing historical buildings, which are used to manage heritage projects in a similar digital setting (Cooperative Research Centre for Construction Innovation, 2009). The word "Information" in HBIM is key, a central digital platform that does not only resemble the geometrical attributes of the historic asset, but also the identity, history, culture and construction logic (Hichri *et al.*, 2013).

HBIM's in Context

Contrast to new construction BIM, where the asset is not yet realized, HBIM raises the question of modelling necessity when the asset could be experienced in reality. This question soon is answered when projects of post-disaster reconstruction are in question, the motivation to virtually document heritage manifested in the last century as a response to many sites lost due to World Wars. Sutherland (1963) is often named the initiative of CAD, followed by Intergraph and Calcomp around the 1980s who are perceived to produce the first fully rendered 3D model. In Heritage, Worthing and Counsell (1999) critically analysed the 1996 London Tower and modelled it which served as a detailed database for development proposals. Yet, the first major implementation is often considered the 1995 full-colour virtual reconstruction of UNESCO site Lascaux Caves (Arayici *et al.*, 2017). It may be said that the HBIM concept started emerging in the mid-1990s where heritage projects started using scanning technologies combined with 3D models. In the following two decades many research projects emphasized digitalising heritage, using different approaches such as Geographic Information System (GIS) to reconstruct sites. In 2012, UNESCO further deployed HBIM concept in “The Memory of the World in the Digital Age: Digitising and Preservation” conference, further enhancing the argument that HBIM is capable to respond to the needs of heritage sites.

BIM in Heritage (HBIM)

Despite BIM's constant development concerning newly built projects, HBIM research illustrates its limitations concerning historical modelling. Modelling historical assets is not a simple procedure due to the complex and irregular objects involved which are often not presented in BIM libraries (López *et al.*, 2018). Thus, it is crucial to adopt survey technologies into BIM to produce accurate digitalised reconstructions of heritage projects. Although HBIM is commonly identified as historical parametric libraries, the first papers which discussed it (Murphy *et al.*, 2009, Chenaux *et al.*, 2011, Murphy *et al.*, 2013) described it as a three phases process:

1. Data survey carried through Laser scanning, photogrammetry or both;
2. Surveyed data processing through various procedures such as noise filtering, re-sampling and point clouds registration;
3. Modelling phase where point clouds are imported into BIM environments, assigned mesh surfaces and textures.

In contrast, Hichri *et al.*, 2013 describe the process as three different stages: the existing data survey followed by virtually reconstructing the geometrical elements, attribution of information and materials to the elements and lastly establishing relationships between them. Both descriptions provide an insight into the process yet lack the flexibility that is needed due to heritage buildings unique nature. For instance, destroyed sites may not offer physical elements to be scanned and thus there could be no survey phase, only modelling while relying on historical documents. Other projects may require special uses such as analysis, structural or thermal analysis, or visualization which would require the addition of a fourth phase that includes the usage of the HBIM created according to its purposes. It could be said that the HBIM stages are shaped by the goals and conditions of each project.

HBIM Survey Technologies

Surveying a heritage building means detecting its dimensions, geometrical elements and more. Traditionally, surveys were conducted using a triangulation method which consists of on-site manual measurements (Carpiceci 2000). This section seeks to

briefly explain the current trends of data acquisition technologies and their contribution to HBIM.

- **Laser Scanning:** widely adopted due to its ability to accelerate data collection of complex components and buildings, as well as providing high levels of precision. Laser scanners can be terrestrial (TLS) or aerial, each differentiating according to the range and coverage distance (López *et al.*, 2018). Laser scanners use laser beams which travel towards the scanned area and back, measuring distances and angles to obtain a precise reconstruction of the three-dimensional elements in the form of millions of points (a cloud of points) with different coordinates (X, Y, Z) forming the asset (Martín Leronés *et al.*, 2010).
- **Photogrammetry:** is a contactless 3D measurement method based on several high-quality images used as a reference when creating historical buildings' models (Historic England 2017). Using triangulation principles, shots are taken in several places while having overlapping points. The photographs captured go through various processes individually such as intersecting characteristics and scaling, later they are combined and imported into specific software to generate a point cloud. (Furukawa *et al.*, 2009). This method is becoming increasingly accessible as a cheap and fast way to capture reality due to available software and free quality photographs available online.
- **Point Clouds:** produced as discussed earlier, point clouds accurately represent the elements surveyed. Yet, they hold no information beyond the physical attributes they portray. Thus, post-capturing processing is crucial to correctly recognize elements.

Murphy *et al.*, 2009 describe the common processes as:

1. **Noise filtering:** detecting and deleting scanned elements that are not required.
2. **Point cloud registration:** multiple scans conducted generate several “partial-point clouds” that overlap with a percentage (usually 20-30%), those clouds are merged to produce a “global cloud” that represents the site (López *et al.*, 2018).
3. **Meshing:** creating surfaces to be transformed into three-dimensional elements later in BIM platforms.

It should be noted that the suitable survey method depends on the project's nature, as they hold disadvantages to be considered. For instance, the high cost of laser scanning technologies and specialised labour and the laborious processing and photographic reconstruction in photogrammetry. In projects concerning lost or damages heritage, one can only rely on archival information to reconstruct missing parts while in other instances. Thus, techniques adopted should be chosen according to the nature of the project concerned.

BIM Platforms for Heritage

BIM platforms which can be used to maintain, document and operate heritage can be classified into three sets (López *et al.*, 2018):

- **3D Modellers:** platforms to virtualise the physical components of historical buildings such as Revit, Tekla Structures, ArchiCad and Bentley System.
- **3D Viewers:** platforms used to view spaces within buildings in a virtual reality setting such as SketchUp, Navisworks Freedom and Tekla BIMsight.

- Analysers: tools that are usually external to BIM used to analyse 3D models such as DAYSIM, Energy Plus and Ecotect Analysis.

Furthermore, these sets can be classified according to accessibility into free, commercial and open source depending on the supplier. BIM tools allow constructing parametric elements which hold geometrical and historical information. These elements could be adapted and used in future cases where a similar architectural vocabulary is documented. Many attempts were conducted to construct HBIM libraries such as Murphy *et al.* (2013) and Baik *et al.* (2014). Although such attempts could reduce the time of producing HBIM models, it may be considered that such standardisation approach does not fit heritage nature as historic elements are considered unique and valued accordingly.

RESEARCH METHODOLOGY

To offer insight into the application of HBIM in the reconstruction of damaged sites, systematic literature research was conducted to identify any published case studies that responded to this condition. Keywords were used such as “HBIM”, “Heritage Reconstruction”, “Heritage Restoration”, “Digital Historical Reconstruction”, and “Virtual Reconstruction” in Google and Google Scholar engines. The aim was to identify the various methods and procedures that were used in reconstructing assets after destruction events. Cases deemed eligible to be included were ones that represented a practical example of applying HBIM to a damaged heritage asset. This research was conducted from October 2019 to May 2020 at which time the database was 10 cases (see Table 1). Out of which 1 is a journal paper, 7 were conference proceedings, and 2 a result of support from software commercial suppliers. The small number of eligible cases indicates that little research is conducted at the time of this study concerning post-destruction heritage recovery using HBIM.

Table 1: Information of HBIM reconstruction case studies

Case Study	Location	Historical Period	Destruction Period	Destruction Factor	Reference
Aceh's heritage	Aceh, Indonesia	17th - 20th Century	2004	Tsunami	(Nichols <i>et al.</i> , 2016)
Aleppo's Citadel	Aleppo, Syria	8th to 14th Century AD	2012-2016	Syrian Conflict	(Fangi 2019)
Altai mission churches	Altai, Russia	19th Century	1920-1930	Anti-Religion Campaigns	(Kreydun 2014)
Basilica di Collemaggio	L'Aquila, Italy	End of 13th century	2009	Earthquake	(Oreni <i>et al.</i> , 2014)
Castillo de San Jorge	Seville, Spain	12th century	19th century	Urban development	(Saviello 2018)
The Ice House	Milan, Italy	17th Century	1940-1945	Heavy Bombing in World War II	(Oreni <i>et al.</i> , 2017)
Notre Dame Cathedral	Paris, France	1163-1345	2019	Fire during maintenance	(Milburn 2019)
St. Catherine's Monastery	Nuremberg, Germany	1297	1945	Bombing raid	(Ludwig <i>et al.</i> , 2013)
Turin's Thirties Fascist Houses	Turin, Italy	1920s to 1940s	After 1943	Destruction campaigns	(Bruno Jr. and Spallone 2015)
Vinohrady Synagogue	Prague, Czech	1896 - 1898	1945 - 1951	Nazi Air Raids	(Boeykens <i>et al.</i> , 2012)

Data from each case study was extracted to examine the site studied, project output, methods, and software used in the HBIM production process. This resulted in identifying two sets of variables concerning the case studies analysis, the first relating to the site and the other related to the publication (see Table 2). These variables were the unified measurement tools used in a spread sheet to qualitatively analyse and compare the HBIM methodologies.

Table 2: Case studies Variables

Site Variables		Publication Variables	
Heritage Site	Historical Period	Project Output	HBIM Methodology
Location	Destruction Period	Software	Advantages
Destruction Factor		Disadvantages	Publishing Platform

DATA ANALYSIS AND FINDINGS

A detailed analysis was conducted via a spread sheet using tabulation analysis method. Tabulation was chosen due to its cross-comparative nature and ability to demonstrate the different decision-making procedure within each case. The resulting table is mostly textual to provide direct reference for the variables in each approach, sections of this analysis will be discussed in the points below.

Case Studies Output

HBIM provides many possibilities of usage such as 3D, 4D and 5D models, analysis, visualization, augmented reality and even interactive experiences. Analysis of case studies identified the outputs in Table 3.

Table 3: Stated output of HBIM case studies

Site	Project Output
Aceh's built heritage	Proposing a methodology for re-creating Aceh's destroyed built heritage
Aleppo's Citadel	Perform 3D surveys and comparisons of monuments affected by the war
Altai mission churches	Recreating the look of the lost buildings using archive documents
Basilica di Collemaggio	Produce a detailed HBIM to manage the analysis, simulation of structural behaviour, economic evaluation and final restoration
Castillo de San Jorge	Produce a virtual reconstruction of the medieval configuration of the castle.
The Ice House	<ol style="list-style-type: none"> Fully document the existing condition of the Ice House Develop two BIMs in two leading software to compare the parametric capabilities and modelling conditions
Notre Dame de Paris	Collaborative research through architectural history and BIM.
St. Catherine's Monastery	Deliver a representation of the interior and exterior to present observers
Turin's Thirties Fascist Houses	<ol style="list-style-type: none"> Conserving the memory of this part of the Italian architectural history analysis of architectural language and reinterpretation of architectural works. Visualization by producing Photos and Videos
Vinohrady Synagogue	<ol style="list-style-type: none"> Documenting the existence of the lost heritage Visualization photo-realistic rendering Comparison between archive documents and realistic rendition

The three most common purposes were documenting the original state prior to damage, producing visualizations to initiate interactivity, and finally, to preserve the

memory of a certain architectural style that no longer stands. There were cases such as the Ice House (Oreni *et al.*, 2017) which provided technical outputs such as comparing two BIM software, Revit and ArchiCAD, in HBIM reconstruction. Another is the Notre dame (Milburn *et al.*, 2019) which sought to test the collaboration of BIM with a global team using BIM 360 platform. All cases describe that those outputs have been achieved incompletely and illustrate more future potentials for HBIM purposes.

HBIM Methodology

What can be seen from Table 4, is that there were various methods of Data acquisition depending on the state of the damaged asset, output required, and available expertise. Reconstructing sites that no longer stand provides several challenges that may vary on case to case bases. Four cases show the integration between laser scanning and photogrammetry as a method to produce a textured point cloud that could be converted afterward into a BIM platform. On the contrary, cases, where assets were lost, could not use those technologies and have used various processes.

Table 4: Methodologies used in HBIM case studies

Site	Methodology
Aceh's built heritage	<ol style="list-style-type: none"> 1. Capturing tangible and intangible data using VERNADOC; 2. Digitalising images and drawings to produce models; 3. Incorporating stakeholders through online exhibition.
Aleppo's Citadel	<ol style="list-style-type: none"> 1. Data acquisition using Spherical Photogrammetry in three methods: existing and old scans, existing scans and old photographs, only existing scans; 2. Processing of Data acquired; 3. 3D reconstruction was done by various researchers.
Altai mission churches	<ol style="list-style-type: none"> 1. Surveys using photo fixation, archaeological clearing and on-site measurements; 2. Topology analysis conducted through GIS and using old photographs; 3. 3D models generation based on GIS analysis.
Basilica di Collemaggio	<ol style="list-style-type: none"> 1. Scanning the available structure by laser scanning and photogrammetry; 2. The interpretation of information; 3. Modelling structural elements using Rhinoceros, Bentley Pointools and Revit; 4. Analysing HBIM produced to identify structural integrity and state.
Castillo de San Jorge	<ol style="list-style-type: none"> 1. Accurate historical analysis to understand the origin of the ruins; 2. Using Laser scanning and photogrammetry followed by processing the point cloud; 3. Modelling in Revit and adding complex details through 3Ds MAX; 4. Sharing the HBIM model with stakeholders.
The Ice House of	<ol style="list-style-type: none"> 1. Data collected by laser scanning and photogrammetry; 2. Point clouds processed using AutoCad and modelled in Revit and ArchiCad; 3. Testing cloud-based approach by Autodesk 360.
Notre Dame de Paris	<ol style="list-style-type: none"> 1. Thorough research of the cathedral by studying available documents; 2. Creating and developing parametric families using Revit and 3Ds Max; 3. Visualization using Enscape and Photoshop.
St. Catherine's Monastery	<ol style="list-style-type: none"> 1. Thorough investigation of the available historic data; 2. Laser scanning and photogrammetry data collection on site; 3. Point clouds processing using Elcovision 10; 4. Modelling parts using ArchiCAD, Vectorworks and Revit.
Turin's Thirties Fascist Houses	<ol style="list-style-type: none"> 1. Analysis of all the preserved documentation; 2. Interpretation of the documents and establishing relationships; 3. 2D and 3D Models realization; 4. Texture mapping, addition of lights and rendering.
Vinohrady Synagogue	<ol style="list-style-type: none"> 1. Historical archives search; 2. Comparing the documents with available drawings; 3. Modelling and constructing the elements library using ArchiCAD; 4. Archiving files.

Such unconventional methods can be seen in Aceh's heritage (Nichols *et al.*, 2016) case where Vernacular Documentation (VERNADOC) was used, a method of

applying information directly to paper on-site and later translating it into digitalized models. However, this can be challenging and faulty, moving information from paper to digital platforms may cause errors and be consuming time. Another method is Archaeological Clearing used in Altai mission churches (Kreydun 2014) where the author collected old resident's memories of the assets' appearance. Yet, basing reconstruction on residents' memory and building style speculation may result in inaccuracy. Lastly, Vinohrady Synagogue's case (Boeykens *et al.*, 2012) based all reconstruction information on available city archives. The particular cases mentioned above discussed the issue of incomplete information in lost heritage recovery, the process is often based on archive information and influenced by speculations, personal expertise, and decisions resulting in issues of historical validity. Thus, a key element in the process is properly documenting all decisions made to clarify interpretations adopted in historical models.

For software, the cases highlighted limitations in BIM software towards heritage modelling. For instance, The Ice House study provides a comparison of two BIM software, highlighting that the process of importing point clouds into Revit is laborious and requires using non-BIM software. While the same process is much more direct in ArchiCad where point clouds can be directly imported. Furthermore, multiple cases (Basilica di Collemaggio, Castillo de San Jorge, Ice House, and the Notre Dame) illustrate the lacking ability of BIM software in modelling irregular shapes associated with heritage. The cases used external modelling software, such as Rhinoceros, Maya, and 3ds Max, to model irregular elements and then import them as mesh elements into BIM environments. Hence, those cases illustrate that historical reconstruction in BIM software could be difficult, lengthy and costly. Finally, all cases raised the importance of non-physical data collection in the process of reconstruction. Thorough historical archive research appears to be the first step in all cases discussed to understand materials, structure and state of buildings.

CONCLUSION AND RECOMMENDATIONS

This research introduced a review of HBIM in documenting and modelling damaged heritage. The attention was positioned on illustrating different approaches to properly assess HBIM reconstruction workflow. Despite positive additions to BIM's platforms, it still shows lacking technical support for heritage's complex geometry, existing HBIM libraries seem to be fairly limited and not internationally adapted. Furthermore, the lack of medium platforms between data acquisition technologies and modelling platforms often causes segmentation and error. Thus, there seem to be two main steps towards active historical digitalising: developing libraries that facilitate the management of historical data with other information sources and creating platforms that connect information collection devices with BIM software on common bases of processing data. Perhaps, other lessons that can be learnt the cases is that there should be a proactive recognisance survey on existing monuments that has cultural values; with the intention to commence their digitalisation and documentation. This could provide crucial information in post-damage cases like the Notre Dame which is currently being restored based on laser scans that were done previously. Moreover, the use of HBIM to re-create and restore important cultural edifice has potentials to enhance their commercial quotient, Digitalisation can help museum tourists to access restored edifices in the comfort of their houses, which proved its importance in the COVID-19 epidemic in addition to valuable in sites belonging to risk zone countries.

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PROJECT MANAGING THE SOCIAL VALUE OF BUILT ASSETS: A CALL FOR A FOCUS ON VALUE MANIFESTATION

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Social value of built assets (during their operational phase) is a major topic within the wider debate on social value in construction. Extant research and practical guidance mainly suggest a define-measure-manage approach to project managing the social value of built assets. However, apparent in this literature is the challenge with the definition of social value, which depends on the perspective and timescale as well as on the social and material scales concerned. Arguments from the previous debate on developing a theory of the built environment, which struggled with a similar definitional issue, shed further light on the root causes of the challenge of defining the social value of built assets. Based on a review of these two bodies of literature, it is argued that shifting the focus from defining social value to capturing its manifestations can provide a better basis for developing project management insights and knowledge accumulation. It is concluded that a focus on manifestation would provide a richer understanding of the social value of built assets at the operational phase; thus, providing more comprehensive insights about how it can be project managed. It is also concluded that such a research agenda could enable a transformation that would put social value considerations at the core of professions and businesses in the built environment.

Keywords: definition, measurement, project management, social value, spatiality

INTRODUCTION

‘Social value’ is difficult to grasp and define. According to Social Value UK, the national network for social impact and social value, it is “the quantification of the relative importance that [the affected] people place on the changes they experience in their lives” (Social Value UK 2020). Evident in this definition, as well as in the recent debate on social value of built assets, is the multiplicity of the perspectives, timescales as well as of the social and material scales that can be associated with the term. Hence, there are significant challenges with grasping, defining and measuring social value of built assets (Watts *et al.*, 2019a). These challenges imply a major difficulty for construction project management, the role of which is to ensure that the desired outcomes, including the social ones, are delivered through the project. As stated by Farag *et al.*, (2016), the challenges related to defining social value mean that there is a lack of understanding in terms of how projects should be managed to ensure that the

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desired social outcomes are achieved at the operational phase (i.e. project managing the social value of built assets). As a result, in practice, the delivery of social outcomes has been excluded from core business objectives and approached as a philanthropic activity.

Despite the challenges of grasping and defining social value of built assets, most practical guidance on managing social value in construction projects suggest a define-measure-manage approach (e.g. Building Social Value 2017; UK Green Building Council 2018). The situation is similar in construction research where the debate seems to mainly revolve around developing categories, attributes and/or methodologies to develop definitions of social value to enable measurement and inform project management (Mulholland *et al.*, 2019). Importantly, more often than not, such publications provide little or no theoretical discussion about the limitations of their suggested approaches in capturing the multiplicity of the perspectives that can be associated with the social value of built assets - a common problem that also applies to wider research on social value (Mulgan 2010).

The way in which a problem is formulated (i.e. its problematization) determines the managerial approaches and methods that will be used to address it (Dery 2018). Therefore, in order to effectively project-manage social value of built assets, it is first necessary to find suitable ways of capturing it, justified by a reflection on its substance and nature. With this in mind, this position paper first reviews the construction management literature on social value in order to outline the challenge with defining and measuring social value of built assets, which also leads to problems with its project management. This is complemented with arguments from the previous debate on developing a theory of the built environment, which struggled with similar definitional issues. Overall, the literature review sheds some light on the root causes of the challenge with defining and measuring social value of built assets, and it reveals that there is much to be learned by embracing the emergent substance and multifaceted nature of social value in the context of built assets. From here, the paper makes the point that shifting the focus from defining to the realisation/manifestation of social value is required to develop a more comprehensive understanding of the term, which would enable better informed project management in return. In an attempt to exemplify this suggestion, frameworks developed by Agnew (1987) and Lefebvre (1991) are briefly introduced with a discussion of how analyses based on these frameworks could reveal new ways of evaluating the social value of built assets/environments; and thus, contribute to the knowledge on project managing social value. It is concluded that a focus on manifestation would provide a richer understanding of the social value of built assets at the operational phase; thus, providing more comprehensive insights about how it can be project managed. On a final reflection, the conclusion suggests that the kinds of knowledge derived from such a research agenda could inform the core practices of professions and businesses in the built environment; thus, enabling social value to be treated not as an additional function but rather as a transformational impulse to rethink the professions and businesses in the built environment.

The growing interest in 'social value' in construction research in the last decade mainly stems from a recognition that construction projects can have significant social impacts (Smyth and Vanclay 2017). This has led to the understanding that the economic arguments that underlie the decisions relating to construction should be balanced with social ones; hence creating additional (socially concerned) liabilities on the key decision-makers of construction projects such as planners, clients and contractors (UK

Public Services Social Value Act 2012). The influence of the 'balancing' rhetoric is apparent in earlier research relating to social value in construction which has mainly reflected on how new concepts can be incorporated into the existing construction industry practices and organisation in a top-down manner for a better balance; such as through the concepts of 'shared value' (Awale and Rowlinson 2014), 'social enterprise' (Loosemore and Higgon 2016) and 'corporate social responsibility' (Murray and Dainty 2009). The rhetoric of 'balancing', or in other words seeing social value as an addition to existing considerations, is an important point to highlight. This is because, arguably, it is this rhetoric that gave prominence to the above-mentioned top-down approaches to understanding and managing social value in construction which offer only a limited level of engagement with social issues through the logic of define-measure-manage. In other words, arguably, such top-down approaches to social value align with a define-measure-manage logic because of their quest for using social value as a balancing element rather than a core one.

However, there is a growing acknowledgement that (top-down) define-measure-manage approaches to social value have significant challenges with appropriately addressing issues relating to social value. This is mainly because of the challenge of defining and quantifying social value, which ultimately causes issues with effectively implementing/project managing it (e.g. Raidén *et al.*, 2019). The challenge with defining social value is partly due to the diversity in the language employed to discuss social value related issues (Raidén *et al.*, 2019), partly due to the variety of the theoretical and analytical foci adopted (e.g. social development perspective vs. social procurement perspective etc.) (Farag *et al.*, 2016), and partly because of the multiplicity of the different interpretations of social value (which are formed through complex social processes) by the different stakeholders (Watts *et al.*, 2019a). Managerial difficulty associated with the multi-facetedness of the term has led to a recognition that define-measure-manage approaches to social value needs to be evaluated critically. For example, Watts *et al.*, (2019b) show how corporate social responsibility reports of contractors may be used as a pure rhetorical device using ambiguous language in order to hide lack of consideration of the contrasting/different views of clients. Another example is Watson *et al.*, (2016), which argues that 'Social Return on Investment' (a quantitative methodology for measuring social impact) cannot effectively capture the value produced by the sociality of building users.

Overall, the major issue with define-measure-manage approaches is that when a comprehensive definition of social value is pursued, it becomes too broad and complex, and therefore, unmeasurable and unmanageable. Whereas, when a narrower definition is adopted, the concern arises that certain dimensions or aspects of social value are not reflected within the respective managerial approach. Acknowledging this conundrum, recent studies on social value in construction advocate for qualitative considerations to be given more emphasis in grasping, defining and measuring social value. For example, a define-measure-manage approach is proposed in Raidén *et al.*, (2019) but the authors suggest that a project-specific 'theory of change' needs to be developed for each project in order to effectively implement a project-specific definition of social value that would be developed together with key stakeholders of the project. Through interviews, meeting observations and document analysis, Mulholland *et al.*, (2019) show that the 'social value' of a megaproject is dynamic and the meaning of it changes with changing spatial and temporal factors. As a result, they critique approaches quantifying social value but do not argue for it to be abandoned. Instead, they conclude that qualitative approaches should be used next to

define-measure-manage approaches in order to 'sense check' the meaning-making process employed in developing definitions and metrics of social value.

Contributions to a previous debate about the possibility of a theory of the built environment provide further insight into the issue with devising managerial frameworks for social value based on a define-measure-manage logic. The struggle to define 'built environment' in this debate is similar to the challenge of defining 'social value' of built assets because the definition of each of these terms depends on the reason or the perspective of the inquiry. Contributions to this debate reveal the different ways in which the built environment can be thought about. These include, for example, the built environment as a social-ecological system that is integrated with the natural environment (Moffatt and Kohler 2008), as the locus of user experience (Vischer 2008) and as the material environment that enables particularistic activity (Hillier 2008).

However, as pointed out by Cairns (2008), all these different ways of conceiving the built environment indeed present a richness that needs to be embraced rather than circumvented. What is required for working with such a multiplicity of perspectives is an awareness of the role of power and politics within the process of negotiation of what a 'good' outcome is. This argument is supported by Boyd (2007), who argues that the delivery of buildings needs a view using multiple rationalities to account for the contradictions inherent in different conceptions of the built environment. According to Boyd (2007), contradictions and multiple rationalities occur in all industries, but they are more evident in the built environment because of its substantive interdependence with society. Hence, he suggests that the built environment does not exist theoretically but as a series of practices of negotiation of power using different rationalities. In line with Boyd (2007) and Cairns (2008), Rabeneck (2008) advocates for an instrumentalist methodological plurality in which multiple strands of theorisation are welcomed as long as they are informed by practical issues and are useful for practice.

Define-measure-manage approaches to social value of built assets suggest that for social value to be manageable it needs to be defined and measured, which leads to a reductionist understanding of social value. Previous literature on developing a theory of the built environment shows that such a reductionist stance is counterproductive. Hence, research on social value of built assets should embrace the multiplicity of perspectives that relate to social value of built assets but should do this with a focus on the issues in practice. It can be argued that this corresponds to shifting the inquiry from the question of 'what is social value?' to 'how does social value manifest itself?'. This means shifting the attention from what researchers/managers/selected stakeholders in the built environment 'think' social value is, towards the practices of those who are supposed to be realising the social value. In other words, it means developing insights into how built assets are valued in practice by those who engage with them, and then using such insights for managing social value during construction project delivery. Such a shift is not only promising in itself, but also in line with the previous literature on developing a theory of the built environment, in at least two senses. First, it prioritises empirical evidence; thus, eliminating ungrounded conceptual confusion and inflation about what social value is (and what it is not), as well as conceptual domination (i.e. whose definition of social value is better or more valid). Second, it liberates the empirical space of what can/should be seen or studied as 'social value'; which also opens up the conceptual space for multiple interpretations of, and perspectives on, what 'social value' is, in line with the multi-faceted nature of

the phenomenon. In other words, it can expose the inherent political and power issues amongst various perspectives relating to the social value of built assets.

In order to enquire into the manifestation of social value of built assets, we need social analyses that treat spatiality as a central concern. The role of spatiality in social phenomena has long been a topic of research with a renewed interest since the 1970s, with the so-called 'spatial turn' (Warf 2017). However, what has been missing is an interaction between these domains and construction research with a view to improving the social value of built assets. Research into construction management can make use of this extant work to develop extensive insights into how social value manifests itself at the operational phase of built assets and relate such insights to construction project delivery. This can enable the empirical richness required to adequately establish the complex phenomenon of social value of built assets. It can also enable a diversified knowledge base to drive the social agenda in construction based on the diverse needs of practice.

The extant literature on the role of spatiality in social phenomena is vast and it includes entire disciplines, such as urban studies and human geography, as well as other disciplines that have developed an increasing interest in spatiality such as political sociology, organisational studies and history. For this reason, in the next section, a very limited discussion of this work is provided with a focus on highlighting the variety of ways in which 'spatiality' could be conceived for studying the social value of built assets.

Since the 1970s, there has been an increasing number of studies in humanities and social sciences that consider space, or more specifically spatiality (term further explained below), as a key issue in their analyses of social phenomena. The so-called 'spatial turn' in social theory (Blank and Rosen-Zvi 2010) has (re)emphasised that space is not fixed, inert or given, but rather it is performative, transient and dynamic in the sense that it is a fundamental part of human experience, actions and interactions (i.e. social practices) (Warf 2017). Borrowing concepts from traditionally space-focused disciplines such as geography and physics, this "spatial turn" has "influenced the understanding of reality as constructed and determined by complex spatial relations" (Lähdesmäki 2018, p.1).

The increasing attention paid to 'spatiality' in various domains of social analysis has led to a variety of space-related concepts, metaphors and perspectives (see for example Crang and Thrift 2000; Sheller 2017). However, one of the biggest conceptual challenges that remained is what Agnew (2011) labelled as the space-place conundrum: the difficulty of making sense of the different ways spatiality can be understood for social analysis. According to Agnew (2011), the issue is that conceptualisations relating to spatiality for social analyses, particularly the most commonly used terms of 'space' and 'place', tend to emphasise either one or the other end of a continuum running from nomothetic (generalized) location at one end to idiographic (particularistic) place at the other. The challenge is, as Agnew (2011) puts it, to bring these meanings together as they both have something to contribute to our understanding of the relationship between spatiality and social phenomena. This argument highlights that research on the manifestation of social value of built assets should recognise i) the different ways in which spatiality could be considered for social analyses; and ii) the theoretical approaches that aim to jointly consider 'generalized location' and 'particularistic place' (i.e. the ends of the continuum mentioned above). It is only through such a recognition that construction

management researchers could develop adequate conceptions of built assets that can help deliver the intended social value at the operational phase. Due to the limited amount of space available in this paper, only Agnew's (1987) framework on 'place' and Lefebvre's (1991) triadic view of 'space' will be introduced here. These two works nicely expose the ontological and analytical complexity of spatiality in social analysis, thus providing insights into how built assets could be conceptualised when analysing the manifestation of social value at operational phase of built assets.

One of the studies that provides a framework of how 'spatiality' could be considered for social analysis is the seminal work of Agnew (1987). In his work on political sociology, Agnew (1987) suggests that 'spatiality' could be viewed as 'location', 'locale', and 'sense of place'. 'Location' refers to the absolute/objective position within a certain spatial framework, such as longitude and latitude. Hence, 'location' also allows situating ourselves in relation to other locations and provides the answer to the question of 'Where?' (Cresswell 2014). 'Locale' refers to the socio-material context within which social relations unfold. Therefore, 'locale' considers the physical environment (i.e. the morphometry of an environment - a set of buildings, parks, roads etc.) but importantly it does this in relation to the patterns of activity and interactions (e.g. organising institutions of work, education etc.) that take place within that physical environment. Hence, 'locale' is the unique assemblage of particular social practices taking place in a particular material setting. As stated by Cresswell (2014), "we often know a place, in some sense, as a locale - a unique combination of things and practices within which life unfolds" (p. 5). According to Agnew (1987), 'locale' and 'location' are intimately connected: 'locale' is the setting for activity or social interaction, but "the reproduction and transformation of social relations must take place somewhere [i.e. must be 'located']" (p. 27). Finally, 'sense of place' refers to the subjective aspects of 'spatiality': "the meanings that are attached to it [i.e. a place] either individually or collectively" (Cresswell 2014, p. 5). Hence, 'sense of place' embraces the affective attachment that people have to a place (Withers 2009).

Agnew's (1987) framework of place exposes several ways in which 'spatiality' could be considered for social analysis as well as exposing the interrelations between those different ways. Agnew (1987) develops this framework as a critical response to the extant literature that conceives spatiality from only one of these three different ways of seeing it. According to Agnew (1987), conceptions of place that do not acknowledge the different ways that place could be understood are ontologically too limited for an adequate social analysis considering spatiality. Hence, the main arguments of Agnew (1987) were almost entirely ontological, suggesting a structuration between the different ways spatiality has been so far dealt with (i.e. 'location', 'locale' and 'sense of place').

On the other hand, Henri Lefebvre's seminal 'The Production of Space' (1991) conceives of space as the outcome of an ongoing social (re)production process that appropriates the material context with which it is bound. Lefebvre (1991) suggests that space is produced through three dialectically interlinked dimensions, each defined through a pair of concepts (Schmid 2008). These are 'spatial practices / perceived space', 'representation of space / conceived space' and 'spaces of representation / lived space'. The concept of 'spatial practices' designates the material dimension of social activity and interaction; thus, the concept highlights that social and material patterns of particular practices are interlinked. This means that organisations of social practices and material spaces are mutually dependent and being part of a social practice requires a particular type of spatial competence to be able to undertake a

particular spatial performance (Shields 1999), hence the pairing concept of 'perceived space'. 'Representations of space' refers to the discourses and the imagery used to think and communicate about a space; thus, including definitions, descriptions, theories of space as well as maps and plans. Therefore, 'representations of space' determine our epistemological framework for abstract thinking, knowledge and truth claims, as well as our communication with others about a space, hence the pairing concept of 'conceived space'. Finally, 'spaces of representation' refers to space 'as directly lived through its associated images and symbols, and hence the space of "inhabitants" and "users"' (Lefebvre 1991, p.39). This aspect represents situatedness, individuality, diversity and deviation of experiences of space (Watkins 2005), hence the pairing concept of 'lived space'. Lefebvre (1991) suggests that the social production of space can be explained through the dialectical relationships between each pair of concepts. This means that 'spatial practices / perceived space', 'representations of space / conceived space' and 'spaces of representation / lived space' mutually shape each other on an ongoing basis; thus, continuously (re)producing what we consider as routine spatial experiences and socio-spatial orders while also enabling new ones to break through the routines and emerge anew.

The two frameworks presented above already provide some important insights in terms of how built assets could be conceptualised to analyse social value at the operational phase for the purposes of construction project management. For example, Agnew's (1987) framework suggests that 'spatiality' must be understood at various levels of organisation of social structures both locally (e.g. individual and group identities, historicity and traditions) and globally (e.g. planning institutions, national identities), but also that these different levels need to be interpreted as potentially conflicting and mutually shaping. Also, Agnew's (1987) framework suggests that knowledge domains relating to the built environment (e.g. economic and investment policy, interior design, architectural design, landscape design, city planning, regional development) are also interlinked and potentially in conflict with the local and individual understandings of 'spatiality'.

Hence, Agnew's (1987) framework, which was initially developed for political sociology, provides a sound theoretical foundation to capture the different (and potentially conflicting) views on the social value of a built asset at its operational phase. In a similar fashion, Lefebvre's (1991) framework, which explains space as socially produced, highlights three major themes that need to be considered together to understand the social value of built assets at the operational phase. While the concept of 'perceived space' highlights the importance of the unique socio-material context of actions and interactions involving a built asset (e.g. organising institutions and corresponding space morphology), 'conceived space' points to the importance of the ways in which space-related issues are represented, communicated, taught and researched as they define the horizons of our understanding of space and spatial practices.

On the other hand, the perspective of 'lived space' emphasises the situatedness of spatial experiences, thus directing the attention to the unfolding of events relating to a space as well as to individual circumstances of people involved in those events. Lefebvre's (1991) framework also implies that time and space are inseparably intertwined by suggesting that space is socially produced on an ongoing basis; thus, highlighting the importance of the history of spaces as well as the events during project delivery for understanding the social value of the built assets at the operational phase.

CONCLUSION

In construction and elsewhere, social value is as much a political concern as it is a managerial one. For this reason, studies of social value of built assets need to consider the multiple ways in which different social entities perceive and realise value in their practices depending on their unique circumstances. In line with this argument, the present paper proposed the idea of understanding social value of built assets focusing on value manifestation/realisation, as opposed to focusing on definitions of social value, in order to liberate the empirical space. It is argued that this would establish a better understanding of social value and how it can be project-managed than those promised by current dominant define-measure-manage approaches. An initial review of the literature that treats spatiality as a central aspect of social phenomena suggests that a fruitful engagement is possible between the domains that engage in socio-spatial analyses and construction project management in order to realise this research agenda. It is argued that the insights that will be developed by pursuing the proposed research agenda can enable an empirically grounded knowledgebase on how to project-manage social value to effectively address the practical needs relating to a built asset. Hence, the approach proposed herein is important to create an alternative to the narrow definitions of social value and the corresponding top-down, define-measure-manage approaches which promise only a limited level of engagement with the diverse range of social issues in practice.

Following from the point above a further conclusion can be drawn. By embracing the diversity of perspectives on social value of built assets and their various connections to project delivery, professions and businesses in the built environment may start recognising their not-so-visible roles in various social value outcomes. Hence, this can act as the necessary trigger to shift the current dominant rhetoric of social value in construction, which sees social value considerations as a balancing element, to a new rhetoric where social value is a core concern for professionals and businesses in the built environment; thus, transforming them. Indeed, a shift like this is already happening in the discipline of architecture. According to Allweil (2010), architecture has reformed its understanding about its object of study as a result of the 'spatial turn' which enabled various new ways of understanding the connection between spatiality and social phenomena. The spatial turn has brought the multifaceted understanding of the intertwined nature of spatiality, social relations, power, and the built environment to the core of theoretical discussions on architecture (Lähdesmäki 2018). This means that, as a result of this reformation, architectural scholarship now rejects the exclusivity of 'form' as its object of study but rather considers 'form' as the locus of answers to a variety of social issues. Building upon the ideas from the spatial turn and domains that traditionally engage with socio-spatial analyses, other professions and businesses in the built environment could engage in a similar transformation.

The question that remains is how to include these ideas in future research. For engaging with the proposed research agenda, a practice-based theoretical lens (Stern 2003) can be promising to undertake project-management inquiries with a focus on various realisations of social value for two main reasons. First, a practice-based theoretical lens places a crucial role on unique contexts of practices to explain social value realisation; thus, it can embrace the vast diversity of meanings that can be assigned to social value from different points of view. Second, it provides a sound ontology and epistemology that allows us to relate the realisation of social value in practice to previous practices of project delivery as well as the wider context within which projects are delivered. Developing insights into such relationships is promising

in that they have the power to expose how wider contexts of, and specific events in, project delivery result in certain value outcomes for certain social groups; and what it would take to amend those outcomes.

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A THEORETICAL FRAMEWORK OF SOCIAL VALUE IN CONSTRUCTION EMPLOYMENT

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Construction companies are increasingly being required to demonstrate the social value they create when tendering for projects for both public and socially responsible private sector clients. However, the concept of social value remains theoretically under-developed and there are many unanswered questions about how to define and measure it. Addressing these gaps, the aim of this empirical paper is to present a new theory of social value grounded in Meinong's (1894) Value Theory and in the context of social procurement practices in the Australian construction industry. We test this theory using a survey of 61 construction workers in Australia, showing that construction companies create social value when they provide employment that promotes 'work benefits' and 'culture benefits'. Critical work benefits include adequate training; autonomy; and fair remuneration. Critical culture benefits include fostering good quality working relationships; promoting employees' autonomy and personal identity and values; and high levels of engagement with local communities and workers. It is concluded that other researchers should test or develop this theory in other settings to explore geographical or cultural variables in other countries.

Keywords: community, employer-of-choice, social value, procurement

INTRODUCTION

Construction companies are increasingly being required to demonstrate the social value they create when tendering for public sector projects and for socially responsible private clients. There are five critical drivers to this requirement: the historical use of public procurement to achieve social outcomes (McCrudden 2007); a receding welfare state in the context of New Public Governance (NPG) (Barraket *et al.*, 2016); increased focus on evaluation and measurement of social performance in order to command legitimacy with government funders (*ibid.*); recognition that construction work often operates in areas of significant disadvantage and purchasing construction materials, professional services and contractors has significant potential to address complex problems and create social value (Loosemore 2016, Fewings and Henjewe 2019: 82); and an increasing number of socially responsible private clients in the context of growing corporate social responsibility practices (Raiden *et al.*, 2019).

Despite the interest in social value, it remains an underexplored area because, as Mulgan (2010: 38-40) writes, social value is inherently “subjective, malleable and variable” in nature and means different things to different people based on their ethics,

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morals and priorities. This is especially relevant in the context of emerging construction social procurement requirements (Loosemore 2016) which require firms to create social value by providing employment opportunities for targeted groups such as Indigenous people (see Australian Government 2015) who come from different cultures which see value differently. In addition, social outcomes of construction procurement are often intangible (Troje and Kadefors 2018), which presents difficulties for construction clients seeking to evaluate the social value their procurement creates. This has resulted in many definitions of what social value is and how it is created, which has complicated attempts to understand social value conceptually and operationally (Raiden *et al.*, 2019). Troje and Gluch (2020) argue that this means there is often little to no follow-up by construction clients on the social value of their social procurement policies. Social value therefore remains a theoretically and operationally ambiguous concept (Raiden *et al.*, 2019).

In the above context, the aim of this paper is to address these issues by developing a theoretical framework of social value which addresses the employment-focussed nature of social value creation activities in the construction industry. More specifically, this paper addresses three main research questions: (1) What do construction employees want out of work? (2) What factors are critical to creating social value in the context of construction employment? and (3) What is the relationship between social value and work benefits for construction workers?

This paper proceeds with an overview of the conceptual foundation of our work. Merging Meinong's (1894) Value Theory with employer-of-choice research, we hypothesise that construction companies create social value for groups targeted by social procurement initiatives when they provide employment that promotes both 'work benefits' and 'culture benefits'. We then discuss the methodology to empirically test our theory using a survey of 61 construction workers from the Australian construction industry. The results are then presented and discussed in terms of their relevance to the emerging yet under-theorised field of social value and to practitioners working in this new area.

SOCIAL VALUE THEORY

Given the above challenges of conceptualising social value, several recent attempts have been made to better understand it. For example, in a construction management context, Raiden *et al.*, (2019: 17) reviewed numerous definitions from different fields and define social value as "the social impact of any construction organisation, project or programme makes to the lives of internal and external stakeholders affected by its activities". Outside of construction, Nicholls (2018: 148) theorised that accounting for social impact should give voice to and empower people through "the materiality of uncertainty data...via careful stakeholder engagement...that acknowledges the empowering potential of such processes as communicative action". To this end, Denny-Smith and Loosemore (2017) argue that positive social value in an Indigenous social procurement context in Australia is the result of 'acceptance' by social value recipients of various employment opportunities and the values or expectations held by their culture or society. More recently, Watts *et al.*, (2019) developed a social value tool which could be understood by numerous stakeholders simultaneously. While valuable, the tool is administered by employers who ask staff to complete a questionnaire, increasing the risk of employees answering based on social desirability bias. Social desirability bias is the possibility of respondents providing answers perceived to be culturally or socially acceptable and positive (Nardi 2003).

As Denny-Smith *et al.*, (2019) argue, it is too often those in a position of power who determine what social value is and how it should be measured. This excludes the perspectives and experiences of people meant to benefit from social value practices. In addition, there are also many controversies around existing tools that attempt to quantify and monetise social value, such as social return on investment (SROI) (or other prescriptive metrics) which Watts *et al.*, (2019) criticise for being too reductionistic and overly simplistic, by aiming to combine social impacts into a single financial value. This points to the lack of social value theory where, in the social sciences generally, Haugh (2012) argues that good theory development will lead to good practice. Therefore, there is a need for theory that explains the creation of social value, so that existing tools can be adapted to communicate the true impacts social value practices have on the people they are meant to benefit.

Theory development

Despite its age, Meinong's (1894) Value Theory is particularly useful in understanding social value creation because it proposes that there are four components acting together in a process of determining value: (1) Value subject: A person perceiving the social value created by social procurement policies or construction employment opportunities the policies provide; (2) Value object: the construction employment opportunities provided by social procurement policies which will be given a social value; (3) Existence judgement: An evaluation of the relationship between the value object (construction jobs) and someone's personal and cultural values, that determines the social value created by social procurement policies, and; (4) Value feeling: A person perceiving the social value that construction employment creates, based on the relationship between a value object (a job) and the existence judgement.

While useful for conceptualising the notion of value, Meinong's (1894) theory was not developed in a social value context which as discussed above, in the construction sector, is linked primarily to the creation of employment opportunities for disadvantaged groups targeted by social procurement policies. In this context, social value is created through employment which meets the needs of those targeted by these policies and research in the area of employer-of-choice (EOC) may hold some value in adapting the theory to a construction environment. Founded in efficiency wage theory, the concept of EOC suggests that workers have a choice of where to work and realise that different choices will likely lead to different levels of success and job satisfaction. Workers will therefore choose employment where they can take advantage of their skills and there is a balance between theirs and the organisation's values (Elving *et al.*, 2013). A review of the EOC research indicates that they generally include various combinations of the following criteria, in no specific order of priority: pay, conditions and benefits; employee engagement; leadership quality; safety and well-being; quality of workplace relationships; positive workplace culture and climate; equal opportunities, career development opportunities; flexible work practices, worker involvement and empowerment; receiving and giving feedback on work performance; clear company strategy and values; healthy and stimulating work environment; and corporate citizenship (Kuhnel *et al.*, 2009, Gill 2013). More recently, Bellou *et al.*'s (2015) research found that critical EOC factors include the following workplace characteristics: Adequate remuneration; positive working relationships; opportunities for self-development; recognition of achievements and making new employees feel welcome, and; corporate image, including a company's commercial and social image.

While useful, the large body of work on EOC is generic and as Hunter (2015) notes, research on the relationship between disadvantaged populations like Indigenous workers in Australia and their employers is scarce. Indeed, EOC research does not provide insight into the employment attributes workers seek in specific industry sectors such as construction which represent the focus of social procurement policies. While Sedighi and Loosemore (2012) explored EOC characteristics in construction from a graduate perspective, there has been no research into the types of employment which are likely to maximise social value in a construction context. The following section describes the method which was used to address this gap in research in order to provide a foundation for the refinement of Meinong's (1894) theory in the context of social value creation in construction employment.

METHOD

Based on an in-depth review of the employer-of-choice literature summarised above, we undertook an online anonymous survey of construction workers in Australia to explore the employment conditions which would create maximum social value for people specifically working in the construction industry. While the positivist conventions of surveys could be argued to counter the socially constructed and subjective nature of social value research (Denny-Smith *et al.*, 2019), a survey tool was employed after extensive consultation with construction industry partners. Online surveys offered several benefits, including: reducing costs to distribute and collect survey responses from geographically dispersed sites in regional areas of Australia where staff were based; maximising survey coverage to the target sample population; improving response rates because of improved ease to complete the survey, and; reducing social desirability bias (Dillman *et al.*, 2009). In this research the anonymous electronic survey meant respondents could complete the survey in private and minimised the risk of social desirability bias.

The survey consisted of two sections and respondents were identified and approached through our partner contracting organisations using purposive nonprobability sampling on the basis of their employment in the construction and property maintenance industries. The first part of the survey asked demographic questions about age, cultural identity and the state or territory they worked in. The second part of the survey asked respondents about their values based on Bellou *et al.*'s (2015) research that shows that EOC's have values that are strongly aligned with the values of employees and include, for example: inter-personal relationships within the company; relationships between the employer and employees; and relationships of the employer company to society/communities. In Australia, this includes attitudes towards family, communities and obligations to society that differ between cultural groups in that country (see for example Byrnes 2000).

The third part of the survey asked respondents to rank the importance of 31 EOC characteristics based on a four-point Likert Scale. The four-point scale was used as a forced-choice question that makes respondents choose an option for or against a question (Nardi 2003). Forced-choice questions were used in this survey to minimise the risk of social desirability and helps highlight respondents' relationships between different questions (see Aupperle *et al.*, 1985). The questions in this part of the survey was adapted from the results of EOC research on construction graduates by Sedighi and Loosemore (2012) to include cultural variables which research on 'old institutionalism' (Austen 2000) indicates that people consider when perceiving social value. For example, research on successful employment programs for minority

populations, such as Indigenous Australians, shows that culture benefits of employment opportunities include culturally safe and supportive environments, having clear career progression pathways for employees, positive engagement with employees' heritage, family and community, and boosting employees' confidence, autonomy, self-efficacy, identity and resilience (Wilson *et al.*, 2019).

Recognising the subjective nature of social value and the lack of research into what construction employees may want out of an EOC, one open question was included to allow respondents to insert EOC variables not covered in our closed questions.

After developing the semi-structured survey with the above cultural variables, the research team consulted our industry partners for further discussion on the survey content and how the research would be managed, and the results used. For example, the research team took direction from industry partners on the length and format of the survey, and shared agreement was reached that the content was accurate to investigate social value in a construction context, thus improving the content validity of the survey (see Fowler 1995: 139). The survey was distributed to 190 people working for our two industry partners across Australia, using purposive sampling to ensure respondents met the sampling criteria listed above. Sampling construction employees, including management, allowed a broad sample representation for this exploratory research on social value in the construction industry. To maximise the response rate, an email was sent from our industry partners to each respondent with an invitation letter which ensured respondent anonymity and allowed them to ask any questions of the research team and withdraw their data at any time. This resulted in a total of 61 usable survey responses (a response rate of 32 per cent), producing a sample as illustrated in Table 1. The response rate may be explained by the fact that our industry partners also have sites in regional and remote Australia, which could limit participants' access to mobile data to complete the survey.

Table 1: Sample structure

Category	Response	Frequency	Percentage
Australian citizen	Yes	53	86.9
	No	8	13.1
Australian state or territory	ACT	2	3.3
	NSW	43	70.5
	QLD	8	13.1
	SA	2	3.3
	WA	6	9.8

RESULTS

Table 2 below shows the highest rated values and employer characteristics. For brevity, only the five highest rated variables are listed. The variables in Table 2 were also characterised by lower standard deviation than other responses, indicating a high degree of consensus among respondents. In support of Bellou *et al.*, (2015), the results show that construction EOCs develop employees' skills, promote good working relationships and have a good corporate image. Supporting Raiden *et al.*, (2019: 168), Table 2 also shows that "values help shape the way social value...[is] created" through construction employment. For example, construction employers who promote employee autonomy to learn and complete work may create social value

through improved employee confidence and better skills that benefit their long-term career.

A test for Pearson's correlation coefficient (Pearson's r) was also performed to check for association between variables in the second and third sections. Pearson's r is a measure of association that represents the extent to which respondents occupy the same position on two variables (Blaikie 2003). The strength of association between two variables may be small ($r = \pm 0.10$), medium ($r = \pm 0.30$) or large ($r = \pm 0.50$) (Rosenthal 1996). In this study, Pearson's r allowed us to test for relationships between respondents' values and their EOC preferences. This meant we could infer the work and culture benefits that may contribute to positive social value creation in the context of construction employment.

Table 2: Highest five rated responses for culture and work benefits

Question	Variable	Mean	Std. deviation
Which of the following values are important to you? (culture benefits)	Sharing with and looking after my family	3.87	.386
	Finding things out and learning for myself	3.78	.415
	Making sure I have enough for today	3.61	.670
	Knowing who I am and where I came from	3.57	.621
	Respecting my elders and what they have to teach me	3.44	.696
Please indicate what characteristics describe our ideal employer? (work benefits)	Good quality of working relationships	3.88	.334
	A good reputation	3.81	.395
	High level of personal physical safety	3.81	.476
	Seeing and understanding the overall purpose of tasks	3.77	.423
	A manager that focuses on leadership and energy in the workplace	3.72	.453

Table 3 shows the results of testing for Pearson's r . Associations where $r > \pm 0.50$ are presented to show the strongest associations. Variables with strong associations were then checked for their statistical significance ($p < 0.05$, see Nardi 2003). It is interesting to note that all variables with a strong association were positive relationships and showed extremely high significance ($p \leq 0.001$).

Table 3 shows there are recurring variables that strongly influence other outcomes. For example, construction workplaces that were responsive to employees' cultures had a strong association with the importance of 'culture benefits' of construction employment. In addition, values like making sure traditions, rituals and practices are maintained had strong associations with numerous 'work benefits' like physical safety, emotional stability and a workplace that is involved with local communities. These relationships suggest that construction companies who want to create social value through their employment may need to move beyond "creating employment opportunities for people from disadvantaged communities" (Raiden *et al.*, 2019: 73), to investing in the economic and cultural wellbeing of their employees. Although, this may be difficult and require a significant paradigm shift in the construction industry when it is considered that many contractors see the disadvantaged groups targeted by social value practices as a significant safety, productivity and cost risk to their business (Loosemore *et al.*, 2020). Further research is needed in this area to explore how contractors are utilising their employment to create social value for employees.

Table 3 give several interesting insights into how social value is created in construction employment. For example, culturally inclusive workplaces are clearly associated to numerous culture benefits and there are more non-financial

characteristics (e.g. emotional stability, learning on the job and workplaces that are involved in local communities) of EOCs than financial. Indeed, this insight supports Murphy and Eadie's (2019) findings that construction contractors need to adopt a more person-centric approach to generate social value through construction employment. Our findings suggest that this could be done by familiarising staff with company routines and creating a workplace that encourages commitment to work, training and employee development as well as engagement with local communities.

Table 3: Association between work and culture benefits using Pearson's r

Work benefit	Culture benefit	Pearson's r	Sig. (2-tailed)
A workplace that allows me to stay connected to my culture	Sharing with and looking after my community	.654	< 0.001
	Making sure traditions, rituals and practices are maintained	.645	< 0.001
A manager who is aware of and responsive to my heritage and culture	Sharing with and looking after my community	.676	< 0.001
	Knowing who I am and where I came from	.615	< 0.001
	Making sure traditions, rituals and practices are maintained	.609	< 0.001
	Respecting my elders and what they teach me	.509	< 0.001
Emotional stability and feeling protected by the organisation	Making sure traditions, rituals and practices are maintained	.530	< 0.001
A high standard of accommodation and fit-out of the workplace	Making sure traditions, rituals and practices are maintained	.525	< 0.001
High pay and income	Making lots of money	.688	< 0.001
Working extra hours (paid or unpaid)	Making lots of money	.512	< 0.001
Being able to learn on the job	Making sure traditions, rituals and practices are maintained	.528	< 0.001
A workplace that has a high commitment to work	Making sure traditions, rituals and practices are maintained	.514	< 0.001
A workplace that is relaxed and people can have fun and enjoy social interaction	Making sure I have enough for today	.509	< 0.001
Being involved with my local community	Sharing with and looking after my community	.615	< 0.001
	Making sure traditions, rituals and practices are maintained	.563	< 0.001
A workplace that cares about protecting the environment	Sharing with and looking after my community	.579	< 0.001

Theoretical framework

Drawing on the above results, Figure 1 presents a new theoretical framework explaining how social value is created in the context of construction employment and using Value Theory. Bounding Figure 1 is the value subject, construction workers, as they are the people meant to realise social value through construction employment

which acknowledges the subjective nature of social value. Within the bounded area there are three parts: the value object, in this case construction employment characteristics informed by responses to the third survey section; the existence judgement informed by people's values in the second survey section; and the value feeling which is produced by the existence judgement and value object. The variables influencing people's perception of the value object and existence judgement are based on the strongly associated variables of important work-culture benefits (see Table 3). In operation this means that construction employees would accept employment promoting autonomy and self-development, therefore creating positive social value. Construction employers can use Figure 1 to review their own employment practices, so they create social value in their workforce.

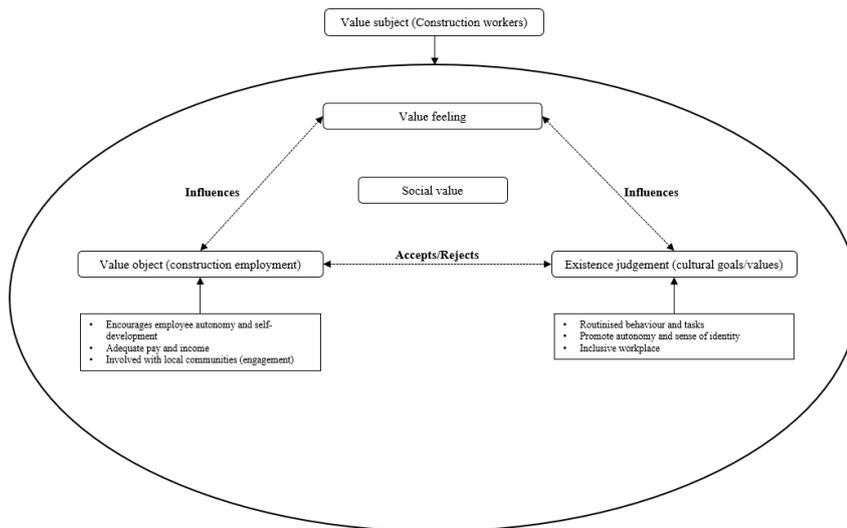


Figure 1: Theoretical framework for the creation of social value from construction employment

CONCLUSION

This empirical paper presented the first attempt to explain the variables contributing to creating social value in the context of construction employment in Australia. Employment requirements are now included in many public works construction projects to create social value for disadvantaged populations. This theoretical framework fills the identified knowledge gap by explaining that social value is created when construction employers provide work benefits and culture benefits to their employees, including good pay and employee autonomy in an inclusive environment. This supports arguments that employee participation and holistic focuses on socially responsible procurement are key to creating social value (Murphy and Eadie 2019). Our framework also responds to recent research that has suggested how to conceptualise and operationalise social value in the construction industry (Raiden *et al.*, 2019).

This paper does not attempt to be universally applicable; the authors acknowledge that the research is limited to Australia and a limited sample. This limits its contribution as a major theoretical framework but as it is tested over time its validity will improve. This paper also provides interesting avenues for researchers and practitioners. Researchers can test or develop this theory in other settings, such as different countries, to explore geographical and cultural differences of our findings. Practitioners can use this theory to plan for social procurement or evaluate their

existing business practices. For example, practitioners may begin more cultural engagement with their employees to promote social value based on our findings. The significant potential of this theory lies in planning for social value to address the complex issues facing disadvantaged groups in Australia and internationally.

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FROM PARTNERSHIP TO FIRM: HYBRIDITY AS SOURCE OF ROUTINE CHANGE

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Strategic partnerships have recently gained foothold in the Danish construction industry as a novel collaborative interorganisational relationship. Strategic partnerships have so far been used in major construction programmes and can be seen as a hybridised organisational form that draws on multiple existing organisational forms in creating new interorganisational routines and developing collective knowledge. The objective of the paper is to explore how a strategic partnership creates new routines by developing collective knowledge, and how these routines are transferred to the constituent organisations as firm-specific routines. Empirically, we draw on data from a strategic partnership between the City of Copenhagen's client unit, ByK, and a group of six AEC firms that constitutes the consortium named TRUST. Data is collected in the period 2017-2019 and consists of 22 interviews describing developments in the strategic partnership and in the constituent firms. In the analysis, we apply an institutional theory perspective in a parallel analysis of developments in the strategic partnership and in two of the constituent firms (the client and the contractor). We show that the strategic partnership creates new interorganisational routines in pursuit of collective knowledge and that the constituent firms learn from their engagement in the strategic partnership, which leads to creation of new routines and changes in existing routines. As such, the paper contributes to an understanding of how new intraorganisational routines created in a strategic partnership ramify to firm-specific routines in the constituent firms.

Keywords: hybridity, organisational learning, routines, strategic partnership

INTRODUCTION

Firms' ability to acquire new knowledge and learn from experiences is critical for organisational survival and prosperity in contemporary societies (Chan *et al.*, 2005). Along with the worldwide transition from industrial societies to knowledge societies, the acquisition and utilisation of knowledge have become of greater importance across industries and firms. As such, knowledge can be perceived as a fundamental resource in contemporary societies to obtain social and economic wealth while capital and labour have become secondary (Drucker 1993). This is in part due to the increasing complexity of modern markets and the services that companies have to deliver. Institutional complexity (Jay 2013) stemming from external demands from clients and

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other stakeholders to deliver on different and potentially conflicting concerns, necessitates firms engage in learning to acquire new knowledge to develop their organisational routines. For instance, Javernick-Will (2009) argues that organisations that expand into new international markets need to acquire institutional knowledge to reduce the knowledge gap - i.e., the difference between knowledge a firm possesses, and the knowledge required to operate in the new market.

In construction management research, inquiries on organisational learning have primarily examined intraorganisational learning processes at the project level with reference to the fragmented and project-based nature of the industry (e.g. Chan *et al.*, 2005; Eriksson *et al.*, 2017; Styhre *et al.*, 2004). However, firms can also acquire knowledge and learn from experiences made by other firms (Greve 2005), or through engagement in collaborative interorganisational relationships, such as strategic partnerships, where knowledge is developed collectively among firms (Larsson *et al.*, 1998; Ring and Van de Ven 1994). Strategic partnerships, likewise, other collaborative concepts such as partnering (Bresnen and Marshall 2000), aim to deal with fragmentation and lack of integration in the industry. However, where partnering mostly has been applied in attempts to improve project performance on single projects (Bresnen 2009), a strategic partnership aims to ensure performance across multiple related projects (Gottlieb *et al.*, 2020). This involves development of organisational routines that go beyond needs of the single projects and capitalising on the learning processes that develop in the joint organisation. An interesting topic that remains yet underexplored is how collective knowledge developed in a strategic partnership is adopted at an organisational level and results in firm-specific routines. A common premise in the literature on organisational learning is that organisational routines are created and changed when organisations acquire new knowledge and thereby learn (Levitt and March 1988). A considerable number of studies have examined how routines are created or changed through learning from organisations' own experiences (Ingram 2002). Feldman *et al.*, (2016) argue that routines are enacted in specific times and places and are inseparable from the context in which they are embedded. This means that transferring routines is an effortful enactment. Moreover, Bertels *et al.*, (2016) show that the transferral and integration of an external routine is shaped by organisational culture to establish a fit. This begs the questions of how and what firms individually learn from routines developed in collaborative interorganisational relationships such as strategic partnerships.

The objective of the paper is to explore how a strategic partnership creates new routines by developing collective knowledge, and how these routines are transferred to the constituent organisations as firm-specific routines. The paper empirically draws on data collected in a strategic partnership between 2017 and 2019. The theoretical basis of the paper is literature on organisational learning and the institutional theory concept of hybrid organising.

ORGANISATIONAL LEARNING AND ROUTINES

Organisational learning processes are central as a basis for achievement of strategic advantages in rapidly changing environments (Ingram 2002; Levinthal and March 1993; March 1991). According to Levitt and March (1988: 320), organisations are learning by “encoding inferences from history into routines that guide behavior”. In this context, routines should be understood as the conventions, forms, procedures, rules, strategies and technologies, which organisations are intermingling with and constructed by through their daily operations (Levitt and March 1988).

In his pioneering work on organisational learning, March (1991) distinguishes between two types of organisational learning processes - exploration and exploitation. Exploration refers to experimentation with new alternative organisational routines while exploitation refers to the refinement and extension of existing organisational routines (March 1991). Both learning processes are critical for the development of sustainable competitive advantages but are, however, also difficult to manage simultaneously because of their different natures, which cause ongoing tensions in most modern firms (Battilana and Lee 2014; Eriksson *et al.*, 2017).

While individual firms are deemed to learn through changes in their prevalent organisational routines (March 1991), a strategic partnership can learn by creating or changing its interorganisational routines or repertoire of possible joint activities (cf. Larsson *et al.*, 1998). A strategic partnership can facilitate collaboration among the constituent firms by providing an organisational form that encourages joint activities and where interorganisational routines are created and adapted to pursue development of collective knowledge (Larsson *et al.*, 1998). Such organisational forms are combinations of assets, competences and resources that are located within and transferred from the constituent firms of the strategic partnership. The forms can therefore be labelled hybridised organisational forms that draw on multiple existing organisational forms (Battilana and Lee 2014; Oliver and Montgomery 2000).

Hybrid organising as a mechanism for changing routines

Hybridised organisational forms are mixtures of multiple far more 'parent' organisational forms (Oliver and Montgomery 2000). According to Battilana and Lee (2014), hybridised forms uphold their sustainability through ongoing hybrid organising that manage internal and external tensions when interacting and fusing aspects of multiple organisational forms. Hybrid organising can be defined as "the activities, structures, processes and meanings by which organizations make sense of and combine aspects of multiple organizational forms" (Battilana and Lee 2014: 398). Thus, hybrid organising is introduced as an approach to deal with disorders stemming from interaction of multiple organisational forms that are conventionally separated (Battilana 2018).

Strategic partnerships are likely to engage in hybrid organising to deal with multiple organisational forms and their related activities, structures, processes and meanings in pursuit of specified objectives. Formation of new hybridised organisational forms allows strategic partnerships to adhere to institutional prescription from multiple established organisational forms that are recognised as legitimate (Battilana 2018). The interorganisational routines and joint activities, which are highlighted as being important in development of collective knowledge in strategic partnerships (cf. Larsson *et al.*, 1998), can thus be viewed as a result of the mixing of multiple organisational forms through hybrid organising (Battilana 2018). By understanding hybrid organising in strategic partnerships, we will be able to better understand how collective knowledge is developed by mixing organisational forms (Battilana and Lee 2014). Furthermore, we will be able to understand how constituent firms may use the strategic partnership as a vehicle for organisational learning by enacting and recreating routines developed in the strategic partnership.

RESEARCH CONTEXT AND METHODS

Strategic partnerships have recently gained foothold in the Danish construction industry as a novel collaborative organisational form. A strategic partnership can be

defined as a legal frame between a 'client' and a consortium of 'suppliers' with strong focus on collaboration and sharing of organisational assets, competences and resources throughout a programme of projects to achieve specified objectives (Gottlieb *et al.*, 2020). Since 2016, six strategic partnerships have been announced in the Danish construction industry by client organisations from the public sector and the social housing sector, which is showed in Table 1.

Table 1: Ongoing and forthcoming strategic partnerships in the Danish construction industry

Client/Sponsor	Supplier/Consortium	Estimated value	Duration
Copenhagen Municipality	TRUST	€320M	2016-2020
Copenhagen Municipality	DSP PLUS	€90M	2016-2020
FSB	HJEM	€400M	2019-2024
KAB	&os	€800M	2019-2024
Capital Region of Denmark	To be determined	€960M	2021-2024
Egedal Municipality	To be determined	€50M	2021-2024

Common to the strategic partnerships is that they rely on a long-term and integrated organisational setup, which can be considered an alternative to the fragmented and project-based nature of the industry where focus typically is on short-term efficiency. Moreover, the strategic partnerships rest on the assumption that it is possible to achieve cost efficiency and diminish conflicts and disputes by: (i) dedicating multiple related projects to the strategic partnerships; and (ii) mobilising multi-firm assets, competences and resources into the strategic partnership organisations.

Establishment of strategic partnerships is thus touted as a way to obtain collective benefits such as market access, scale economies and competence development through the development of collective knowledge (cf. Larsson *et al.*, 1998). The collective knowledge in strategic partnerships is developed by encouraging joint activities and by creating new interorganisational routines (Larsson *et al.*, 1998). However, this type of knowledge is also attractive for the constituent firms in order to ensure competitive advantages and improvements of future returns (March 1991) and adopt to future demands when delivering complex construction projects (Eriksson *et al.*, 2017). Thus, an important perspective is how strategic partnerships create and change their interorganisational routines in pursuit of collective knowledge and how the constituent firms, simultaneously, learn from their engagement in a strategic partnership.

Empirical data and data collection

The empirical point of departure is the strategic partnership between Copenhagen Municipality and TRUST (see Table 1). The strategic partnership was tendered in 2016 and is organised as a €320M four-year programme comprising 40 new-build and renovation projects of schools and day care institutions in the City of Copenhagen. Copenhagen Municipality is represented in the strategic partnership with their client unit, ByK, while TRUST represents a consortium of employees from two architecture firms, two engineering firms, one landscaping firm and one contractor. The contractor, E&P, is contractual responsible on behalf of the entire TRUST consortium.

The data set used in the study consist of 22 open-ended interviews with informants from ByK and E&P, which we conducted between 2017 and 2019. This means that we have limited the empirical scope of the study to include only the two contract holders who are also the largest and most decision-intensive parties. The aim of the

interviews was to gain in-depth information pertaining experiences and viewpoints on selected research topics regarding the strategic partnership (Turner 2010). During the interviews, we used an interview guide with predetermined questions that were closely related to our research topics and thus set the scene for each of the conversations (Weiss 1995). Moreover, we asked follow-up questions when the interview questions were either too unclear to the informant or if we wanted a more thorough answer on a specific question. Each interview was audio-recorded with permission of the individual informant, and all the conversations started with a short non-audio-recorded briefing about the purpose of the study where the informant also could express his or her concerns. The informants are listed in Table 2.

Table 2: Conducted interviews

Organisation	ByK	E&P
Number of interviews	12	10
Informants	Head of Construction (x2); Head of Finance and Secretariat; Head of Office I (x2); Head of Office II (x2); Legal Director (x2); Project Manager (x2); Senior Consultant	Business Area Director; CEO of E&P; CEO of TRUST; Collaboration Developer; Head of Calculations; Head of Productions; Head of Resources; Project Director I; Project Director II; Project Manager
Duration (min)	Between 53 and 85 with an average duration of 68	Between 38 and 73 with an average duration of 56

EMPIRICAL FINDINGS

This section is divided in three subsections. The first subsection describes joint activities and interorganisational routines that have been created in the strategic partnership in pursuit of collective knowledge development. The last two subsections describe how ByK and E&P, respectively, are in the midst of creating and changing their routines as a result of their engagement in the strategic partnership.

New interorganisational routines and development of collective knowledge

The strategic partnership between ByK and TRUST is a temporary multi-firm construct expected to achieve specified objectives in the public and private sectors through collaboration and sharing of assets, competences and resources. Public sector organisations, such as ByK, are traditionally known to be nested in a wider administrative system and conforming to a bureaucratic-hierarchical organisational form for the benefit of the public institution (Morris and Farrell 2007). Firms operating in the construction industry, such as E&P, are largely project-based (Chan *et al.*, 2005; Eriksson *et al.*, 2017), which is an organisational form associated with low degree of bureaucracy and hierarchy to make project-specific goals achievable for the benefit of the firm. The strategic partnership provides a hybridised organisational form that mix aspects of the forms found in public sector organisations as well as in project-based firms. The hybridised organisational form is supposed to facilitate creation of joint activities and new interorganisational routines allowing the strategic partnership to develop collective knowledge (Larsson *et al.*, 1998).

The strategic partnership created a hybridised organisational form by defining an overall and quite broad objective that ByK and TRUST endorsed. The objective was to balance cost and quality of the projects in the best possible way, and to build trust

among the constituent firms to diminish and resolve conflicts effectively. This objective was comparable to strategic objectives found in ByK and E&P. One of ByK's objectives was to achieve cost efficiency, as also emphasised by ByK's Head of Construction: "we have seen comparable projects at significantly lower prices in other municipalities, so it is likely that this can also be realised in Copenhagen". According to the CEO of E&P, one of their objectives was: "to get closer to our clients [and] restore the bad reputation of the industry associated with low productivity development and many conflicts". The strategic partnership's objective thus mirrored ByK's and E&P's own interests and gave incentives to work together despite of compliance to different organisational forms.

The strategic partnership promoted joint activities, work procedures and cultural aspirations, in effort to create new interorganisational routines that were considered essential in meeting the defined objective of the strategic partnership. For instance, an office dedicated to the strategic partnership was established and working from the office was mandatory for project members (i.e. employees) from the constituent firms that were allocated projects in the strategic partnership. Project members were moreover expected to adhere to the prevalent activities, work procedures and cultural aspirations in the strategic partnership. These included, among other things, new types of meetings aimed at disseminating knowledge laterally to bridge knowledge gaps between project members that had different professional backgrounds. The project members were also required to use the same hour registration system so the strategic partnership's operational management group could monitor resource usage on ongoing projects and plan resource allocation on forthcoming projects regardless of the project members' organisational affiliation. Furthermore, project members were expected to participate in weekly SCRUM sessions where all project members presented their tasks for the week and set deadlines on internal project-specific deliveries. These examples illustrate how the strategic partnership developed and extended the hybridised organisational form by promoting activities and work procedures that spanned multiple organisational forms and thereby created new interorganisational routines (Battilana and Lee 2014; Oliver and Montgomery 2000).

The strategic partnership also endeavoured to socialise project members from the constituent firms into the hybridised organisational form by nurturing cultural aspirations of how to behave as part of the strategic partnership. For instance, the strategic partnership's management group formulated a core story describing the values and beliefs that the strategic partnership wanted to be associated with and the project members had to follow and respect. The values and beliefs were, among other things that all project members had to stimulate and propagate high degrees of belonging, collaboration, empowerment, risk sharing and trust. Furthermore, all new project members had to attend so-called onboarding activities, which were an introduction to the hybridised organisational form and training in how to behave in accordance with the core story of the strategic partnership. The socialisation of project members was an attempt to conform behaviour to the activities and work procedures and thereby make the interorganisational routines more stable (Battilana 2018). It is worth mentioning, that the development of the hybridised organisational form was not as smooth as the description may indicate. Several project members were for instance replaced along the way, as they could not reconcile themselves with working in the new organisation form.

The strategic partnership thus commenced hybrid organising by creating joint activities and interorganisational routines that broke down the traditional

organisational boundaries. The hybrid organising allowed the strategic partnership to grow as a joint organisation and develop knowledge for the benefit of the entire strategic partnership. This was also expressed by ByK's Project Manager: "when a problem arises in the strategic partnership, it is a problem for all of us [...] the community is distinguished and there is way more genuine collaboration that are not guided by a contract". Hence, the strategic partnership developed collective knowledge on issues such as long-term orientation, interorganisational trust building and collective awareness (Larsson *et al.*, 1998). Moreover, the strategic partnership learned and developed gradually through the collective knowledge. For instance, a new calculation concept tailored for the strategic partnership was developed over a period of one-and-a-half-year because of ambiguity about project costs. Also, principles for involvement of the contractor, E&P, in the design phase of the projects were made to add knowledge on buildability as early as possible. This was agreed because too many projects had to be redesigned in the construction phase.

Creation and changes of routines in ByK

Following the initial work in the strategic partnership, ByK initiated changes in their own organisational routines. A new 'fourth' office (i.e. division) is established and expected to get a prominent role in ByK in coming years. The office will in the beginning be the only that does not handle any strategic partnership projects. The office is, however, likely to become a dedicated strategic partnership office in ByK if more strategic partnership tenders are prepared in the municipality. As elaborated by ByK's Head of Construction: "we are about to establish a new office in ByK and have decided that it, as the only of our office, should not be part of the [existing] strategic partnership [...] but if we prepare a new strategic partnership tender, we definitely need to consider whether we should dedicate the office to the strategic partnership". There are two reasons why ByK is reluctant to place strategic partnership projects in the new office but would reconsider if a new partnership were established. The first is that it takes a long time for employees affiliated to the office to socialise into the strategic partnership and learn the new routines. The second is that it is complex for the employees to work simultaneously in the strategic partnership and on conventional projects. ByK is thus aware that partnership-specific routines are a challenge to existing in-routines.

ByK has also established a new cross-organisational forum in an attempt to coordinate laterally in the organisation that is otherwise known to be highly hierarchic. This is emphasised by ByK's Project Manager: "when problems arise in ByK, they are often addressed in the top of the hierarchy, but they should also be addressed and managed across our organisation". The cross-organisational forum, is according to ByK's Project Manager, directly inspired by experimentation with lateral meeting types in the strategic partnership. The forum can thus be deemed as a routine that initially was explored and developed as a partnership routine, and subsequently has been transferred and adapted in ByK as a part of their efforts to coordinate laterally, which their existing routines otherwise do not support.

Ongoing evaluations of the strategic partnership is also undertaken by ByK in order to assess what can reasonably be expected and demanded if a new strategic partnership tender is prepared. This is elaborated by ByK's Legal Director: "this partnership is the beta version and if we prepare a new one it will be the first version and the one after will be the second version [...] we have already developed many paradigms together, but we must be more consistent in our needs and how to measure them". ByK is thus

aware that there not necessarily is a fit between the demands of the routines developed in the strategic partnership and in their own organisation (Bertels *et al.*, 2016).

Creation and changes of routines in E&P

In E&P, engagement in TRUST has resulted in strategic partnerships being defined as a new business area. E&P has accordingly established a new partnership division under the control of the CEO of TRUST. The new division has its own strategy and group of employees as well as processes and procedures. The partnership division was established after several discussions in E&P's board whether a strategic partnership constitutes a large project with numerous sub-projects, thus fitting within existing organisational routines, or a programme organisation requiring a new governance structure. The prevalent understanding that a strategic partnership is a hybridised organisational form that mixes multiple established forms (e.g. the bureaucratic-hierarchical organisational form and the project-based form), however, conflicted with the notion that a strategic partnership constitutes a large project. Strategic partnerships were therefore recognised as a new business area and assigned its own division. As argued by E&P's Project Director II: "TRUST is a brand-new organisation that we have built. The organisation handles project development, design and construction, and it is not typical for a contractor to work within all these areas [...] some would definitely say that it is too imaginative".

As a direct consequence of their engagement in TRUST, E&P has also adopted routines developed and tailored for use in the strategic partnership such as the new calculation concept. The calculation concept was developed as a partnership routine to deal with discrepancies associated with different institutionalised calculation routines in, respectively, public sector organisations and project-based firms. According to E&P's Head of Calculations, the concept has been adopted in E&P as it can be refined to accommodate other client organisations and thus be used to clarify discrepancies stemming from having to comply with different calculation routines.

Finally, E&P has established a career path within strategic partnerships that young employees can choose in the same way that they can choose to become traditional project managers or BIM experts. Employees who choose a future within strategic partnerships will be trained in the values and beliefs known from the strategic partnership such as belonging, collaboration, empowerment, risk sharing and trust.

DISCUSSION

Studies on hybrid organising has mostly examined hybridity from the perspective of the development of organisational forms, identities or rationales (Battilana *et al.*, 2017). In the study, we have studied hybridity from the perspective of routines to understand how the pursuit of collective knowledge in a strategic partnership shape interorganisational routines. We argue that the creation of new routines is important in the formation of hybridised organisational forms as they provide a way to manage internal and external tensions when multiple organisational forms interacts and are fused. By focusing on the level of routines, we contribute to an understanding of the diffusion of hybrid practices and their influence on firm-specific operations. Routines are patterns of action, and while these might be situated, they can also be enacted (as effortful or emergent accomplishment) across contexts and form connections with other routines (Feldman *et al.*, 2016) to create change, innovation and variation.

In the empirical findings, it was thus illustrated how both ByK and E&P create and change routines that are directly inspired by the interorganisational routines created in

the strategic partnership; ByK by creating a cross-organisational forum and E&P by adopting the bespoke calculation concept. Moreover, both ByK and E&P have established new divisions based on their experiences from the strategic partnership. ByK established their division to relieve the pressure on their employees that are allocated the strategic partnership projects. E&P established their division in effort to strengthen their market position and to exhibit their belief in the strategic partnership as a hybridised organisational form. Furthermore, ByK is part of a political reality characterised by bureaucratic-hierarchic structures and processes and thus considers the strategic partnership as an opportunity to create new routines that can help them navigate in the administrative system. E&P, on the other hand, is a project-based firm, and considers the strategic partnership as an opportunity to develop routines that can improve outcomes at project level, but also as a way to move closer to their clients by mixing aspects of multiple organisational forms. The hybridised organisational form thus implies the development of collective knowledge and the creation of interorganisational routines to allow experimentation with existing institutionalised routines associated with the bureaucratic-hierarchical form and the project-based form of organising. Moreover, the organisational form allows the constituent firms to refine and implement new firm-specific routines based on collective knowledge developed in the strategic partnership.

CONCLUSION

The objective of the paper was to explore how a strategic partnership creates new routines by developing collective knowledge, and how these routines are transferred to the constituent organisations as firm-specific routines. In the study, we have shown that the strategic partnership promotes activities, work procedures and cultural aspirations in the formation of a hybridised organisational form. We have also shown that the constituent firms learn from their engagement in the strategic partnership, which leads to creation of new and changes in existing routines. Common to ByK and E&P is that they adopt and refine routines created in the strategic partnership as firm-specific routines when they are considered attractive alternatives or add-ons to already institutionalised routines.

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REFUGEE EXPERIENCES OF FINDING DECENT WORK IN THE AUSTRALIAN CONSTRUCTION INDUSTRY

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Construction is a major source of employment for refugees in most countries yet there has been a surprising lack of research into their experiences of securing work in the industry. Addressing this gap and also the lack of voice for refugees in the construction management literature, this paper reports the results of a survey of refugees who have worked or attempted to seek work in the Australian construction industry. Findings reveal that the main perceived barriers to securing decent employment in construction relate to lack of local work experience, employers discriminating against refugees and not recognising previous qualifications, skills and experience and both employment agencies and employers not understanding the challenges they face. Government procedures and systems are also perceived to be overly complex. Recommendations are made to address these barriers including initiatives to provide refugees with work experience in the industry, education to break-down negative stereotypes of refugees among employers and simplification and targeting of government and employment agency systems and procedures.

Keywords: decent work, diversity, employment, HRM, migrants, refugees

INTRODUCTION

A refugee is a humanitarian migrant who has been granted the right to stay in a country because of a well-founded fear of being persecuted due to their race, religion, nationality, political opinion or membership of a particular social group (United Nations 1951). According to the International Organization for Migration (2018) the number of international refugees has grown continuously since the 1990s and a recent study by Rioseco and Maio (2017) found that the most common jobs for male refugees was in construction. There has been a considerable amount of research into the experiences, both positive and negative, of 'migrants' working in the construction industry in many countries and regions (Loosemore and Chua 2002, Golden and Skibniewski 2009, Missa and Ahmed 2010, Khatleli 2015, Kaminsky and Faust 2018). However, apart from recent research by Loosemore *et al.* (2019) which explored barriers to employment for refugees in construction from a subcontractors' perspective, there has been no research into refugees' experiences of finding decent

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work in the construction industry from their perspective. This is despite refugees seeing construction as a major potential source of employment opportunities and being grossly overrepresented among the ranks of unemployed and under-employed members of the labour force in most countries (Colic-Peisker *et al.*, 2007a, b, Kosny *et al.*, 2017). For example, in the UK the unemployment rate for refugees is 70% (compared to 4% for the wider population) and in Australia, refugees have the highest unemployment rate of any group other than Indigenous people. Furthermore, research shows that 71% of the world refugee population are of working age, they have a very strong motivation to work, and considerable skills, qualifications and experience to contribute to a construction sector which is facing skills shortages in the future (Legrain 2017, International Organization for Migration 2018, CEDA 2019).

Set within this context, the aim of this paper is to address this lack of voice for refugees in construction management research through a survey of perceived barriers to employment of refugees who have experienced searching for decent employment in the Australian construction industry. This research is important given research outside construction which indicates that the construction industry represents a major source of 'survival work' for these people due to its large size (it is the world's largest employer) and the large numbers of low skilled jobs it provides (Hedwards *et al.*, 2017).

Refugee Experiences of Securing Meaningful Employment

The United Nations Economic and Social Council (2006) defines decent work as employment which respects the fundamental rights of workers in terms of conditions of work safety and remuneration and respect for the physical and mental integrity of the worker in the exercise of his/her employment. While there has been little research into the experiences of refugees in securing meaningful employment in the construction industry, there has been considerable research outside of construction which documents the many struggles they can face in finding decent work. This research shows that while refugees are not a homogenous group (skills, qualifications, experience, cultures, nationalities and attributes vary greatly), there also appear to be some common barriers that they face. For example, Olliff (2010) revealed a widespread perception by employers and the community in Australia that refugees should mainly be used for unattractive jobs where there are local labour shortages. Olliff (2010) also pointed to considerable pressures on migrants and refugees to take jobs below their abilities and qualifications due to low incomes and because of a need to support their family and to send money to relatives who remain in unsafe situations overseas. Furthermore, employment agencies (which get paid by the number of people they place into employment in Australia) also place pressure on refugee and migrants to find work as quickly as possible. Once employed, it becomes more difficult for them to leave low-paid and low-skilled jobs due to loss of original skills and missed opportunities for networking and career progression. Wickremasinghe's (2018) interviews with numerous refugees described a life of disrupted employment and a 'web of uncertainty' which makes it hard to compete for work. According to Legrain (2017), Wickramasinghe (2018) and Hiruy (2019), other common barriers to employment faced by refugees and skilled migrants include:

- limited English proficiency (plus lack of options for improving English)
- lack of locally recognised qualifications, work experience and referees
- difficulties in gaining local industry experience
- low recognition of past experience and qualifications

- documents evidencing qualifications are hard to get and require full translation to be useful
- regulatory bodies often prevent qualifications and experience from being recognised
- prohibitive costs for bridging courses to upgrade qualifications
- time taken to get new qualifications
- limited or complex assistance from local government; transportation problems (expensive, limited access, lack of drivers' licence/car)
- visa restrictions which limit working hours, rights and options; lack of affordable housing close to employment
- lack of knowledge of local workplace culture and systems; pressures of juggling employment and domestic responsibilities
- lack of appropriate services to get into work; pressure to accept any job available just to get work (poorly paid, insecure work, part time work, illegal work)
- discrimination in recruitment (bias against migrants/refugees, intimidation in the workplace, religious discrimination, racism in the media and stereotyping of communities)
- difficulties accessing complaints processes.

Mobilising the insights above, the following section describes the methodology we employed to investigate the extent to which these barriers exist for refugees seeking decent work in the Australian construction industry.

METHOD

Data was collected using an anonymous on-line survey of refugees who had sought decent work (both successfully and unsuccessfully) in the Australian construction industry at professional, administrative and trade levels. The survey employed a combination of open, categorical, interval and Likert scaled questions and was pretested and validated in partnership with a major refugee and migrant support agency which provides support for refugees and their families through early intervention programs and activities which have been funded by government. The survey comprised three sections. The first section required respondents to provide general demographic information such as gender, age, first and second languages, ethnicity, religion, years lived in Australia, construction industry experience, qualifications (construction and generic) and visa status. The second section was informed by our detailed literature review as summarised above and designed to explore the experiences of respondents who had successfully found work in the construction industry. Questions included types of work found (part time, full-time, temporary, casual), length of time taken to secure employment, numbers of jobs held, number of applications before securing work, job quality (pay, match to skills/experience, conditions). The third section of the survey was open to all respondents (successful and unsuccessful) and asked questions about barriers to employment covering three main areas: skills barriers (employers not recognising experience and skills, access to training etc); government barriers (employment agencies support, assistance to find and apply for jobs, confusing laws/compliance, access to government support such as child care, visa issues etc); and integration/culture barriers (negative perceptions/discrimination by employers, pay and conditions, employers understanding migrants and refugee workplace

requirements/challenges etc). Factors that compose the barriers to employment from the perspective of refugees were assessed on a five-point Likert scale ranging from 1 = “not a problem” to 5 = “huge problem”.

Purposeful sampling was employed to recruit respondents by selecting them from a sampling frame of individuals who were clients of our partner refugee support agencies in Sydney, Australia. The research team also distributed surveys at a number of refugee employment fairs, refugee construction companies and refugee community forums. Ethics clearance required full disclosure of the aims, objectives, methods involved in the research, and participation rights, to all respondents, all of which was explained via a formal invite that guaranteed anonymity and allowed respondents to withdraw their data at any time. Working with a partner refugee support agency and ensuring anonymity through clear ethical procedures was critical in building trust with our vulnerable respondents. A total of 68 people were formally invited to participate in the survey and 25 usable responses were received as illustrated in Table 1. The formal invitation numbers are low even after translating the survey into relevant languages and working with a major refugee support agency as a partner. This is because many refugees are reluctant to participate in research due to fear of upsetting authorities on which their visa status depends. However, among those invited to participate, the response rate of 35% was strong, especially for studies which address potentially sensitive areas (Marszalek *et al.*, 2011), and given the logistical challenges and sensitivity of our research and the language limitations and time constraints of our respondents.

Following pretesting for Kurtosis and Skewness, the data sample was deemed to be not normally distributed, hence requiring the use of nonparametric methods for further data analysis. To re-affirm the non-normality of the data, a Kolmogorov-Smirnov (KS) was conducted. In order to address the research questions posed in this study, a range of statistical techniques were adopted, including descriptive tests (mean and media), frequencies and the Wilcoxon Signed-Rand test (one-way sample t-test equivalent) (Pratt 1959), Wilcoxon signed rank test was adopted to reveal how likely it is in the population to have a result as in the present sample.

RESULTS

It is important to interpret the following results within the context of our very small sample and the large percentage of Arabic respondents cannot be claimed to be representative of the ethnic profile of migrant population in Sydney (or Australia). Nevertheless, given the many methods used to collect data we have no reason to believe that this is not the ethnic profile of refugees looking for work in construction in Sydney. within this constraint, it is notable in Table 1 that 84% of respondents in our sample were male, while only 16% were female. This reflects De Maio *et al.*'s (2017) findings which shows that males make up the majority of refugees working in construction.

The majority of respondent refugees were 30-39 yrs old and Arabic by background. This presents the first insights that we are aware of, into the ethnic profile of refugees seeking work in construction in Australia. Interestingly this is a starkly different profile to the only ethnicity data of workers in the wider Australian construction industry (Loosemore *et al.*, 2010) where those of Arabic background represented a very small proportion.

This is important since according to Dunn *et al.* (2011), this may cause integration challenges in both seeking work and working within the construction industry, especially since workers from a ‘Middle Eastern’ background were perceived by managers to be the most problematic group.

Table 1: Sample Structure

Topic	Grouping	Percentage %
Gender	Female	16
	Male	84
Age	18 - 29 years	24
	30 - 39 years	40
	40 - 49 years	28
	Over 50 years	8
Construction experience	0 - 4 years	52
	10 - 19 years	8
	5 - 9 years	20
	Over 20 years	20
Current Profession	Accounting	4
	Admin	12
	AEC professionals	64
	Trades	20
Contract Type	No work yet	32
	Casual	16
	Temporary employment (fixed duration)	8
	Full time	44
Education Qualification	High School Education	8
	Masters	24
	Technical Education	8
	Undergraduate	60
Years lived in Australia	0 - 4 years	72
	10 - 19 years	12
	5 - 9 years	12
	Over 20 years	4
Time taken to find work	Less than a year	34
	1 - 2 years	4
	2 - 3 years	20
	3 - 4 years	8
	More than 4 years	4
	No work yet	30
Jobs applied for	1 - 5	20
	5 - 10	12
	15 - 20	8
	More than 20	30
	No work yet	30
Jobs held in past 5 years	1 - 5	64
	5 - 10	6
	No work yet	30
Happy with Job	Average	35.3
	Mostly Happy	23.5
	Very Happy	41.2

In terms of language proficiency, most respondents (52%) nominated Arabic as their first language, and 45% nominated English as their second language. It is reasonable to assume that the remaining 55% would experience significant language difficulties, a common problem recognised in the wider literature (Wickramasinghe 2018). Notably, Trajkovski and Loosemore (2006) found that on construction sites, this lack of language proficiency lead to significantly higher safety risks to both themselves and their co-workers, further exacerbating negative stereotypes among employers and potential problems in securing decent work in the sector. The sample illustrates a highly qualified group with 84% having an undergraduate qualification or above (40% of the sample being Engineers). This profile of education and experience adds further

granularity to other research such as Colic-Peisker *et al.*, 2007a, b) who highlighted the importance of construction as a source of potential refugee employment. However, supporting Krahn *et al.* (2000), our results also show that despite being highly qualified, a high percentage of refugees remain unemployed for a considerable time reflecting research by Hiruy (2019) which points to the precarious nature of employment experienced by this group. While 68% had managed to find work in the construction industry, only 44% had full time employment. Interestingly, no respondents said they were unhappy in their work they had found and 41.5% said they were very happy, which doesn't support other research which suggest that the quality of work provided for refugees by construction is poor (Buckley *et al.*, 2016).

In the following section, the perceived barriers to finding employment in the construction industry for the refugees in our sample are explored in more detail. This discussion is based on Table 2 which ranks the examined barriers based on the Wilcoxon signed-rank test, along with listing the mean and median for each barrier.

Table 2: Perceived barriers to employment by Refugees (in Rank order)

Barriers	Median	Mean	Rank	Not a problem %	Small problem %	Medium problem %	Major problem %	Huge problem %	One-Sample Wilcoxon Signed Rank Test (Z values)
Lack of Australian work experience	4	3.56	1	12	16	12	24	36	3.703*
Employers not recognising my past skills qualifications	4	3.48	2	12	16	20	16	36	3.604*
Complex systems and procedures getting a job	4	3.44	3	8	24	12	28	28	3.63*
Employers not understanding the challenges refugees face	3	3.32	4	8	24	28	8	32	3.494*
Government employment agencies not understanding	3	3.24	5	8	28	24	12	28	3.39*
Discrimination by employers	2	2.84	6	16	36	8	28	12	2.838*
Support from government to get into work	3	3.08	7	20	24	12	16	28	2.693*
Confusing laws and regulations to get work	3	2.68	8	16	32	28	16	8	2.57*
Assistance with applying for jobs	2	2.44	9	12	44	32	12	0	2.296*
Access to information about job opportunities careers in	3	2.64	10	28	20	24	16	12	2.163*
Being forced to take low quality work	2	2.56	11	20	40	12	20	8	2.176*
Access to training and new qualifications	2	2.64	12	28	28	12	16	16	2.093*
Support to setup your own business	2	2.56	13	20	36	24	8	12	2.043*
Language problems	2	2.48	14	20	48	8	12	12	1.818
Poor pay and working conditions	2	2.36	15	16	52	20	4	8	1.565
Discrimination by other workers	2	2.36	16	24	44	12	12	8	1.458
Understanding Australian workplace culture and	2	2.28	17	40	20	24	4	12	0.796
Access to other government support services such as	2	2.2	18	16	60	16	4	4	1.026
Visa problems	2	2	19	4	92	4	0	0	0.000

*The significance level is .050

Thirteen out of 19 barriers examined are significant at $p < .005$, with values ranging between $Z = 2.043$ and $Z = 3.703$. In particular, 36% of respondents found that 'Lack of Australian work experience' (rank = 1) was a major problem in terms of securing employment in the Australian construction industry. This reinforces findings in (Pittaway *et al.*, 2009) and (Colic-Peisker and Tilbury, 2007a) where lack of relevant work experience was also deemed a major barrier to employment for refugees. Despite indications in the literature that point to the fact that refugees possess skills that are highly useful in the construction industry (Australian Government, 2019), refugees still perceive "Employers not recognising my past skills qualifications and experience" as a significant barrier to finding employment in the construction industry, with 36% of respondents indicating it as a huge barrier (rank = 2). This result ties in closely with the previous findings of (Tilbury and Colic-Peisker, 2007a), where it was stated that a major hurdle facing refugees when looking for work was the unwillingness of employers to recognise relevant skills that refugees have from their home countries. The 3rd ranked barrier was the 'Complex systems and procedures getting a job', supporting wider criticisms of Australia's employment

system which has been criticised by both employers and job seekers as being overly bureaucratic and complex and not effective at matching employer and employee needs and skills (Commonwealth of Australia 2019). Another significant barrier identified was ‘Employers not understanding the challenges refugees face’ (rank = 4), supporting previous research that cites widespread stigmas against the capability of refugees in terms of their skill sets in the job market (Colic-Peisker and Tilbury, 2007). In Australia this problem has been exacerbated by the commoditisation of refugees and other job seekers in a privatised employment market of private providers which get rewarded by the number of people they place rather than the quality and suitability of those jobs in terms of their suitability to people’s individual qualifications and needs (Bowman and Randrianarisoa 2018, Commonwealth of Australia 2019). This is reflected in the fifth and sixth-ranked barriers “Government employment agencies not understanding challenges” and ‘Lack of Support from government to get into work’. Our results also indicate that ‘Discrimination by employers’ was also viewed as a significant barrier (rank = 6), supporting previous research by Loosemore *et al.* (2010) and Dunn *et al.* (2011) which highlighted considerable levels of discrimination in the Australian construction industry - especially towards people of Middle Eastern origins as in our sample. Outside construction Colic-Peisker and Tilbury (2007) have also reported refugees commonly experience discrimination by their employers. Indeed, it is notable in our results that concerns about ‘employers’ represent three out of the top six ranked barriers, suggesting that more needs to be done in educating employers about the potential value of refugees to the industry, the value and nature of their existing qualifications, skills and experience, the challenges they face and addressing negative stereotypes that lead to discriminatory behaviour. Providing refugees with work experience opportunities to address their top ranked barrier is especially important. Notably, with two references to government-related barriers in the top six barriers, our results indicate that governments also need to address the perceived complexities of securing work and the lack of understanding in employment agencies of the special challenges which refugees face.

Lesser barriers considered a small problem or not a problem included: ‘Confusing laws and regulations to get work’, ‘Assistance with applying for jobs’, ‘Access to information about job opportunities and careers’, ‘Being forced to take low quality work’, ‘Poor Access to training and new qualifications’ and ‘Weak Support to setup your own business’. Although not statistically significant and requiring further research to confirm, it is notable that while ‘Language problems’ are often cited as a barrier to employment for refugees (Casimiro *et al.*, 2007, Wickramasinghe 2018); our results do not support this (rank = 14). This contrasts with our findings above in relation to 55% of the sample not nominating English as either their first or second language and may be explained by the Trajkovski and Loosemore (2006), Loosemore *et al.* (2010) and Dunn *et al.* (2011) who found that many languages are spoken on construction sites within culturally distinct work teams, effectively protecting people who do not speak English. However, management level ethnic profiles (primarily the structure of our sample) are less diverse their work also shows that this is a major concern for managers especially in relation to those from a Middle Eastern background and relating to issues such as safety and productivity - which may explain our results relating to high levels of perceived discrimination by employers (ranked 6). Furthermore, supporting our findings about happiness in work, discussed above, ‘Poor pay and working conditions’ was not considered a barrier to employment supporting Rioseco and Maio (2017) who point to construction providing an important source of

good quality work for refugees. Interestingly, in contrast to Dunn et al's (2011) findings, in contrast to 'Discrimination by employers', discrimination by other workers in the construction industry was not seen as a problem. Rather, in support of Raiden *et al.* (2019), it would seem that the construction industry provides a tolerant and supportive environment for workers from other cultures because of the diversity of its workforce and the support structures that provides. Finally, another interesting result yielded from Table 1, and which is contrary to research conducted in Europe and North America (Harney, 2013) is the insignificance of 'Visa Problems' as a barrier perceived by the respondents. Additionally, in contrast to Legrain (2017), respondents' 'understanding Australian work culture' was a low barrier (rank = 17).

CONCLUSION

Set within the context of a growing refugee crisis across the world, the aim of this paper was to address the lack of research into and voice for refugees in construction management research through a survey of perceived barriers to employment of refugees who have experienced searching for decent employment in the Australian construction industry. We note the limitations of our very small sample and that the large percentage of Arabic respondents cannot be claimed to be representative of the ethnic profile of migrant population in Sydney (let alone Australia) where this research was based. However, our findings revealed that the ethnic profile of the refugee population looking for work in the Australian construction industry is significantly different from the current workforce profile, as far as we understand it. While the literature suggest that this may cause integration challenges, our results indicate the contrary in that refugees consider the construction industry a supportive environment to work, at least from fellow workers. Our results suggest that this workforce structure may protect refugees with low English proficiency, although refugee perceptions that employees discriminate against them may reflect manager concerns about the risks this poses to safety and productivity in such a highly regulated industry. While these concerns may be valid, employers emerge as a significant perceived barrier to employment for refugees indicating that more initiatives are also needed to provide refugees with opportunities to gain work experience in the industry and to educate employers about the value and nature of their existing qualifications and experience and the potential value that many refugees could bring to the industry and to break-down negative stereotypes of refugees among employers. Our results indicate that employers would appear to be the main reason why, despite the highly qualified nature of our sample (albeit mainly focussed around engineering) and the obvious knowledge they could bring to the industry, many of our respondents struggled to find work, applying for numerous jobs over a long period and remain unemployed for a considerable time. When they do find work, it is often insecure, although the quality of work, especially pay and working conditions and levels of satisfaction with work appear to be high. However, our results indicate that government employment systems could be significantly simplified and more targeted towards addressing the specific needs of refugees, which are distinct from other job-seeking groups.

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SOCIAL VALUE IN THE DIGITALISED CONSTRUCTION ENVIRONMENT

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The construction industry has been under increasing pressure by clients to demonstrate its social contribution to the community. This social contribution has been termed as Social Value (SV). Although SV has been explored in non-digitalised construction environments, less is known about how digitalised construction environments can ensure the delivery of SV within a socio-technical systems approach. The aim of this paper is to identify how digitalised construction environments could integrate SV within their processes. To achieve this aim, a comprehensive literature review of the existing conceptualisation of SV in the construction industry is carried out and synthesised into a conceptual framework for integrating SV in the digitalised construction process. The literature reveals that various construction stakeholders conceptualise SV in different ways. SV is commonly shaped by short-term compliance to fulfil the requirement for procuring contracts. Also, there is a lack of common approaches for integrating the delivery process of SV. The conceptual framework demonstrates the importance of early integration of SV in the design phase to identify alternative methods to cogenerate, monitor and communicate SV. Thus far, this study advances the knowledge about how digitalised construction environments can ensure SV delivery. This paper highlights the need for further research to integrate SV in digital construction environments. A future study could validate the framework across the design phase with different construction project stakeholders.

Keywords: BIM, digitalised construction environments, social value, socio-technical

INTRODUCTION

The construction industry has been under increasing pressure to demonstrate their contribution to the community while carrying out their day-to-day business. The idea of a commercial organisation having some responsibilities to the community beyond making profits has been around for years (Carroll and Shabana, 2010). To drive this social change, the UK Government has put in place a procurement approach called Social Value (SV).

The public sector has adopted SV by encouraging commissioning authorities to procure services considering economic, social, and environmental well-being which benefit the local community (Social Value Act 2012, 2012). SV has gained an outstanding interest among the private industry sector and its stakeholders (Awuzie *et al.*, 2018; Barraket and Loosemore, 2018). In the construction industry sector,

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remarkable work to communicate SV has been carried out by organisations such as UKGBC and Action Sustainability (Supply Chain Sustainability School, 2018; UKGBC, 2018).

Nevertheless, SV literature is still in an early stage of development (Burke and King, 2015; Loosemore, 2016). In the construction industry, SV has been investigated in non-digital environments. For example, Daniel and Pasquire (2019) studied how Lean construction can create SV within the delivery of construction projects. Also, Watts *et al.*, (2019) explored different methods of measuring SV within various stakeholders in the construction industry. Yet, the construction industry is undergoing a digital transformation. The digital transformation of construction aims to ensure that the built environment can harness new technologies and digital connectivity to deliver environmental, economic and social benefits (Centre for Digital Built Britain, 2018). By this means, digital construction will drive up the competitiveness, productivity and new skills of the construction industry, as well as the quality of life and well-being of the society. Therefore, there is an opportunity to align the emerging digital approach of delivering projects with the need to deliver SV.

The aim of this paper is to identify how the digitalised construction environment can leverage the integration of SV to deliver social, economic and environmental well-being to the community. To address this aim, a comprehensive literature review of the current knowledge of SV and how digitalised construction environments can ensure the delivery of SV within a socio-technical system approach has been conducted. The paper is structured as follows; (1) methodology (2) conceptualising SV in the digitalised construction environment and (3) conclusion, future work and limitations.

METHODOLOGY

While there is a large body of research in digitalised construction environments, the current focus on SV is scarce. Therefore, key concepts and definitions in the literature were intentionally selected from relevant sources and relevant citations were followed. The following keywords in searching for papers were used: "Social Value"; "Social Value and Construction"; "Social Value and BIM or Digital Construction or Digitalised Construction Environment"; "Social Outcomes and BIM or Digital Construction or Digitalised Construction Environment"; and "Social Dimension and BIM or Digital Construction or Digitalised Construction Environment".

The search resulted in twenty-two literature sources for SV using Scopus and Google Scholar databases. Key authors and new concepts related to SV were identified. For example, Raiden *et al.*, (2019) have published the first book looking at SV in construction; Loosemore (2016) has carried out significant research in the area of social procurement; both pieces of research have been fundamental in developing SV in the built environment.

Due to the early stage of research development on SV, the search was extended to include grey literature such as government reports and industry publications. The grey literature offered a broad insight into the current debate on SV and digitalised construction environments. In summary, one hundred and sixty-eight publications were collected, of which forty-four documents were comprehensively reviewed.

Conceptualising Social Value in the Digitalised Construction Environment

Social Value background

According to the literature review, SV has evolved around three main themes. 1) Morality and ethics that explores the theoretical foundation of duty-based ethics that

broadly support the SV agenda (Raiden *et al.*, 2019). 2) The importance of the social efficacy and the sense of community (Cartigny and Lord, 2017). Finally, 3) Theory of value in which authors such as Choi *et al.*, (2018); Wood and Leighton (2010) and Burke and King (2015) discuss SV in terms of generating benefits to society by ensuring "value for money" in the delivery of services. Value mainly refers to the worth the end-user put on some product or service (Husted *et al.*, 2015).

Moreover, SV is related to and indeed overlaps with different concepts. For example, Cartigny and Lord (2017) discuss the background and similarity with social capital and sense of community. Other authors such as Daniel and Pasquire (2019), and Watts *et al.*, (2019) explore the relationship between SV, corporate social responsibility and shared value. These concepts are tied to the triple bottom line of sustainability (social, environmental and financial) and agree on the enhancement of the social dimension to generate improvements in the community. Nevertheless, each concept emphasises different aspects. For example, Social Capital focuses on networks and how communities can work together to generate positive impacts (Paranagamage *et al.*, 2010). In the case of corporate social responsibility, Carroll and Shabana (2010) define it as the social commitment of business to contribute to the economic, legal, ethical, philanthropic expectations of society. The concept behind shared value is to integrate social issues into the capitalistic economic mechanism to extend benefits for both business and community (Porter and Kramer, 2011). This means a business can gain economic returns and create value simultaneously. Porter and Kramer (2011) identify three ways by which organisations can create shared value: "by reconceiving products and markets; by redefining productivity in the value chain and by enabling local cluster development".

Corporate social responsibility and shared value intend to contribute to society and create value while doing business, but there are differences with the SV perspective. The main differences are that, corporate social responsibility and shared value refer to contributions that are mainly aligned with the organisational business model (top-down approach) (Daniel and Pasquire, 2019; Watson *et al.*, 2016). Whereas SV refers to identifying specific needs of the community (bottom-up approach) and collaborating with multiple stakeholders.

Social Value Act 2012

Lately, the UK Government has been promoting social procurement practices by adding SV criteria in the services they commission and procure. This is enforced by the Public Services Social Value Act 2012. The Legislation Public Services Social Value Act (2012) came into force on 31 January 2013. The Social Value Act 2012 requires all public authorities to consider economic, environmental and social well-being "value" in the services they commission and procure, and it applies to all local authorities. The Act extends to England; its application is limited in Wales and does not extend to Scotland or Northern Ireland.

The Social Value Act (2012) has been challenging to implement due to the lack of guidance and methods of measuring social value (Awuzie *et al.*, 2018; Cabinet Office, 2015). The Cabinet Office (2015) review on the SV implementation revealed three significant barriers for the Social Value Act 2012. First, the awareness among organisations of the Social Value Act 2012 act shows contrasting understanding among stakeholders; second, there is inconsistency in the practice of SV frameworks; and third, the lack of developed tools to measure the SV.

Social Value Definition

The concept of SV is considered a "recent" term. Diverse definitions and vocabulary terms have emerged in the developing of knowledge of SV across various disciplines, such as rail safety (RSSB, 2018); the National Themes, Outcomes and Measures (TOMs) (National Social Value Taskforce, 2019); construction industry (Supply Chain Sustainability School, 2018; UKGBC, 2018); housing association (HACT, 2016); among others. However, the conceptualisation of SV is vague and has a lack of agreed definition and vocabulary. After a comprehensive review, definitions on SV reinforce the Legislation Public Services Social Value Act 2012. SV refers to maximising soft outcomes which are difficult to measure, such as mental well-being and social skills (Wood and Leighton, 2010). Most documents highlight the relative importance (value) that people place on changes that happen in their lives (Cartigny and Lord, 2019; Opoku and Guthrie, 2018; Social Value UK, 2011). These changes are mainly triggered by the activities of any organisation and secured through the procurement process (Loosemore, 2016).

From the construction industry perspective, the definitions of SV highlight the positive and negative impacts a project can bring to the community including internal and external stakeholders (Awuzie *et al.*, 2018; Raiden *et al.*, 2019). Table 1 presents three definitions from a construction perspective that have emerged from this review.

Table 1: SV definitions

Source	Source Type	Definition	Focus
Daniel and Pasquire (2019)	Academic Publication	SV is the benefit a community and its inhabitants obtain in terms of social, economic and environmental well-being from companies or organisations conducting business around the community.	Lean approach
Raidén <i>et al.</i> , (2019)	Academic Publication	The "Social Impact" any construction organisation makes to the lives of the internal and external stakeholders affected by its activities, including those working in the industry and in the communities in which it operates	Explore and context
Supply Chain Sustainability School (2018)	Industry Publication	SV means the direct, positive impacts for people and communities that can be created by going beyond 'fit for purpose' built environment design and creating socially sensitive infrastructure or architecture.	Guidance

One distinction of the construction industry is that the work process is undertaken within projects-a temporary endeavour, and with many different stakeholders at different stages. Therefore, considering the definitions in Table 1, this paper agrees that SV refers to the broader impacts in terms of social, economic and environmental well-being that a community (internal/external stakeholders) obtains by the activities of an organisation or project (Daniel and Pasquire, 2019; Raiden *et al.*, 2019).

Social Value in the Construction Industry

The construction industry has a massive impact on communities. The creation of SV can occur during each stage of project-life cycle (Raiden *et al.*, 2019; UKGBC, 2018). To date, a number of studies demonstrate that SV is intensely focused on the construction phase (Sainsbury *et al.*, 2017; Supply Chain Sustainability School, 2018). This is because the SV policy has been aimed primarily at the social procurement of the asset in the form of job creation and training and local growth.

In order to create and maximise SV, social organisations have produced their own SV toolkits/publications to advice how to deliver SV. Notable examples include UKGBC (2018), Supply Chain Sustainability School (2018) and RSSB (2018). The growing numbers of frameworks, guidelines and toolkits emphasise the need to:

- Identify the needs of the community (bottom-up approach).
- Involve stakeholders.
- Plan and program development.
- Embed SV in procurement.
- Develop or chose a measurement framework to assess and monitor.
- Report and communicate the changes to learn and improve.

Two frameworks are the main references for driving SV in the UK. The TOMs framework (National Social Value Taskforce, 2019) and the Social Value Bank (HACT, 2016) aim to provide a minimum standard to embed social into procurement and management processes.

Despite positive results in other sectors (Social Enterprise UK, 2018), Burke and King (2015) revealed a slow uptake on SV in the construction industry. The study identified that SV adoption by local authorities had been inconsistent, with up to 75% of local authorities have not embedded SV in their procurement strategies, and less than 10% have an SV policy. Similar, Cartigny and Lord (2018) found that the SV Act 2012 has not impacted on public infrastructure projects in England. The frequency on the contracts considering SV is quite low. Only a few contracts contained specific SV award criteria, and those criteria are weighted around 5-10%.

The Role of Digitalised Construction Environments to Unlock Social Value

Digitalised construction environments comprise the process of using digital technology for producing and managing information of the digital asset (Craveiro *et al.*, 2019). Digitalised construction aims to improve the delivery and operation of the built environment. The potential range of digital technology in the construction industry is considerable. Digitalised construction environments include, but are not limited to, Building Information Modelling (BIM), digital twins, augmented reality, virtual reality, sensors, building surveying, autonomous vehicles, drones, robots, advance materials, additive manufacturing, artificial intelligence and internet of things (CITB, 2018; Craveiro *et al.*, 2019).

Within digitalised construction, BIM is identified as a significant enabler in the digital transformation. BIM can be defined as a set of an interacting social-technological process aiming to produce and manage information in digital format to improve collaboration among the stakeholders throughout the life-cycle of a building; (Demian and Walters, 2014; Eastman, 2011; Succar, 2009). The socio-technical approach prioritises the improvement of 'social' and 'technical' at the same level (Mumford, 2006). At the heart of digitalised construction are the people along with information, clear processes and their interaction with technology (CITB, 2018; Oesterreich and Teuteberg, 2019). Therefore, it is particularly important to create the right conditions for digital innovation and skills to unlock the SV of digitalised construction.

Digitalised construction has already changed how sustainable construction is conducted. However, the adoption of digitalisation for sustainability is still strongly focused on specific dimensions. Chong *et al.*, (2017) stated that research on BIM adoption for sustainability mainly focuses on the use of BIM-based tools for energy consumption (environmental-economic). Similarly, Santos *et al.*, (2019), highlighted that the terms most used in BIM literature for sustainability are energy efficiency (economic-environmental), green building (environmental), and safety (social).

Digitalised construction can unlock SV in two main areas: (1) For the external stakeholders (the users of the asset), digitalisation can provide better designed places that people value and provide community well-being. For example, Micolier *et al.*, (2019) proposed an agent-based model (Li-BIM) that simulates occupant behaviour and their indoor comfort to design better buildings. (2) The delivery of the digital asset delivery process, which impacts the working relationship among the internal stakeholders. Blay *et al.*, (2019) confirmed the need for social solutions to mitigate BIM management challenges, such a lack of skills.

Proposed Framework

The conceptual framework (Figure 1) aims to integrate SV in the digitalised construction process. Although the findings emphasis the need to establish a conceptualisation of SV, a practical framework should be flexible enough to adapt to different scenarios. This practical SV framework must start by including the needs and perceptions of various stakeholders (bottom-up approach). Then, this framework can be embedded within a standardised digitalised construction environment process (top-down approach). Consequently, this process will generate a balanced/hybrid approach.

The framework is organised in three main blocks. The first block summarises a conceptualisation of SV in digital construction environments which is developed based on four key steps identified in previous SV literature and frameworks (Cabinet Office, 2012; Raiden *et al.*, 2019; Social Value UK, 2011; UKGBC, 2018):

1. Early involvement of stakeholders, including both internal and external stakeholders (community) to provide a clear view of their needs and to identify SV outcomes.
2. Adding SV in planning and designing will define the SV scope and establish a common language among various stakeholders
3. Procurement for value as a primary way to ensure the delivery of SV. Procure for value instead of cost and time.
4. Monitor and report to take timely decisions, adapt and improve. However, SV is challenging to assess due to the nature of its soft outcomes.

In the same block, the language of SV and how it can be identified in digitalised construction environments have been synthesised. The literature review highlights that SV refers to impact on social, economic and environmental well-being (positive and negative) that a project can create for the community. From the different SV frameworks, (National Social Value Taskforce, 2019; RSSB, 2018; UKGBC, 2018), the impacts that the digitalised construction can potentially create are selected. Finally, these impacts have been categorised into six groups.

The second block connects with established frameworks and standards for digitalised construction environments, such as the RIBA 2020 Plan of Work, UK BIM Framework and the ISO 1950 series (BSI, 2018; RIBA, 2020). RIBA 2020 Plan of Work organises the process to complete the design and construction of an asset in eight stages. The UK BIM Framework specifies an approach for implementing BIM and digital technologies by (1) deploying digital techniques; (2) taking advantage of new and emerging digital construction technologies and manufacturing processes; (3) using information in real-time to transform the built environment; and (4) understanding how the digital built environment can improve the quality of life for citizens. ISO 19650 part 1 recommends concepts and principles in support on how to

manage building information. ISO19650 part 2 supplies the requirements in the delivery phase of digital assets. The UK BIM Framework and the ISO 19650 series are the foundation for developments around the National Digital Twin (Centre for Digital Built Britain, 2018).

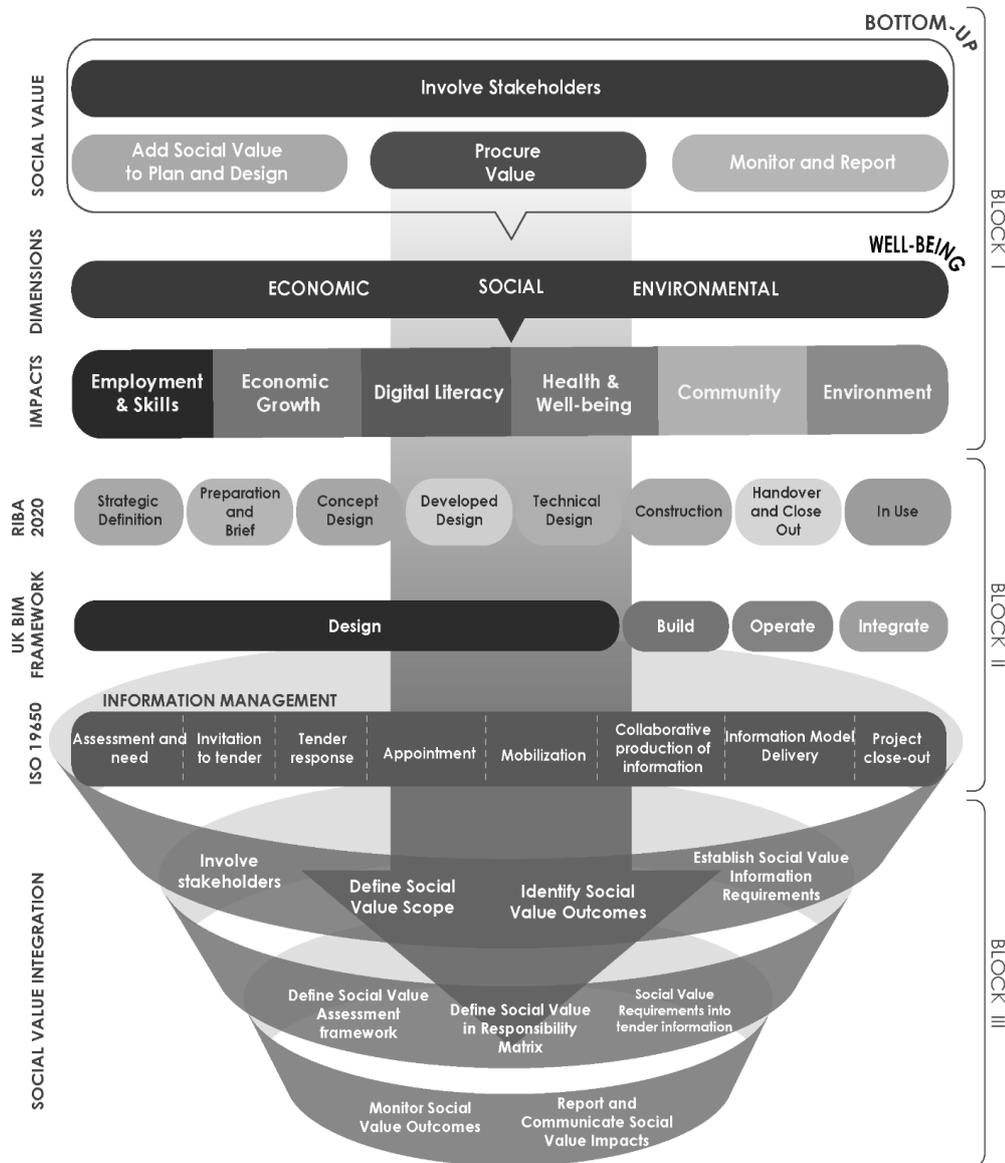


Figure 1 Social Value in the digitalised construction environment framework (first version)

Finally, the third block contains nine proposed steps that integrate SV in digitalised construction environments. These nine steps have been deduced from academic publications, guidelines, and frameworks embedding SV, digitalised construction and information management processes (BSI, 2018; Cabinet Office, 2012; Raiden *et al.*, 2019; RIBA, 2020). This is a conceptual integration of SV and digital construction environments; further work is being carried out with construction project stakeholders to validate the framework and assess its feasibility.

CONCLUSION

This paper presents a comprehensive literature review of the concept of SV. The paper offers the opportunity to identify/describe how SV can be integrated into the digitalised construction environment. This paper presents a framework that integrates

SV in the context of digitalised construction; focusing on information management because of its relevance to digitalisation in construction.

There are some noteworthy limitations. The concept of SV is in its infancy, and it is possible that other terminologies being used were not included in the search. Also, the literature review focused on identifying published SV perspectives which have not been covered in current construction frameworks; thus, some emerging digitalised construction aspects may not have been integrated into this framework. The development of this framework is part of an ongoing PhD research. Therefore, it is expected to expand and validate the proposed framework with internal stakeholders in further studies. These studies will include other digitalised construction impacts and defining specific SV outcomes is required.

This paper creates an awareness of SV in digital construction environments. The result of this research enhances the understanding of SV in the digital construction environment and offers its first conceptualisation.

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THE IMPACT OF A FIRST-YEAR ORIENTATION TEAM BUILDING EVENT: A LONGITUDINAL REVIEW

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The purpose of the study is to determine the impact of a one-day orientation team building event (TBE) directed at enhancing first-year students' ability to manage themselves, work as a team, interface with each other, strategise, plan, evolve tactics, and take action that would lead to their team winning the 'amazing race' style event. A quantitative approach, which entailed the completion of a self-administered questionnaire after the TBE over a period of three years, determined the students' perceptions. Findings include: the TBE activities contributed to enhancing participants' ability to communicate with first-year colleagues; built confidence in their abilities including that of completing a task, and enhanced participants' alternative thought processes, ability to be creative, strategise, evolve tactics, take action, and plan. Conclusions include: non-traditional academic programme interventions, such as the TBE, do impact on first-year students' ability to manage themselves, strategise, plan, evolve tactics, and take action, which in turn should contribute to their ability to study, undertake assignments, projects, and successfully complete the undergraduate programme, and the activities built confidence in their abilities, enhanced communication amongst them, and provided an opportunity for them to test alternative thought processes. Recommendations include: the TBE should be undertaken on an annual basis, with the impact thereof on participants to be determined following the completion of a full academic year and again post-graduation, and further potential events directed at enhancing students' abilities and increasing confidence in their abilities should be investigated.

Keywords: education, orientation, students, team building

INTRODUCTION

In recent years, the Department of Construction Management, Nelson Mandela University, has struggled to engage with students to prepare them adequately for the rigours of the first year of study, and undergraduate programme. This is manifest in the students' inability to manage themselves, strategise, plan, evolve tactics, and take action, which in turn should have contributed to their ability to study, undertake assignments, and projects, has increased failure rates, and negatively impacted throughput rates. Poor performance results in rework, a waste of resources, demoralised and disappointed students, stressed students and academic support staff, and a burden to the economy resulting from the inability to secure employment.

Furthermore, a perception has formed, confirmed in industry liaison forums, that students attending employment interviews, or undertaking industry work during employment, lacked skills and attributes to fulfil the management role expected of

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them. This weakness, and the way graduates communicated their abilities and applied knowledge gained during their studies required an intervention at the earliest opportunity in the education process.

The Department's experiences are not unique, as Hill *et al.*, (2018) state that students struggle with the transition from high school to university, which places a responsibility on universities to intervene. Larmar and Ingamells (2010) in turn, inform that there has been increasing focus in higher education on identifying approaches for assisting first-year university students in their transition into the university environment in Australia. Gass (1986) in Vlamis *et al.*, (2011) contend that the first year of college is often a time of immense transition for young adults in terms of their social, moral, and educational development. Orientation is advocated and implemented by many higher education institutions (HEIs) globally to address this transition, and according to Owusu *et al.*, (2014), orientation encompasses activities that support the transition into HEIs.

The aforementioned led to the Department of Construction Management introducing a first-year orientation one-day TBE in 2018, which was styled on the 'Amazing Race' television programme. Given the Department's focus on 'lecturing and learning' research, a survey was conducted among the participants of the first TBE in 2018, and then after subsequent events. The aim of the research being to determine whether the intervention developed confidence in their abilities, enhanced communication amongst them, and provided an opportunity for them to test alternative thought processes, thereby better preparing the students for the challenges of first year and the undergraduate programme. The objectives were to determine whether the activities involved in the TBE contributed to an improvement in participants' understanding and appreciation of ten core competencies; enhanced seventeen skills; developed the ten core competencies, impacted on seven abilities, and enhanced fifteen states / attributes relative to emotional intelligence.

LITERATURE REVIEW

Student Engagement

Student engagement is a key issue with respect to orientation, and Larmar and Ingamells (2010) state that staff can promote it by fostering positive attitudes and relationships with students, inclusive teaching and learning strategies, collaboration between staff and students, and a diversity of social spaces to cater for students that embrace their individuality and various needs. Due to the need to accommodate the various backgrounds of students and promote a positive student culture it is not only staff-student relationships that are important, but relationships between students can promote engagement as students can provide each other support during stressful times. Hence the introduction of the first-year orientation one-day TBE, which promotes interaction between students and team building.

The Impact of Orientation Programmes

Bell *et al.*, (2014) in Hill *et al.*, (2018) state that outdoor orientation programmes significantly impact student development, as well as social and academic success. Hill *et al.*, (2018) cite Barefoot's (2000) contention that orientation programmes have numerous positive outcomes on both students and institutions. Furthermore, the study conducted by Hill *et al.*, (2018) during a four-day university outdoor orientation programme determined a significant improvement of resilience and well-being in participants.

Skills, Competency, and Employability

According to Smallwood (2006), construction management programmes need to empower graduates to manage the business of construction and projects, which requires that the learning environment develops their ability to manage themselves, work as a team, and interface with each other. The Confederation of British Industry (CBI) (2008) report focused on positive attitude and employability, the latter including: self-management - a readiness to accept responsibility and improve performance, flexibility, and time management; team working - respecting others, co-operating, persuading, and contributing to discussions, and problem solving - analysing facts, issues, and applying creative thinking to develop appropriate solutions. The problem-based learning (PBL) approach provides a platform within which “students learn content, strategies, and self-directed learning Skills Through Collaboratively Solving Problems.” (Hmelo-Silver *Et Al.*, 2007)

Core Competences and Emotional Intelligence

Smallwood *et al.*, (2013) noted in ‘Emotional Quotient and Managing Construction Projects’, the ten core competencies that fall within the categories of self-concept, traits, and motives, as well as the fifteen attributes / states of emotional intelligence (EI), impact on students’ performance as well as their performance in the work environment post-graduation. Therefore, tertiary construction management education programmes and training must develop such core competencies (Smallwood and Emuze, 2011) as the employers expect students to perform upon employment. Songer and Walker (2004) describe Emotional Intelligence (EI) as an “individual’s ability to identify emotions in oneself and others and to exhibit appropriate responses to environmental stimuli.” Chinowsky and Brown (2004) in turn point out that students with inadequately developed EI will lack problem solving capabilities as well as other professional attributes such as leadership, communication skills, creativity and an understanding of the external variables impacting upon their business. This emphasises the need to develop the emotional intelligence of construction managers, commencing during tertiary education (Smallwood *et al.*, 2013).

Mo *et al.*, (2007) emphasise that skills include the ability to think across disciplines, team working, and social and environmental awareness. The traditional education model is not providing students with these core skills and acquiring this in the traditional classroom environment is challenging. In the context of higher education, students have the ability to “transition from visualising and listening and actually attempt to ‘do’ what they are being taught” (Jackson, 2015) whilst “team-based discovery learning’ is ‘very effective’ in improving students.” As project managers usually face problems on projects that require them to react to unexpected events and cope with ‘uncertainty’ scenarios (Zwikael and Gonen, 2007), problem solving, stress tolerance, and the ability to forge strong interpersonal relationships become key attributes organisations will seek in graduates.

RESEARCH

Each year the ‘Amazing Race’ TBE entailed the completion of various, but differing activities, which were decided upon by the TBE organiser. The 2018 TBE entailed seven activities: hoop; blindfold object hunt; hike; puzzle; letter matrix; 3 stick triangles and conveying of golf ball. The 2019 TBE entailed five activities: hoop; zip line; obstacle course; caterpillar ski, and alphabet web. The 2020 TBE entailed six

activities: gold shift; hardhat relay; lateral thinking challenges; survivor puzzle; water pipe challenge, and zipline.

Each year the activities were led by the resorts' events' team leaders and entailed one or more of the following: strategising; planning; evolving of tactics and taking of action. Furthermore, completion of the activities required certain skills, whilst core competencies play a role in the completion of such activities, so too the fifteen attributes / states of emotional intelligence. The attendance during the three years was: 21 in 2018; 26 in 2019, and 16 in 2020. The students that attended the TBE were requested to complete a self-administered questionnaire after the completion of the event, and a 100% response was achieved. The questionnaire consisted of thirteen questions, twelve of which were closed-ended, and either a five-point or six-point Likert scale type question. This paper's focus is on the findings relative to five of the questions as presenting comparative findings relative to the specific activities would be challenging due to them differing from year to year.

A measure of central tendency in the form of a mean score (MS) between 1.00 and 5.00 (five-point), and 0.00 and 5.00 (six-point) was computed, based upon the percentage responses to the points on the respective scales to enable interpretation of the responses and to rank variables where necessary. Table 1 indicates the extent to which the TBE activities enhanced seventeen skills in terms of mean scores (MSs) and related rank (R) based upon percentage responses to a scale of 1 (minor) to 5 (major), an additional point did not, and MSs for the three years, and the mean thereof. Given that there are effectively six points on the scale, the MSs are between 0.00 and 5.00, the midpoint being 2.50. It is notable that the MSs for all three years and a mean based thereon are > 2.50, which indicates that in general the TBE activities contributed more of a major than a minor extent to an enhancement in participants' skills.

Table 1: Extent to which the TBE activities enhanced participants' skills

Skill	Response / Year							
	2018		2019		2020		Mean	
	MS	R	MS	R	MS	R	MS	R
Team building	4.10	1	4.15	1	4.31	1	4.19	1
Coordinating	3.74	5	3.88	3	3.87	3	3.83	2
Communicating - oral	3.81	4	3.73	10	3.81	4	3.78	3
Motivating	3.86	3	3.84	7	3.60	8	3.77	4
Planning	3.67	7	3.68	12	3.94	2	3.76	5
Organising	3.90	2	3.32	17	3.79	6	3.67	6
Leadership	3.55	10	3.96	2	3.44	12	3.65	7=
Decision making	3.48	11	3.85	5	3.63	7	3.65	7=
Procedures development	3.48	12	3.88	4	3.54	10	3.63	9
Initiating	3.10	17	3.83	8	3.80	5	3.58	10
Supervisory	3.25	15	3.84	6	3.50	11	3.53	11
Leading	3.62	8	3.76	9	3.06	16	3.48	12
Interpersonal	3.29	13	3.48	13	3.58	9	3.45	13
Controlling	3.62	9	3.70	11	2.92	17	3.41	14
Persuading	3.71	6	3.33	16	3.07	15	3.37	15
Negotiating	3.29	14	3.36	14	3.43	13	3.36	16
Technical	3.14	16	3.33	15	3.42	14	3.30	17

Only 1 / 17 (5.9%) mean MS is $> 4.17 \leq 5.00$, which indicates the TBE activities enhanced team building as a skill between a near major extent to a major extent /

major extent - team building was the primary objective of the TBE. 13 / 17 (76.5%) mean MSs are $> 3.34 \leq 4.17$, which indicates the TBE activities enhanced the skills between some extent to a near major extent / near major extent. 4 / 13 (30.8%) of the skills in the form of coordinating, oral communicating, motivating, and planning fall within the upper half of this range, namely $> 3.75 \leq 4.17$. It is notable that 2 / 5 functions of management work, namely coordinating and planning are in the upper range. 9 / 13 (69.2%) of the skills fall within the lower half of this range, namely $> 3.34 \leq 3.75$. The remaining three (17.7%) skills' MSs are $> 2.50 \leq 3.34$ - persuading, negotiating, and technical.

Table 2 indicates the extent to which the TBE building activities contributed to an improvement in participants' understanding and appreciation of ten core competencies in terms of MSs, related rank (R), and an overall rank (OR) based upon percentage responses to a scale of 1 (minor) to 5 (major), and an additional point did not, for the three years and the mean thereof. Given that there are effectively six points on the scale, the MSs are between 0.00 and 5.00, the midpoint being 2.50. It is notable that all the MSs are > 2.50 , which indicates that in general the TBE activities contributed more of a major than a minor extent to an improvement in participants' understanding and appreciation of the ten core competencies.

No mean MS is $> 4.17 \leq 5.00$, which indicates between a near major contribution to a major / major contribution. However, the 2020 MSs of attitude, team player, and focus on success, and the 2019 MS of attitude do fall within this range, which were objectives of the TBE. 8 / 10 (80%) mean MSs are $> 3.34 \leq 4.17$, which indicates between a contribution to a near major contribution / near major contribution: Attitude and self-image (self-concept); self-confidence, team player, and handle ambiguity (traits), and focus on success, preservation of team integrity, and preservation of personal integrity (motives).

Table 2: Extent to which the TBE activities contributed to an improvement in participants' understanding and appreciation of ten core competencies

Core competency	Response / Year											
	2018			2019			2020			Mean		
	MS	R	OR	MS	R	OR	MS	R	OR	MS	R	OR
Self-concept:	3.39	3		3.70	3		3.50	3		3.53	3	
Values	3.29	3	9	3.57	3	9	2.87	4	10	3.24	3	9
Aptitude	2.95	4	10	3.32	4	10	3.08	3	9	3.12	4	10
Attitude	3.95	1	2	3.78	2	8	4.27	1	2	4.00	1	3=
Self-image	3.38	2	7	4.13	1	2	3.79	2	7	3.77	2	7
Traits:	3.59	2		3.92	2		3.87	2		3.79	2	
Self-confidence	3.52	2	6	4.12	1	3	3.80	2	6	3.81	2	6
Team player	3.95	1	1	3.81	3	7	4.25	1	3	4.00	1	3=
Handle ambiguity	3.30	3	8	3.83	2	6	3.55	3	8	3.56	3	8
Motives:	3.76	1		4.13	1		4.15	1		4.01	1	
Focus on success	3.52	3	5	4.31	1	1	4.44	1	1	4.09	1	1
Preservation of team integrity	3.90	1	3	4.08	2	4	4.13	2	4	4.04	2	2
Preservation of personal integrity	3.86	2	4	4.00	3	5	3.88	3	5	3.91	3	5

Table 3 indicates the extent to which the TBE activities contributed to the development of participants' core competencies in terms of MSs, related rank (R), and an overall rank (OR) based upon percentage responses to a scale of 1 (minor) to 5 (major), and an additional point did not, for the three years and the mean thereof.

Given that there are effectively six points on the scale, the MSs are between 0.00 and 5.00, the midpoint being 2.50. It is notable that all the MSs are > 2.50, which indicates that in general the TBE activities contributed more of a major than a minor extent to an improvement in participants' understanding and appreciation of the ten core competencies.

No mean MS is > 4.17 ≤ 5.00, which indicates between a near major contribution to a major / major contribution. However, the 2019 and 2020 MSs of focus on success, and the 2019 preservation of team integrity MS do fall within this range. All the mean MSs are > 3.34 ≤ 4.17, which indicates the contribution can be deemed to be between a contribution to a near major contribution / near major contribution. Attitude, self-confidence, focus on success, preservation of team integrity, and preservation of personal integrity fall within the upper half of this range, namely > 3.75 ≤ 4.17. In terms of categories of core competencies, motives (MS = 3.97) is ranked first followed by traits (MS = 3.83), and self-concept (3.59). This ranking follows the ranking relative to the extent to which the TBE activities contributed to an improvement in participants' understanding and appreciation of the ten core competencies.

Table 3: Extent to which the TBE activities contributed to the development of participants' core competencies

Core competency	Response / Year											
	2018			2019			2020			Mean		
	MS	R	OR	MS	R	OR	MS	R	OR	MS	R	OR
Self-concept:	3.60	2		3.47	3		3.71	3		3.59	3	
Values	3.50	3	8	3.33	3	9	3.57	3	9	3.47	3	9
Aptitude	3.30	4	9	3.24	4	10	3.50	4	10	3.35	4	10
Attitude	3.95	1	2	3.64	2	8	4.07	1	5	3.89	1	4=
Self-image	3.65	2	5	3.65	1	7	3.69	2	7	3.66	2	7=
Traits:	3.57	3		3.98	2		3.94	2		3.83	2	
Self-confidence	3.15	3	10	4.04	2	4	4.10	1	3	3.76	2	6
Team player	4.05	1	1	4.08	1	3	4.07	2	6	4.07	1	1
Handle ambiguity	3.50	2	7	3.83	3	6	3.64	3	8	3.66	3	7=
Motives:	3.63	1		4.15	1		4.13	1		3.97	1	
Focus on success	3.65	2	4	4.26	1	1	4.20	1	1	4.04	1	2
Preservation of team integrity	3.65	1	3	4.18	2	2	4.13	2	2	3.99	2	3
Preservation of personal integrity	3.60	3	6	4.00	3	5	4.07	3	4	3.89	3	4=

Table 4 indicates the extent to which the TBE activities impacted on participants in terms of MSs, and related rank (R), based upon percentage responses to a scale of 1 (minor) to 5 (major), and an additional point did not, for the three years and the mean thereof. Given that there are effectively six points on the scale, the MSs are between 0.00 and 5.00, the midpoint being 2.50. It is notable that all the MSs are > 2.50,

which indicates that in general the TBE activities impacted more of a major than a minor extent on participants.

Only 1 / 7 (14.3%) MS (2020) and mean MS are $> 4.17 \leq 5.00$, which indicates the impact can be deemed to be between a near major extent and a major / major extent - your ability to communicate with your 1st year colleagues. 4 / 7 (57.1%) mean MSs are $> 3.34 \leq 4.17$, which indicates the impact can be deemed to be between some extent to a near major extent / near major extent: your ability to complete a task, building confidence in your own abilities, enhancing alternative thought processes, and your ability to be creative. The remaining 2 / 7 (28.6%) mean MSs are $> 2.50 \leq 3.34$, which indicates the TBE activities impacted between a near minor extent to some extent / some extent - removing you from your ‘comfort zone’ and improving your time management skills.

Table 4: Extent to which the TBE activities impacted on participants

Impact	Response / Year							
	2018		2019		2020		Mean	
	MS	R	MS	R	MS	R	MS	R
Your ability to communicate with your 1 st year colleagues	4.00	1	4.12	2	4.56	1	4.23	1
Your ability to complete a task	3.95	3	4.19	1	3.69	2	3.94	2
Building confidence in your own abilities	4.00	2	4.08	3	3.50	4	3.86	3
Enhancing alternative thought processes	3.86	4	3.96	4	3.31	5	3.71	4
Your ability to be creative	3.67	5	3.42	7	3.67	3	3.59	5
Removing you from your ‘comfort zone’	3.33	7	3.62	6	2.88	6	3.28	6
Improving your time management skills	3.52	6	3.62	7	2.50	5	3.21	7

Table 5 indicates the extent to which the TBE activities enhanced the participants’ attributes / states which collectively constitute emotional intelligence in terms of MSs, and related rank (R), based upon percentage responses to a scale of 1 (minor) to 5 (major), for the three years and the mean thereof. Given that there are five points on the scale, the MSs are between 1.00 and 5.00, the midpoint being 3.00. It is notable that all the MSs are > 3.00 , which indicates that in general the TBE activities contributed more of a major than a minor extent to the enhancement of the participants’ attributes / states.

Only 2 / 45 (4.4%) MSs and 1 / 15 (6.7%) mean MS are $> 4.20 \leq 5.00$, which indicates that the extent of enhancement is between a near major extent to a major extent / major extent - happiness relative to 2019, 2020, and the mean. 14 / 15 (93.3%) mean MSs are $> 3.40 \leq 4.20$, which indicates that the extent of enhancement is between some extent to a near major extent / near major extent. The MSs of social responsibility, problem solving, optimism, interpersonal relationship, stress tolerance, self-regard, and assertiveness fall within the upper half of the range, namely $> 3.75 \leq 4.20$. The MSs of flexibility, independence, reality testing, impulse control, empathy, self-actualisation, and emotional self-awareness fall within the lower half of the range, namely $> 3.40 \leq 3.80$.

DISCUSSION

Due to the need for brevity, and that the activities differed from year to year, findings from only five of the twelve closed-ended questions were presented. However, the

findings constitute the overarching findings in the form of the contribution of the TBE to an improvement in participants’ understanding and appreciation of ten core competencies; enhancement of seventeen skills; development of the ten core competencies, impact on seven abilities, and enhancement of fifteen states / attributes relative to emotional intelligence.

Table 5: Extent to which the TBE activities enhanced the participants’ attributes / states

Attribute / State	Response / Year							
	2018		2019		2020		Mean	
	MS	R	MS	R	MS	R	MS	R
Happiness	4.10	2	4.38	1	4.93	1	4.47	1
Social responsibility	3.90	3	4.14	2	4.07	5	4.04	2
Problem solving	3.80	5	4.04	5	4.19	2	4.01	3
Optimism	3.76	7	4.13	3	4.07	4	3.99	4
Interpersonal relationship	3.79	6	4.00	6	4.07	3	3.95	5
Stress tolerance	4.10	1	3.91	9	3.60	10	3.87	6
Self-regard	3.55	13	4.08	4	3.67	7	3.77	7
Assertiveness	3.75	9	3.91	9	3.63	9	3.76	8
Flexibility	3.85	4	3.71	12	3.53	11	3.70	9
Independence	3.75	8	3.95	7	3.27	14	3.66	10
Reality testing	3.25	14	3.91	9	3.62	8	3.59	11
Impulse control	3.60	11	3.73	11	3.40	12	3.58	12
Empathy	3.20	15	3.68	13	3.67	6	3.52	13
Self-actualisation	3.60	10	3.65	14	3.29	13	3.51	14
Emotional self-awareness	3.55	12	3.61	15	3.27	15	3.48	15

The findings indicate that the TBE activities enhanced seventeen skills and various abilities and developed the ten core competencies, and fifteen states / attributes relative to emotional intelligence. These constitute objectives of the TBE and complement student engagement in general.

It is notable that relative to the seventeen skills, the enhancement was between some extent to a near major extent / near major extent in the case of thirteen (76.5%) skills, team building, coordinating, oral communicating, motivating, and planning predominated, which also constitute key skills. These were focus points of the TBE activities.

Given that the performance of students and practitioners is affected by the extent to which core competencies manifest themselves, and differentiate between average and above average performance, the extent to which the TBE activities contributed to the development of participants’ core competencies is notable. The findings indicate that the activities made between a contribution to a near major contribution / near major contribution - attitude, self-confidence, focus on success, preservation of team integrity, and preservation of personal integrity predominated. This is in alignment with the findings in the literature, especially that of Larmar and Ingamells (2010) relative to students supporting each other, and Hmelo-Silver *et al.*, relative to the PBL approach.

The ability to communicate with first year colleagues, the ability to complete a task, and building confidence in students' abilities predominated in terms of the extent to which the TBE activities impacted on participants. These were focus points of the TBE, especially the ability to complete a task. This is in alignment with the findings of Hill *et al.*, (2018) arising from the 'impact of an outdoor orientation programme' study.

In terms of the extent to which the TBE activities enhanced the participants' attributes / states, which collectively constitute emotional intelligence, happiness predominated, the extent of enhancement being between a near major extent to a major extent / major extent. The extent of enhancement in the case of the remaining fourteen was between some extent to a near major extent / near major extent - social responsibility, problem solving, optimism, and interpersonal relationship predominated. Developing the ability to solve problems was a focus point of the TBE. Furthermore, student engagement should enhance students' well-being (Hill *et al.*, 2018).

CONCLUSION

Non-traditional academic programme interventions, such as the TBE, do impact on first-year students' ability, to manage themselves, strategise, plan, evolve tactics, and take action, which in turn should contribute to their ability to study, undertake assignments, projects, and successfully complete the undergraduate programme, although this can only be quantified on completion of a full academic year. In addition, the activities developed confidence in their abilities, enhanced communication amongst them, and provided an opportunity for them to test alternative thought processes.

It is thus recommended that the TBE be undertaken on an annual basis, with the impact thereof on participants to be determined following the completion of a full academic year and again post-graduation. Further potential events directed at enhancing students' abilities and increasing confidence in their abilities, as well as providing them opportunities to test alternative thought processes, should be investigated. In addition, the results from this study will be used to enhance the intervention in future years including 'tweaking' events to better align to students' areas of concern as detailed in the comments provided.

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OPEN INNOVATION WITHIN LOUGHVIEW TIMBER: HOW KNOWLEDGE TRANSFER IS OPENING DOORS TO NEW MARKETS

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Open Innovation (OI) presents an opportunity for small to medium enterprises (SMEs) to gain a competitive advantage over their peers in their respective markets. This study aims to determine the effectiveness of adopting an open innovation model in the context of SMEs. In doing so, Loughview Timber; a small manufacturer and supplier of timber external door sets, fire rated doors, staircases, windows, based outside of Gilford in Northern Ireland, is used as a case study. They have partnered with the University of Limerick in a knowledge transfer project on product development, using open innovation as a vehicle. Using existing processes and procedures as a base, the study aims to analyse the need for open innovation within Loughview Timber; thus, analysing the effect open innovation would have on the organisation whilst providing recommendations for the company's innovation practices. Based on a review of existing literature, a questionnaire and subsequent review of Loughview Timber's internal documents and market reports, findings emerge. It is recommended that Loughview Timber continue to exploit the benefits of knowledge transfer available, in this case, in the form of InterTradeIreland's FUSION programme, while also looking for further opportunities to partner with other third level educational institutions. Further research is required across a wider range of SMEs to more accurately determine the effectiveness of open innovation on supporting SME's product development activities.

Keywords: industry, FUSION Programme, InterTradeIreland, Open Innovation

INTRODUCTION

Open innovation (OI) involves leveraging residual expertise from outside the organisation to support and improve the process of internal innovation, increasing organisational competitiveness (Chesbrough and Crowther 2006a). 78% of large US and European firms have adopted some form of OI, and of this 82% have stated that they were practising OI more intensely at that time than the three years' prior (Chesbrough and Brunswicker 2015). Although OI is prominent in large organisations, in Northern Ireland (NI), small to medium sized enterprises (SMEs) account for 75% of employment and 80% of these SMEs stated their intentions for future growth, highlighting the importance of innovation for these companies

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(Federation of Small Businesses 2015). Traditionally SMEs adopt an inside-out approach to OI, by supplying excess knowledge, ideas and resources to larger organisations, in return for some form of payment. However, recent trends show growing numbers of SMEs adopting different forms of outside-in OI to support growth and competitiveness (Van de Vrande *et al.*, 2009). Despite this trend, there is still limited research into the effects and challenges of adopting OI in SMEs, with existing research in this area focusing on high-tech industries (Spithoven *et al.*, 2012). Based on this, the aim of this paper is to investigate the effects of OI on SMEs, with a particular focus on manufacturing, to judge the impact of outside-in OI on a small firm's innovation process. In doing so, a case study subject is identified; Loughview Timber Ltd. Based in Banbridge, Northern Ireland; a privately-owned SME, employing 28 people. Loughview produces a range of specialised products including staircases, windows and pre-hung fire door-sets. These pre-hung fire door-sets provide Loughview with a distinct market advantage and unique selling point, due to the benefits they provide to industry.

To tackle pending legislation and to capture market share in line with the company's growth strategy, Loughview has adopted an OI model to accelerate the process of innovation and develop a range of fully certified fire door-sets. After an internal analysis, Loughview discovered skills, financial and knowledge gaps. To address these gaps, Loughview partnered with the University of Limerick under the InterTradeIreland, FUSION programme. This programme linked Loughview with an academic knowledge base and subsequently, a graduate, filling the skills and finance gaps in the organisation. The aim of this partnership is to address five key objectives within the company, all of which are included in the discussion.

Subsequent to this, the project will critically analyse OI within traditional industries such as manufacturing and passive fire safety; thus, acting as an academic resource for SMEs operating in these industries which may consider the implementation of an OI. This is an area of research yet to be fully explored; therefore, this project will aim to partially fill this research gap. Secondly, the project will aid Loughview in the implementation of OI. This will support increased levels of innovation across the organisation, which should positively impact organisational competitiveness (Kumar *et al.*, 2013). Finally, this project will support the development and production of high quality and fully third-party certified door-sets.

Moving from Closed to Open Innovation

Historically, organisations adopted a form of 'closed innovation', creating new products or services, from ideation and development to marketing and sales, using only the resources available internally (Bae and Chang 2012). The concept of closed innovation is centred on the idea that innovation requires the highest levels of control within the organisation and is derived from a reliance on internal staff members for innovation activities (Alawamleh *et al.*, 2018). In closed innovation, organisations heavily invest in research and development and hire whom they believe to be the smartest people, to develop new products at a rate which allows them to reach the market before their competitors (Mayle 2006). Despite the early popularity of closed innovation, with the advent of new technologies and the increasing mobility of the 'knowledge worker', the closed innovation model began to erode as firms struggled for control of their intellectual property and internal knowledge (Mayle 2006; Bogers *et al.*, 2018). These difficulties led to organisations realising that 'not all the smart people work for us' (Chesbrough 2003a); thus, leading to a paradigm shift for

innovation towards a more open model; Open Innovation (Chesbrough 2012). Open innovation is often described as the process of altering something already established, to make a significant positive change (Berkun 2010). More specifically, innovation is a tool used to exploit change as an opportunity, aiming to support the development of new and improved products and services (Drucker 2014). Additionally, innovation is the process of ongoing learning, resulting not only in new products and services, but also new organisational structures, techniques and markets (Lundvall 1995). Although the history of OI is often disputed, with sources claiming it has roots ranging from Xerox's Palo Alto Research Centre (Chesbrough *et al.*, 2006) to the music creation process of The Grateful Dead (Diasio 2018), there is limited dispute over the founder of the theory, Henry Chesbrough. Open innovation was first investigated by Chesbrough (2003a; 2003b; 2003c) over 15 years ago, and research has since developed and expanded into countless areas and disciplines (Randhawa *et al.*, 2016; Dahlander and Gann 2010).

Chesbrough (2006) defines open innovation as the purposeful use of outflows and inflows of knowledge to accelerate the process of internal innovation and expand the markets for the external use of innovation. Therefore, OI is based on leveraging external knowledge and expertise, to assist internal innovation activities (Chesbrough and Crowther 2006). Key to this is that OI allows for the mutual and equal exploitation of benefits for both parties involved, either through the exchange of resources or knowledge. Central to Chesbrough's definitions is that OI is an approach supported by the organisations business model (Gobble 2016) and a set of tools and processes created to facilitate relationships (Slowinski and Sagal 2003). In recent years, the OI model has been steadily increasing in popularity. A recent study of large firms across the US and Europe (more than 1000 employees) found that 78% of companies reported practising some form of OI, and of these, 82% stated that they were practising it more intensely than the previous three years (Chesbrough and Brunswicker 2015). Despite this, research suggests that many SMEs do not adopt OI, choosing instead to conduct R&D internally. This is likely due to the challenges associated with OI and its implementation (Kang 2012; Jeon and Degraevl 2019). These results, along with the limited existing research in the area, has led to calls to further explore the implications of OI for SMEs and their ability to overcome the associated challenges (Gassmann *et al.*, 2010).

In the context of the construction sector, as a more traditional industry, often needs assistance in this area (Spithoven *et al.*, 2010). However, as Pöyhönen *et al.* (2016) argue, the adoption of innovation in the construction sector and in particular, management systems to support its development, is lacking. Steninger (2014) concludes that the leading barriers for the adoption of OI in the construction sector is averse to change due to culture, strategy and perceived risk of losing proprietary knowledge, jeopardising quality and safety, and intellectual property, among others. In the construction section, Steninger (2014) outlines the benefits of overcoming these barriers and adopting OI includes integrating external key competencies for problem solving, opening a company to culture of innovation and 'thinking outside the box', building long-term relations with external strategic stakeholders and advisors, providing motivation and incentivisation for adopting new and unique approaches to addressing inherent problems, and also revisiting traditional norms in favour of more strategic and innovative approaches to undertaking more traditional practices, while minimising risk and extrinsic market shocks.

Research Design

The focus of this paper is to ascertain the viability of OI within manufacturing SMEs with Loughview being identified as the case study. To address research bias, a two-stage process was used in the identification of the case study. Firstly, the case study had to be an SME, and secondly, they had to be open to discussing and subsequently engaging in the adoption of OI within their organisation. Furthermore, the interviewees were selected from a pool of potential candidates, not just from within the company, but those who are external to, but are aware of the company's practices. To complement this, a desk-based research is being used as a secondary data collection method. Additionally, it will act as a support mechanism for primary data collection by validating samples, ensuring they are representative. To provide relevant background information and validating materials, four areas were chosen;

Firstly, academic literature relating to OI, as this provides a general overview of OI and its development as a business model approach. Secondly, previous studies and research are reviewed to ensure there was no overlap in research, allowing this research to build on previous work in the field. Thirdly, company documents, such as Business Plan, Minutes of Meetings, etc. are reviewed, to provide an in-depth analysis of Loughview, allowing for a review of existing organisational resources, which supported the development of recommendations relating to the introduction of OI. Fourthly, secondary business data in the form of market reports and analysis are reviewed, to support the creation of short, medium and long-term innovation plans for the organisation, by highlighting industry trends.

To complement this, six semi-structured interviews are conducted. As this is an exploratory research project, semi-structured interviews were used. With this interview type, several key questions are addressed; however, their order and use may vary between interviews, depending on the flow of the conversation (Saunders, *et al.*, 2016). The interview respondents were chosen from across the OI project, to provide a broad scope of experience and knowledge relating to both sides of the OI process (DeJonckheere and Vaughn 2019). The interviewees included; Loughview Timber' Managing Director (#1), University of Limerick Academic (#2), InterTradeIreland FUSION Consultant (#3), and Loughview Timbers Management Consultant (#4). To limit the potential for positive bias from those involved in the OI project, two employees from Loughview with no involvement were also chosen as respondents; the Business Development Manager (#5) and Estimator (#6).

Face to face interviews were chosen, as respondents are grouped closely together geographically, as well as facilitating effective communication, allowing for both verbal and non-verbal communication between the interviewer and interviewee (Daft and Lengel 1986). During the interview, respondents were asked open-ended questions, which followed no particular order. Interviews were conducted in the order of availability of respondents. After all interviews had been completed, the qualitative data was reviewed and collated, trends highlighted and compared to secondary data sources, to draw appropriate and accurate conclusions and recommendations.

RESULTS

Taking a thematic analysis approach, themes and patterns that occur across the qualitative data set and is related to the research question are identify (Saunders *et al.*, 2016). This offers a systematic and flexible approach to analysing large sets of qualitative data in a logical way (Braun and Clark 2006). As this research project has

taken a deductive approach, the research question has been firmly established in existing work and a thematic analysis will allow a focus on particular parts of the data which are applicable to research, rather than take an indiscriminate approach to analysing the data set (Saunders *et al.*, 2016). The results are structured around response themes from interviewees.

The opening question to all interviewees focused on their previous knowledge of OI. In all cases, participants had some previous knowledge of OI models, with respondents two (#s 3 and 4) having detailed knowledge of the subject. One of those respondents noted that much of their work resonates around OI by holding “companies, to ‘look outside the box’, when considering and implementing new ways of working and solving problems”. To further explore the respondent’s exposure to OI, an additional question was posed to determine how many OI structures they had previously partaken in. Of the respondents, four declared participating in between two and four previous structures, with two respondents claiming to have participated in more than fifteen previous OI models (#s 2 and 3). However, of the fifteen, these respondents noted that the majority were through similar projects to that of the InterTradeIreland FUSION programme. As a follow up question, interview participants were asked how many of the OI models took place in manufacturing SMEs. Excluding Loughview, only two respondents claimed to have participated OI structures within manufacturing SMEs. As all respondents had experience and knowledge of OI models, they were then asked about their views on the difficulties associated with implementing an OI model. Although several difficulties were highlighted, including three participants noting cultural change issues and participant one discussing a lack of resources, all participants except respondent #5 noted ‘management buy-in’ as a major difficulty. Participant #2 stated that “getting management level buy-in to considering developing and implementing a new approach outside of what would be the normal” was the greatest difficulty. When asked how this should be managed, key responses included the need to “clearly present the benefits of OI and manage expectations” along with “gaining early ‘wins’ and having constant channels of communication”.

Moving on, the focus on the ongoing difficulties associated with managing OI and the benefits of OI for all parties involved was discussed, where two key themes emerged. Firstly, all respondents noted that the major benefit of utilising an OI model was the limited amount of resources required for innovation to occur. Whilst some respondents focused on the financial resource efficiency of the process, the majority focused on the human resource and time efficiency elements of OI models. Secondly, five of the six respondents discussed the benefits of OI based on an ‘outside-in’ process, focusing on the leveraging of external resources rather than allowing excess internal resources to be used externally. Also, despite the phrasing of the question asking participants to focus on the benefits for ‘all parties involved’, only respondent #2 provided a clear example of the benefits for the second party stating, “For the university, it demonstrates the applicability of research in industry, with tangible results”. Regarding the difficulties associated with OI management, three respondents discussed the difficulty associated with managing the process and the potential for culture clashes between partnering organisations. However, the management of Intellectual Property (IP) was the biggest concern among respondents, with five of the six noting this as an ongoing difficulty.

Although all respondents noted difficulties associated with both implementing and managing an OI model, when asked about its effectiveness in supporting the

achievement of organisational goals, all participants agreed that OI was an effective model for innovation with one respondent stating “All projects (I have) completed to-date exceeded expectations and resulted in significant returns on the investment of time and money included in the project” and another noting that “if the big guys like Google and Samsung are using this effectively, why shouldn’t we?”. Finally, all respondents were asked to reflect on the previous OI models they participated in and consider how effective a CI model would have been in those cases. Respondents one and six noted that in their cases, CI would have been inefficient due to the limited available resources. However, the remaining candidates stated that in certain situations it may be more effective to utilise a CI system. One participant noted “CI may have a place in industry, particularly those where IP/user rights are an issue. It really depends on the topic and in the innovative aspects being considered.” Despite this, all participants agreed that OI was the most effective model to use at Loughview.

Excluding the academic literature discussed, desk-based research focused on internal company documents and market reports. From these, several key results emerged. Firstly, Loughview has experienced steady growth in recent years with support from their strategic plan. The company growth follows the general trend of the passive fire safety market, which grew by 23% between 2013 and 2015, driven largely by increased construction activity (AMA Research 2018). However, with Brexit and the increasing potential for a recession, particularly in light of COVID-19, growth forecasts are subdued for both the overall market and Loughview. Secondly, Loughview’s growth is being slowed due to a lack of available labour. Due to their remote location and skills requirements, Loughview has struggled to find the staff to support an increasing client sheet and are now turning towards technology to facilitate increased productivity. To address this, Loughview have begun to segment the production process to reduce the complexity of tasks, making the positions more accessible to a wider group of people. Thirdly, despite a positive cash-flow and a healthy balance sheet, Loughview relies on funding from organisations such as Invest NI, to support some employment. Although cash reserves are available and the business has a positive profit outlook, there are limited reserves to support innovation activities in the business.

DISCUSSION

The first two objectives looked at critically evaluating OI, where the results of the research suggest that OI is an effective tool for innovation activities. SMEs have limited internal resources to support R&D activities internally, a point reiterated by two interviewees; however, the use of OI allows those SMEs to leverage external resources in an efficient manner providing a competitive advantage (Brunswick and Ehrenmann 2013). With the introduction of government schemes which aim to encourage the adoption of OI, such as InterTradeIreland’s FUSION programme, OI will become more accessible for SMEs as these programmes mitigate the difficulties associated with OI and provide funding and frameworks to support it. With that, we then considered examples where OI was applied within manufacturing businesses and SMEs. With 78% of large firms reported practising OI and many with increasing intensity (Chesbrough and Brunswick 2015), OI is placed to become more widespread, with support from leading universities, in its development and execution. As per the response from interview respondent three, SMEs could also achieve innovation success with OI if it is managed correctly. However, research in this area is limited, specifically for organisations with a primary focus on manufacturing;

therefore, a wider study is required across several organisations to determine OI's true effectiveness for manufacturing SMEs.

The third objective required an analysis of Loughview to ascertain if the levels of knowledge and resources within the company allowed for the use of closed innovation during this project. As discussed by several respondents and supported by previous literature, closed innovation can be an effective innovation tool in certain scenarios (Chesbrough and Euchner 2011). However, this innovation model relies heavily on the resources readily available to an organisation (Alawamleh *et al.*, 2018), and, as noted 'not all the smart people work for us' (Chesbrough 2003a); a sentiment echoed by the case study company, where they state that their specialism is in joinery and not innovation. Additionally, Bae and Chang (2012) state that organisations using a closed innovation model only use the resources available to them internally. Therefore, for closed innovation to be effective, organisations must have excess internal resources that can be leveraged for innovation purposes. However, after an internal analysis of Loughview, the results indicate that the firm had neither the knowledge, manpower nor finances to utilise closed innovation. Although the company has 28 staff and the finances to support recruitment, their remote location and the current job market has mitigated their ability to do so. Of those that are currently employed by Loughview, 22 work in skilled jobs which require training or education that is not suitable to the innovation activities required for this project; thus, limiting the available knowledge. Additionally, of those staff with appropriate training and education, all are currently working at capacity, leaving limited time to engage in internal innovation activities.

The fourth objective aims to analyse the effectiveness of introducing an OI model into Loughview for new product development. OI has been proven as effective at supporting innovation; however, as the literature and research data suggests, it can be both difficult to implement and manage. As stated by interview respondents, a key issue with the adoption of OI is gaining management buy-in. However, in the case of Loughview, senior management both developed and implemented this OI project; thus, nullifying this issue. An additional issue addressed by respondents was the potential for culture change issues. This presents a correlation between the data and existing research, but also the views of the interviewees, in which culture is seen as important for innovation activities (McAdams *et al.*, 2004) and a barrier to adopting a more open model of innovation (Mortara *et al.*, 2010). Although no issues have arisen within Loughview, management must be prepared to adopt a 'change management tool' if necessary. Regarding the ongoing management of an OI model, respondents noted the management of IP as an issue. However, Loughview can be seen to have mitigated this risk by adopting the use of a contract in their partnership with InterTradeIreland and the University of Limerick. Additionally, in the format adopted by InterTradeIreland, the graduate tasked with leading the project is labelled as the 'agent of technology transfer' and is tasked with controlling the flow of information between the company and academic institution. Overall, interview respondents believed OI to be effective for developing new products and is seen as preferable over the alternative. However, there were challenges in its introduction; namely, getting full buy-in from all internal stakeholders, and also acquiring the necessary knowledge.

CONCLUSION

Research and existing literature have supported the theory that OI is the most effective model for new product development within Loughview. The OI model provides

access to external resources including financial, human and knowledge, which are not readily available to Loughview internally, allowing effective leveraging of these to support innovation activities that would otherwise be unattainable. Despite its benefits, OI comes with several costs. Gaining the support of management can cause difficulties during the implementation process, and the potential for culture clashes and the issues associated with changing internal culture can further build on these problems. Despite Loughview's ability to navigate these initial issues, further problems can be expected throughout the innovation process. Although, Loughview has developed measures to counteract issues such as IP rights, flight of knowledge, a loss of internal focus and difficulties with the OI partnership, could lead to future problems. If Loughview continues to effectively manage the model of OI, it will continue to support the development of new products, providing competitive advantage. Contradictory findings on the effect of OI; however, warrant calls for further wider-reaching and in-depth studies into the effects of OI on SMEs.

From the results, recommendations for short, medium- and long-term objectives for the case study emerge. In the short-term, Loughview should continue to use the resources and support provided by InterTradeIreland and the University of Limerick, through the FUSION programme, to support their on-going product innovation. In the medium-term, Loughview should consider further government and academic supported programmes, to complement and develop further innovative products and services. In the long-term, Loughview should continue to leverage external resources, particularly within their supply chain. With the possible increase in available resources internally through efficiency creation, Loughview should develop a plan focusing on the creation of an R&D lab and test facilities. This would support further OI activities and innovation, potentially providing an additional revenue source, should Loughview decide to participate in 'inside-out' innovation activities, allowing these internal resources and test facilities to be used externally. There are also limitations. Given that this is an exploratory study considering the viewpoints of various actors within a specific company in Northern Ireland, the results are not generalisable either across geographic regions or the construction sector as a whole. This therefore then drives the further research agenda, where a more widespread investigation is warranted, getting the viewpoints of various organisations beyond that of the joinery sector. In concluding, this paper, using Loughview Timber Limited as a case study, demonstrates the use of, and benefits of applying OI and knowledge transfer, in this instance, using the InterTradeIreland FUSION Programme as the vehicle, with the University of Limerick as the knowledge base. This therefore demonstrates to other SME's within the manufacturing sector, to consider knowledge transfer as an introduction to, or to proceed with, further research and development.

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CAN I GET SOME HELP DOWN HERE? INTER-PROJECT SUPPORT FOR CREATING SOCIAL VALUE THROUGH SOCIAL PROCUREMENT

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Employment requirements, as an aspect of social procurement, can be used as an innovative way for construction organizations to create internships for marginalized unemployed people, in the process creating social value. However, how to organize and collaborate to implement employment requirements in construction projects is unclear. Therefore, this paper investigates how practitioners working operatively in projects perceive the support from and relationship with their parent company and client when they have to implement and work with employment requirements on a daily basis. Semi-structured interviews with 23 practitioners working in three projects in Sweden were analysed using a theoretical framework of project management focused on resources and collaborative relationships. Findings show how resources and support is often lacking, and how relationships with parent companies and clients are tenuous. There is a lack of knowledge and clear goals from the parent company and client which create uncertainty. The operative actors in the projects have to deal with this uncertainty without formalized routines, standardized information sharing, or enough resources, so to cope they create their own tools and practices. The paper provides a bottom-up perspective on social procurement and illustrates concrete areas where parent companies and clients must rethink their (lack of) resources and support. For research the findings indicate what factors make collaboration regarding social procurement difficult and contributes novel insight into a scarcely researched phenomenon.

Keywords: employment, project management, social procurement, social value

INTRODUCTION

Recent years have seen mass migration, fiscal constraints, and increasing segregation, and as organizations are not immune to these societal challenges, they are trying to find new innovative ways to use their processes in order to build a sustainable common future (Barraket *et al.*, 2016). One such way is for organizations to use their purchasing power to achieve social goals and values that lie outside their normal procurement objectives (McCrudden 2004; Barraket *et al.*, 2016; Raiden *et al.*, 2019). This is called social procurement and it encompasses a wide range of aspects such as buying from local small and medium enterprises, buying from minority-owned or women-owned businesses, ensuring health and safety and fair working conditions, and employment of marginalized groups (cf. Zuo *et al.*, 2012; Loosemore 2016, Raiden *et*

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al., 2019). Sweden is especially battling problems of social exclusion and unemployment for people who are young, disabled, or newly immigrated, so social procurement has been focused on posing criteria called employment requirements (c.f. Lind and Mjörnell 2015). Employment requirements entail offering internships for people outside the labour market. Historically, the construction sector has been one of the main sectors where social procurement has been used, due to its close ties with communities and the spaces where we live. Therefore, the sector has been targeted as suitable for employment requirements (c.f. Lind and Mjörnell 2015).

However, despite that employment requirements have the potential to create social value for organizations and society, working with employment requirements is still novel in Sweden and there is no best practice, which is the case also for other geographical contexts. Organizations in the construction sector are experimenting with different methods to work with and implement employment requirements, but these methods need to be further developed (Petersen 2018). Moreover, social procurement is fairly unexamined conceptually, theoretically, and empirically both in research and in practice (Barraket *et al.*, 2016; Loosemore 2016; Raiden *et al.*, 2019).

Something which needs more insight is the relationship between the organizations who work together to implement employment requirements. When employment requirements are used three main types of organizations are involved: the client posing the requirements, the parent company (main contractor's head office) tendering for the contract, and the individual construction project fulfilling the contract. Of these three it is the individual construction projects and the operative workers therein who on a daily basis deal with the employment requirements and the interns employed through the requirements. How they organize this work and collaborate with their parent company and the client to implement employment requirements is unclear. This is important to investigate to ensure that the multi-party activity of employment requirements becomes effective and efficient to achieve the maximum social value possible, as today this have not been the case (c.f. Petersen 2018).

Therefore, this paper investigates how practitioners working on an operative level with construction or facilities maintenance in projects, who are those who in their daily work deal with both employment requirements and the interns employed through the requirements, perceive the support from and relationship with their parent company and client when employment requirements are implemented. The findings are analysed using a theoretical framework of project management focusing on resources and collaborative relationships. This will enable new theoretical and empirical insights into the complexity of working with employment requirements from a bottom-up perspective.

To implement social procurement and take in interns to work with construction or facilities maintenance means that multiple organizations must come together and collaborate, which has consequences for their practices and relationships. On the one hand previous research has found that social procurement has the potential to increase trust, collaboration, and knowledge sharing between project members (Erridge 2007; Barraket *et al.*, 2016; Troje and Gluch 2020), but on the other, when implementing social procurement trust and collaboration is instead often lacking in practice, which in turn hinders can diminish the social value output. Furthermore, social procurement is not seen as core business, support from governments is lacking, and social procurement is perceived to require more resources from projects (Erridge, 2007; Zuo *et al.*, 2012; Eadie and Rafferty 2014; Loosemore 2016; Murphy and Eadie 2019).

The organization of the construction sector is not always conducive for collaborating to implement social procurement. The construction sector is largely characterized by standardisation, efficiency in time, cost and scope, coordination difficulties, independent specialised work tasks, decentralisation of decision making, and independence (Dubois and Gadde 2002). This way of organizing creates complexity for actors who are tasked with implementing employment requirements and interns into the daily operations of their organizations.

As such, previous research on social procurement show how social procurement is perceived as requiring more resources, and that collaboration is important but difficult to achieve due to how the construction sector is organized. To understand this complexity better, adopting a project management perspective guided by the concepts of resources and collaborative relationships is helpful. Research on project management in construction and social sustainability in construction are nascent but scattered streams of literature (Goel *et al.*, 2020). By adopting a project management perspective when studying social procurement this theoretical gap can be bridged, and the support from and relationship between clients, parent companies, and projects can be better understood. This can in turn create a better base on which to build an effective, efficient, and social value maximizing practice for social procurement.

Project organizing can be described as organizations coming together to deliver a certain outcome (c.f. Winch 2014: 728) where the project owner brings financial resources and the project-based organization brings managerial and technical skills. A problem in research on projects is that the owner is often reduced to just a client who buys a service, and not a strategic actor (*ibid*), but the extent to which the client is involved in the project depends on its previous experience. Experienced clients will likely maintain a close presence as they have personnel that are used to working in coordinating roles between the client and project (Walker 2015).

There are several difficulties when working in projects in relation to lack of resources. For example, human resources are a major problem for project-based organizations, as they tend to stretch their human resources over several projects, leading to overload problems. It could also be that the project organization is bad at managing existing human resources (Winch 2014). In general, more attention needs to be paid to the social sustainability for workers in projects (Goel *et al.*, 2020). Project success is also dependent on the experience of key project members, rather than on specific technical or management skills. Context-specific aspects, like the organizational environment and its history, the previous experience of the parent organization, and the knowledge and experience of project members influence project success (Engwall 2003).

When it comes to collaborative relationships, working in projects also means to start all over again as project members are new for every new project. This can decrease motivation for individual workers, and efficiency is limited due to the lack of prior collaboration (c.f. Packendorff 2002). The episodic and decentralized nature of projects, as well as time and resource constraints diminish reflection, learning, and knowledge transfer between projects (Packendorff 2002; Winch 2014). Also, as the construction sector is decentralized, information is disseminated through different hierarchical levels and organizations, leading to inefficiently delivered and diluted information. To mitigate this issue information should be standardized and aligned across organizations. However, this can be difficult as organizations in the sector have diverse practices and arms' length relationships, making shared information systems scarce (Fulford and Standing 2014). Also, it is not uncommon for objectives

to differ between the client, contractor, project organization, and work teams. Aligning these objectives is an important part of project management (Walker 2015).

There are different ways in which actors can deal with these resource and collaborative constraints and how this impacts the dissemination of new practices, like working with employment requirements. Bresnen *et al.*, (2004) found that actors who promote new working practices in projects attempt to make them standardized, while project actors who are affected by new practices instead try to reconstruct and negotiate their meaning when deciding which aspects of the new practices they wanted to adapt, adopt, or reject. This decision is however dependent on the resources available in the project. Structural factors like already embedded practices, distributed work practices, decentralization, and short-term task performance that trump long-term learning further impact on the dissemination of new practices in projects.

Previous research and the theoretical framework show the importance of resources and collaborative relationships, and how these are interconnected. Collaborative relationships can provide resources, and the way collaborative relationships are managed depends on the level of resources at hand. Both are important for projects success and the embedding of new practices. These two themes therefore guide the analysis of the empirical data: (1) Resources to work with employment requirements, and (2) Collaborative relationships between the project, parent company, and client.

METHOD

To investigate how practitioners perceive the support from and relationship with their parent company and client when employment requirements are implemented, a qualitative research approach was used. Qualitative research is useful when studying social relations and to capture actions and perceptions and the intricacies of daily life (Silverman 2013). This study includes three different projects where employment requirements were implemented. The first project is a private housing company building new apartments, the second project is a municipality building a new pre-school, and the third project is a corporate group of public housing companies who pose employment requirements on the facilities management departments of their subsidiary companies. These cases were chosen as they had advertised a prominent social procurement profile, making them important to study to see if the work with employment requirements unfolded planned and advertised.

Using a semi-structured approach which allowed for interview flexibility (Kvale 2007), 23 practitioners working in projects were interviewed (see Table 1). The interviewees from the first and second project worked with production on site or closely with implementing employment requirements from the parent company or client. Interviewees from the third project worked with facilities maintenance in different subsidiary housing companies. The majority of the interviewees worked as supervisors for the interns in addition to their formal work role. As such, the interviewees from all projects worked with implementing employment requirements and interns on a daily basis. In each project interns were also interviewed.

The interviews lasted around one hour and were conducted between Dec 2018-May 2019, and focused on topics such as the interviewees' experiences of organizing their daily work with employment requirements and the interns, their resources for doing so, their relationships and collaboration with other actors outside the project, and their overall positive and negative perceptions of working with employment requirements.

To enable a systematic overview of the data it was transcribed verbatim and analysed in the software program NVivo.

Table 1 Information on interviewees

Project	Client	Example of roles	Interviewee codes
1: Apartments	Private	Area manager, project manager, site manager, intern	A1-7
2: Pre-school	Public	Area manager, project manager, site manager, work leader, intern, public procurement officer	PS1-6
3: Facilities Maintenance	Internal (public)	Housing officer working with facilities maintenance of buildings, intern	FM1-10

To allow for unexpected themes to emerge, the data was first inductively and thematically coded (Braun and Clarke 2006). All codes were recorded in order to refine the coding structure, so it reflected the data as accurately as possible. The codes were then organized and analysed according to the two themes identified in the literature on social procurement and project management: (1) Resources to work with employment requirements, and (2) Collaborative relationships between the project, parent company, and client.

FINDINGS

In general, the interviewees describe their new working tasks related to the implementation of employment requirements and taking in interns as difficult to do due to resource restraints and lack of practical and tangible support from the parent company and client. Many interviewees, especially those who work as supervisors of the interns, feel as though they have to solve problems on their own and on an ad hoc basis, and that they were unprepared for their new responsibilities as supervisors. For example, despite having supervisory responsibilities added to their role, some interviewees got no training at all on how to handle these new responsibilities. Instead the projects relied on the previous work experience of the supervisors.

In addition to not being fully trained for their new responsibilities, the interviewees had few forums to discuss their experiences with other supervisors in other projects or subsidiary companies. Many wished that their parent company or client had provided an arena for them to exchange knowledge: “We need to sit down in peace and quiet and talk about what we think and find some best practices. But [the parent company] have not enabled that, unfortunately” (FM4). There had been opportunities for intern supervisors to meet, but these were often described as being few and far between, and that turnout was often poor, for example due to the time where the meetings were scheduled: “In the last supervisors’ meeting it was only two who turned up, and then it is difficult to know what is happening in [the organization]” (FM3).

The interviewees described how resources to prepare for the interns had not been provided. For example, the interviewees expressed a wish to meet the interns before they started to prepare both themselves and the interns for the upcoming internships: “I would like to see them when they are in school, so we get to put a face to them, and they get to put a face to us. They would already have an idea what they are going to work with” (FM4). After the internships ended the problem was a lack of follow up of individual interns: “We work very closely together, the intern is with me all the time, so I think it would be interesting to [know what happens to them afterwards]. To know that this leads somewhere” (FM3). The resources for enabling a continuity for supervisors in relation to their interns was therefore low.

A lack of resources was an often-recurring topic in the interviews, and interviewees representing clients explained the lack of resources and low presence in the project as a result of their lack of knowledge of social procurement. One client representative (A5) said: “Employment requirements are new for us, so it is difficult to know what resources are enough”. The clients were often aware of their shortcomings and tried to make amendments: “We have chosen to have low requirements, because we don’t know if we can live up to them. If we don’t have the internal structure the requirements can become too steep, and I know [the contractor] felt like they didn’t get enough support from the municipality” (PS6). This view is shared by the interviewees: “It doesn’t feel like we’ve gotten very good support [from the parent company], but they haven’t really had the knowledge” (PS4).

Many of the interviewees highlighted a lack of time and knowledge as large resource restraints for working with employment requirements and the interns, and this was further aggravated by a lack of formalized practices. This led to frustration, and the interviewees felt like it negatively impacted on the quality of the internships: “It is our lack of time that constrains how many we can take in, and we also have to get along with our client. Sometimes it feels like we are placating the municipality to have a better chance of getting land allocations, but we want to get away from that and instead emphasize the individual and the good we do for the country” (A2).

To overcome the lack of resources and support from the parent company and client some interviewees have taken an initiative to create tools for the internships that they felt were lacking. For example, one interviewee explained how he created a feedback form to see what he as a supervisor could improve for the next round of interns, and another interviewee had recorded informational film clips about different work tasks: “We have made introductory film clips for [the interns], like what safety gear to wear when you are using a hand mower or a hedge trimmer or a leaf blower and other machines. So, they can watch those before they perform these tasks” (FM2). The interviewees describe how they frequently had to engage in work tasks far beyond their formal work responsibilities, like helping the interns read private emails, answer calls from welfare services, showing them how to pay bills, etc. The reason for these tasks was to make the interns’ private lives function, because if their private lives did not work the internships were said to be negatively affected.

The (lack of) resources allotted to the projects is mirrored in the relationship with the parent company and client, where the interviewees from the project organizations described how they felt detached and isolated from the rest of the project environment. Relationships with the parent company and client is described as tenuous and opaque: “I can’t say anything about the client, it doesn’t feel like they have a specific person involved [in the project], at least I’ve never met anyone” (PS4).

Many of the interviewees, especially from the client and parent company, claim that they want to shape the work with employment requirements together, and that this is a reason for why practices are informal. For example, one client representative (A7) admitted that: “Early on we did not really know what we wanted, instead we just said that this is something which we have to shape together along the way, to discuss what is possible or not, in dialogue with the contractor”. However, the interviewees in the project organization mainly saw a lack of participation in the project from the parent company and client, rather than an opportunity for co-creation. “There has been a lot of engagement, but in the beginning, there was also a lot of frustration that we didn’t know how to practically go about it. And the client also didn’t know and have instead

found some text that they've just 'copy pasted', thinking they're doing a good job. But they're not seeing the consequences of the requirements they pose" (PS1). Some interviewees described that they felt like the client added employment requirements to the contract last minute, leaving the project to handle the aftermath: "There is not a real plan for the project, it's more of an initial requirement from the client" (PS2).

Despite the co-creation the client wished to do with the project, few of the interviewees feel like they could affect the current "model" for implementing employment requirements, and that the model was just delivered in a top-down manner: "Everything just came from above, and then it is delegated down, finally reaching me, the facilities manager. That's just how it is [...] and I don't have anybody further down to delegate to, so I have to deal with it" (FM7). The interviewees describe how they feel detached from top management, and one interviewee who was on the board of the parent company described his attempt as influencing the model as: "Not a lot is happening, and finally you reach a point where you cannot nag anymore, it become uncomfortable, and you can't get any further. You become annoying" (FM4). This is problematic as it could potentially diminish commitment in the projects: "If this is supposed to be a long-term commitment maybe it should be better anchored in the whole organization, so you actually know what is going on and what the results from our efforts are" (FM3).

Much like the relationship with parent companies and clients are perceived to be weak, so is the degree of information sharing and knowledge transfer: "We must have a shared view in the project, with our client, so you speak the same language and want the same things. The important thing is communication and having a common goal" (A2). However, despite that information sharing and knowledge transfer was deemed important by the interviewees, in practice it was often uneven, informal, and not yet routinized: "We have some knowledge transfer, because after each project we make a little report about what we have achieved, with good and bad experiences. We have a person at the parent company who coordinates this, but it is not a self-playing piano" (A2). The informality of information sharing was said to be problematic as it diminished the legitimacy of employment requirements.

DISCUSSION

Previous research emphasize how project success is very dependent on the experience of key project members and clients (Engwall 2003; Walker 2015). Experience can be an important resource, and in this study, it is clear that the lack of experience among both parent companies and clients negatively affect projects' abilities to implement employment requirements. A lack of knowledge and experience also comes into play considering the lack of training for the interviewees working as supervisors of the interns. If training for supervisors would had been standardized this could have provided the projects with better prerequisites to implement employment requirements and integrate the interns in a more effective and efficient manner. Instead, resources related to the management of human resources were a general problem, for example in terms of supervisors not receiving the training or time to fully take on their supervisory role, as well as supervisors often being overexerted and stressed in their working life (c.f. Winch 2014). This is in line with Goel's *et al.*, notion that social sustainability of workers in projects must be more acknowledged.

Previous research suggests that the tabula rasa of each new project could decrease motivation (Packendorff 2002). In this study that was not something which was highlighted by the interviewees; instead the one demotivating factor was said to be the

lack of resources that led to supervisors not knowing what happened to individual interns after the internships ended. Because the sector is reliant on project organizations to implement employment requirements, a lack of motivation amongst operative actors working in the project could be very detrimental to a wider dissemination of employment requirements practices.

One way of overcoming the lack of resources was how the interviewees created tools and practices to facilitate the work with employment requirements and the interns. For example, they went beyond their formal work tasks to help the interns with private matters or make instructional film clips or feedback surveys. In a similar vein, Bresnen *et al.*, (2004) explained how project actors who are affected by new practices, like employment requirements, try to reconstruct and negotiate their meaning. The “above-and-beyond” type of work the interviewees engage in could be an example of them trying to reconstruct their practices in order to accommodate employment requirements, as their parent company and client have not been able to do that for them. However, it is unclear how much reconstruction and above-and-beyond work the project workers can really engage in, considering their lack of resources.

Winch (2014) claim that research often portrays clients as non-strategic actors, and in this study, this seems to be true also in practice. The findings show how clients did not always have a clear plan when posing employment requirements, that they lack knowledge on what resources they need to provide to projects, and that they are detached from the project. In this sense they contribute only financial resources without much managerial skills (at least in terms of implementing employment requirements). Involvement was found to be scarce in all three projects, likely due to their self-confessed lack of knowledge (c.f. Walker 2015).

The lack of knowledge led to an informality of information sharing and knowledge transfer, which in turn created uncertainty for project organizations. Furthermore, potential knowledge which could decrease uncertainty is lost due to good experiences not being formally documented. Looking to previous research, and found in this study, this is then likely also related to the time and resource constraints, which in turn can diminish learning and knowledge transfer between projects (Packendorff 2002; Winch 2014). However, despite that previous research suggests that information needs to be standardized and aligned across organizations (Fulford and Standing 2014), this has not yet been established in the case of employment requirements.

Although it is common for objectives to differ between clients, contractors, and project organizations, aligning objectives is an important part of project management (Walker 2015). The interviewees from this study expressed similar views. However, in the case of employment requirements it does not seem to be a divergence of goals that are necessarily creating problems, but rather that the goals of the client and parent company are unclear. Because clients are unsure of how they want to work with employment requirements, their presence in the projects is scarce, and that in some cases the requirements are a last-minute addition to the contracts, this creates uncertainty that the projects are left to deal with on their own.

Lastly, one major reason for why the interviewees perceive that they do not get enough support from their parent company and client is likely due to the traditional organization of the construction sector. Structural factors like coordination difficulties, weak long-term learning, and decentralisation of decision making (Dubois and Gadde 2002) could explain the detachment the interviewees describe. The detachment between clients, parent companies and projects may ultimately

undermine opportunities for organizations to co-create social value, where social value is instead created only from the bottom with the efforts of the operative actors. This is a missed opportunity for the construction sector. If project members work in isolation, and if the work of the projects is unacknowledged by parent companies and clients, this will surely impact negatively on the motivation of the actors who work daily to implement employment requirements. This could in turn decrease the dissemination of employment requirement practices, and by extension diminish social value for interns.

CONCLUSION

This paper aimed to investigate how practitioners working operatively in individual construction projects perceive the support from and relationship with their parent company and client when implementing employment requirements as a part of social procurement. Findings show how resources and support is lacking, and relationships are often tenuous. Firstly, there is a lack of knowledge and clear goals from the client and parent company which creates uncertainty for the projects. Secondly, the projects have to deal with this uncertainty without formalized routines, standardized knowledge transfer and information sharing, or enough resources. To cope they create their own tools and practices to make their and their interns' work life function.

For theory the findings show that it is not divergent goals among project parties that creates complexity (Walker, 2015), but rather that goals were unclear. Previous research (Erridge 2007; Barraket *et al.*, 2016; Troje and Gluch 2020) have found that social procurement can lead to deeper collaboration between different actors and organizations, but that it is difficult in practice. This study corroborates this but adds insight to why it is difficult, and highlight lack of formalized and standardized routines, informal knowledge transfer and information sharing, and a lack of experience among parent companies and clients as especially detrimental factors. Goel *et al.*, (2020) suggests that future research should investigate current levels of social considerations in procurement processes and identify leadership roles and competencies needed to implement social sustainability in construction projects. The findings do not answer these questions specifically, however, it takes a first step to identify some areas where these aspects are lacking.

For practice the findings illustrate concrete areas where clients and parent companies must rethink their (lack of) resources and support. The study shows how operative workers in the projects becomes demotivated by the lack of follow-up of individual interns, lack of acknowledgment in the parent organization, and inability to affect the “model” for implementing employment requirements. Social procurement, if applied properly, can help build a common good in construction. However, without proper support, resources, and knowledge, social procurement will likely be implemented less effectively and efficiently, and maximum social value might be diminished.

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MODELLING THE COST OF COLLUSION IN THE CONSTRUCTION INDUSTRY: A CASE OF CHINA

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Within the construction industry, bidders tend to collude with each other to increase the probability of winning construction projects. To this end, they need to strike a trade-off between costs of collusion and potential benefits from collusion they adopted, to decide whether to participate in the collusion. In this process, the collusion cost and fine are important indicators for the colluder to decide whether to participate in the collusion. This study aims to develop two models, one model used to predict the collusion cost, and another is used to reveal the actual level of collusion fine. 103 collusion cases from China were collected to test the proposed models by regression analysis. It is found that the two models exhibit an upturned positive tendency with the winning bid price. The average of the ratio of collusion fine and collusion cost always remained the range of 0 to 0.5, and also showed the trend of first rising and then falling. The research findings reveal an important reason for the frequent occurrence of collusion, guide the construction unit to understand the negative impact of collusion and provide decision support for relevant government in supervision.

Keywords: collusion in bidding, collusion cost, fines, China

INTRODUCTION

The construction industry has been identified as the most collusion in the world (Chotibhongs and Arditi 2012). Recent decades have witnessed the proliferation of collusion in bidding (CiB) cases in many developed and developing countries. Such as, in examining the popularity of illegal competition in the construction context, the World Bank (2011) found that 14 out of 29 examined road projects competitions involved CiB. In Japan, the media reported that there was collusion in four major construction enterprises in the struggle for the Central Shinkansen Magnetic Levitation project and disclosed that the total contract size of CiB was about 80 billion USD (Xinhua net 2017). These reports have indicated an urgent situation of CiB in the construction industry.

CiB is mainly manifested in the fact that bidders cooperate covertly to win project competition by means of cooperation, information sharing, collective decision-making, and struggle against independent bidders (Zarkada-Fraser 2000). In practice, the key to CiB operation is that the leading conspirator pay fees to partners to ensure the stability of collusion, which fees called collusion cost. Nevertheless, CiB is risky.

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It may be discovered by owners and competitors and causes their partners to be disqualified for future project competition. If a bidder's collusion behaviour is discovered, the bidder's may be fined with administrative penalties (Marshall and Marx 2009). Therefore, conspirators make the decision carefully by taking account of payment of fees, risk of being identified, and the success rate of the project competition.

The willingness of bidders to join a collusion team depends on the magnitude of both collusion cost and fine. The more considerable the amount of the collusion cost, the stronger the willingness of bidders to attend, and the easier the establishment of a collusion team. However, an increase in either collusion cost or collusion fine confronts the leading conspirator with much more financial vulnerability. Therefore, the collusion cost and fine have to be gauged very cautiously before launching a CiB team. It seems that the collusion cost is a signal for the transaction between collusive members and a proxy for tracking illegal competition in the construction sector.

Due to collusion's complexities, dynamism and uncertainties, very few efforts have been made to quantify the collusion cost and the actual punishment faced by the collusive bidders. Consequently, this study aims to model the collusion cost and fine using data from China's construction industry. The proposed models were established by regression analysis. These models reveal the internal mechanism in organized collusion and provide a basis for subsequent research on the detection of collusion through bidding price.

LITERATURE REVIEW

CiB has many different forms. However, no unique test procedure can detect all collusive schemes (GUPTA, 2001). Many scholars claimed that the CiB is a form of corruption in which two or more market players reach agreements for a fraudulent purpose (Chotibhongs and Arditi 2012). In referring to game theory, Shi *et al.*, (2013) uncovered that two types of CiB cases. One is composed of the client's agents and bidders, while the other is a collusion between bidders only. The CiB undermines the foundation of market competition (Zarkada-Fraser, 2000), and it is one of the most severe violations of the Competition Law (Sichombo *et al.*, 2009). Besides, the CiB is conducive to corrode social welfare in the long run (Dorée 2004;). Perng and Chang (2004) found that collusion cost and fine are fundamental causatives leading to higher bid price from the collusive bidders. Hence, as proposed by many scholars, detection of collusion need to be analysed through bid price (Bajari and Ye 2003; Chotibhongs and Arditi 2012).

Although the emergence of CiB cases is attributable to many reasons, a key factor is the excessive business competition that contractors have been aware of in the construction industry (Shi *et al.*, 2013). Fonseca and Normann (2014) consider that the decision to establish collusion should foremost depend on the gains and costs from cartelization. The collusion cost is determined by some external factors such as competition intensity and economic cycle, suggesting that its prediction is overwhelming. Given the predictability of collusion cost, collusive members would be able to determine bid prices regarding key determinants (Porter and Zona, 2008), and control loss in case that they lose project competition (Kenny 2009). But in fact, a precise calculation of the collusion cost improves the transparency of project competition, which aids both government and the clients to explore practical ways to inhibit collusion (Foster and Méndez 2009; Goel and Nelson 2011).

Owing to CiB is a secret conspiracy, its detection requires extensive police investigation in the form of a collection of legal evidence such as recordings of meetings between collusive bidders and witness testimonies (Bajari and Summers 2002). As an economic measure, fine is often adopted by governments to warn those bidders breaching the law of bidding competition (Allain *et al.*, 2015). Exposure to potential administrative punishment weakens bidders' willingness to make collusion. Therefore, CiB may be less if the administrative penalty increases to the extent to which bidders feel the enormous risks of collusion ahead (Tabish and Jha 2012) Roux (2015) looked at the potential of punishment to inhibit collusion and found that punishment benchmarking cannot mitigate collusion from the construction market. Zhang *et al.*, (2017) argued that CiB cases would be less if legal penalties are adequate. Goel and Nelson (2011) disclosed that bidders could find it easier to collude if the fine is not that much. These works of literature reveal that the study of the current actual fine imposed is of considerable significance to the supervision of collusive behaviour.

METHODS

Data Collection

Data collected from the justice system report facilitate the calculation of collusion cost and improve the accuracy of the measurement (Della Porta 2001) as well as reveal more important collusion details. Uytse (2018) mentions in the study of artificial intelligence algorithm technology and pricing strategy that, the cost of collusion can be estimated through existing legal instruments. While referring to the above theory, the data used in this study was collected from China Judgment Online as a website established by the Supreme People's Court of China. Since 2014, the network has published on the Internet a unified website for the valid judgment documents of people's courts at all levels. In this paper, 103 CiB cases collected using the site's advanced search function.

These cases distributed in different provinces of China, including five types of projects, namely, building construction (52%), municipal engineering (21%), water conservancy and hydropower engineering (9%), highway engineering (8%) and others engineering (11%). Collusion cases release times are mainly distributed between 2014 and 2018. In attaining the objective of this study, a total of three sets of data namely, winning bid price, collusion cost and fine were collected from these cases. A detailed description of the data is shown in table 1.

Table 1: Profile of the samples

Variable	Cost		Standard deviation	
	min.	max.	average	
Winning bid price	150.85	68936.18	6121.67	9097.18
Collusion cost	4.12	1720.00	194.20	299.99
Collusion fine	1.14	270.00	24.57	35.21

Note: The unit of 10,000 yuan (about 1405.13USD)

Regression Analysis

Regression analysis is a statistical method used for estimations or prediction of an examined subject (Powers and Xie 2008). It was used to provide the relationship between two or more variables which have a cause-effect relationship as well as the estimations of unknown facts from known findings (Akçay *et al.*, 2018). As presented above, the relationships between collusion cost with winning bid price and collusion fine with winning bid price were computed using regression analysis, the ordinary

least squares (OLS) approach was adopted for parameters estimation. R^2 was used to determine the explanatory power of the model, T-test was employed to determine the correlation between the coefficients and F-test was used to monitor whether the linear relationship between dependent variables and independent variables significant.

DATA ANALYSIS

Statistical Packages for Social Sciences SPSS 25.0 software was used to draw the scatter plot used to show the relationship between winning bid price and collusion cost (see Figure 1). In figure 1, the independent variable is winning bid price, and the dependent variable is collusion cost. It can be seen from figure 1 that the data show a skewed distribution, which means that they cannot be computed straight for regression analysis. Hence, the logarithmic transformation is required. The data were converted by using the natural logarithm of winning bid price and collusion cost. The results fit the requirement of distribution, and it minimizes the impact of sample outliers on regression estimates. Using the new variables $\ln(\text{winning bid price})$ and $\ln(\text{collusion cost})$ are re-scattered and added the fitting line in figure 2. As can be seen from figure 2, a positive direction of the relationship between $\ln(\text{winning bid price})$ and $\ln(\text{collusion cost})$. Moreover, the equation on the line in the diagrams was obtained using the ordinary least square (see Table 2).

Table 2 The calculated equations

Model	Mathematical equation	R^2
1	$\ln(\text{collusion cost}) = 0.76 \times \ln(\text{winning bid price}) - 1.54$	0.691
2	$\ln(\text{collusion fine}) = 0.6 \times \ln(\text{winning bid price}) - 2.04$	0.642

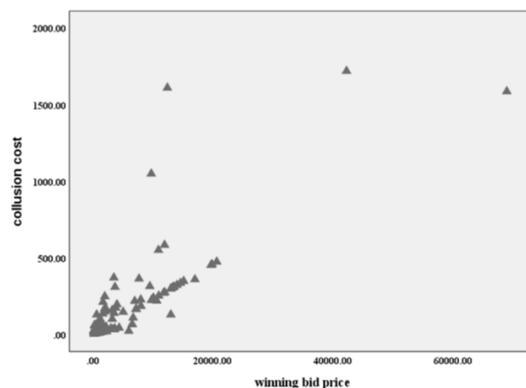


Figure 1: Relationship between winning bid price and collusion cost

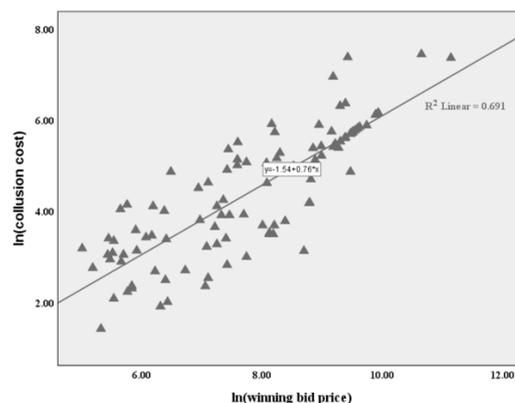


Figure 2: Relationship between $\ln(\text{winning bid price})$ and $\ln(\text{collusion cost})$

The procedure of modelling the relationship between winning bid price and collusion cost is repeated to detect the relationship between winning bid price and collusion

fine. For simplicity, steps for this modelling process are not described here. The scatter plot is shown in figure 3 and figure 4 and the collusion fine prediction equation in table 2.

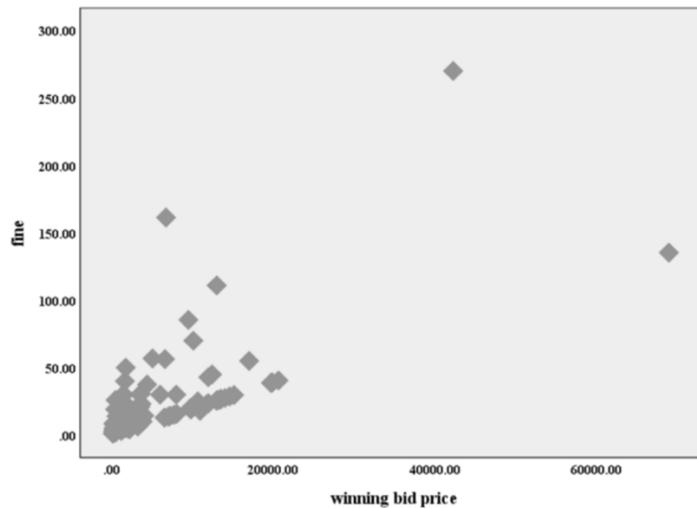


Figure 3: Relationship between winning bid price and collusion fine

Figure 2 and figure 4 all exhibit a positive upturned tendency relationship. In table 3 and table 4, given that the probability value for the T- and F-test statistics have a value less than 0.05 for both evaluation parameters, this led to the rejection of the null hypothesis, which states that the coefficient for the cost of these parameters is zero, and hence this result says that the model is statistically significant at the 95% confidence level. As indicated by the coefficients of R^2 per model, 69% of the variance is explained for the collusion cost (Model 1), and 64% of the variance for the collusion fine (Model 2).

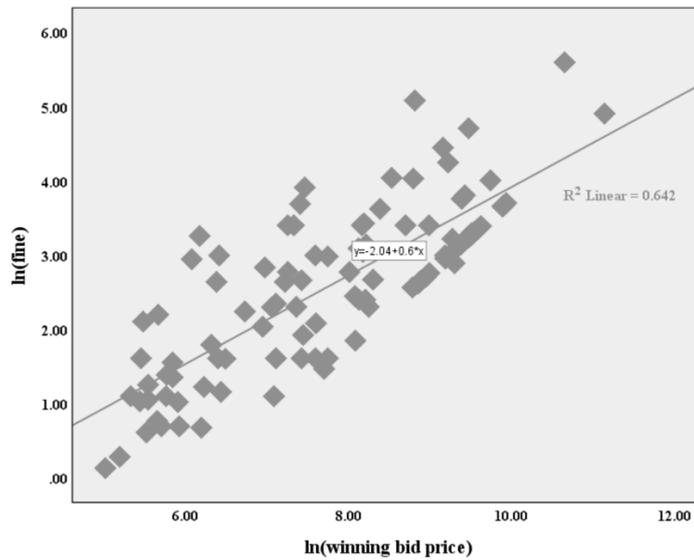


Figure 4: Relationship between \ln (winning bid price) and \ln (collusion fine)

Table 3: Model regression analysis

Model	R	Adjusted R ²	Standard error	R ² variation	F variation	Significant change in F
1	0.831 ^a	0.688	0.765	0.691	225.533	0.000
2	0.801 ^a	0.639	0.666	0.642	181.252	0.000

Table 4: Variables coefficients

Model	Coefficient	standard error	t	Significance
1	constant	0.404	-3.808	0.000
	ln (winning bid price)	0.051	15.018	0.000
2	constant	0.352	-5.811	0.000
	ln (winning bid price)	0.044	13.463	0.000

The relationship between fine and collusion cost is explored using a box plot (Figure.5). First, ln (winning bid price) is divided into five intervals of 5-6, 6-7, 7-8, 8-9, 9-10 from small to large respectively. Second, the ratio of collusion fine and collusion cost is calculated using the mathematical method. Finally, a box diagram is drawn (Figure.5) whereby “×” in each box represents the average of each set of data.

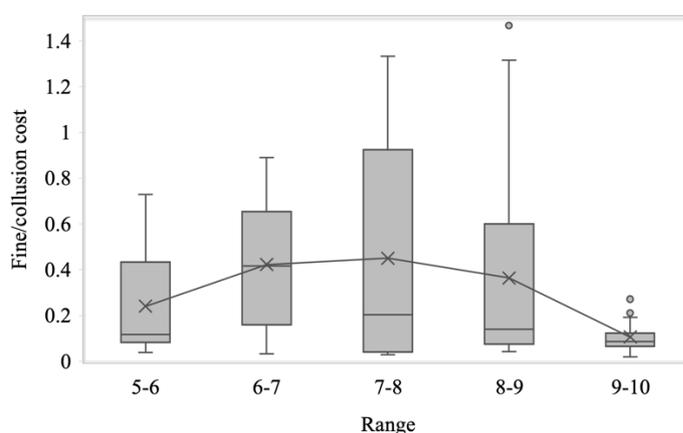


Figure 5: The ratio of collusion fine and collusion cost

FINDINGS

Trends of Collusion Cost

Quantitative analysis of collusion cost and winning bid price was carried out according to the principle of parameter estimation of OLS. It can be seen from figure 2 that, as the winning bid price increases, the collusion cost shows a trend change in the model 1 (Table 2), that is, the collusion cost increases as the winning bid price. The reason is the government will more strictly regulate the project as the project scale increases, and the more likely the conspirators will be found, so the leading conspirators must pay more collusion cost to reach the collusive alliance. Meanwhile, another important reason is the project may bring more benefits as the project scale increases, and the number of enterprises participating in the bidding will also increase accordingly. Therefore, if the leading conspirators want to succeed in the conspiracy, they must ally with more bidders, which will also lead to an increase in the collusion cost.

It is calculated that the adjusted goodness of model 1 is $R^2=0.69$, which means the interpretation degree of the model reaches 69% accuracy. In table 3 and table 4, the t value and F value of model 1 are both less than 0.05, which means that the model passes the test. That is, combined with the above model 1, and the winning bid price can predict the collusion cost. However, if the model is used to predict the collusion cost, the degree of interpretation of the model should be considered to make a correct judgment.

Goel and Nelson (2011) mentioning that the assessment of collusion cost is critical to the development of anti-collusion strategies. Uytse (2018) found that accurate

prediction of collusion cost can contribute to predicting the price of the conspirators' bids. This study is an extension of the above research, the first to analyze the collusion cost from a quantitative perspective. The result was providing a more scientific basis for industry and follow-up research. Besides, the collusion cost development law can give government departments and owners a deeper understanding of the formation mechanism.

Trends of Collusion Fine

The data of winning bid price and collusion fine are analyzed having the same data processing method above to give the result. Fig 4 indicated that, as the winning bid price increases, the collusion fine shows a change in the development trend of the model 2, that is, the collusion fine increases with winning bid price increases.

In the study of anti-collusion competition, a large number of scholars propose to reduce collusion by increase fine (Brown and Loosemore 2015; Oke *et al.*, 2017; Tabish and Jha 2012; Zhang *et al.*, 2017). However, none of the above studies systematically studied the intensity of fine from a quantitative perspective. Although it is possible to deduce the scope of the fine by the winning bid price through the punitive measures of the collusion in the bidding law formulated by the government department, the scope can't reflect the actual punishment of the government for CiB. This study used the collusion fine and winning bid price data in the court judgment paper and conducted a quantitative analysis of the relationship between the two. The assessment model 2 (Table 2) and the law of change (Figure 4) are between winning bid price and collusion fine, which can provide a more reliable basis for government departments, provide a reference for them when formulating punitive measures, and realize the transition from theoretical research to practical research.

Trends of the Ratio of Collusion Fine and Collusion Cost

The collusion fine represents the cost that the collusion violates in a certain social system environment, reflecting a social attitude. The relationship between \ln (winning bid price) and the ratio of collusion fine and collusion cost is explored above using a box plot (Figure 5). It can be seen from figure 5 that as \ln (winning bid price) increases, the average of the ratio of collusion fine and collusion cost increase first and then decrease, but it always remained the range of 0 to 0.5. Meanwhile, when \ln (winning bid price) reaches 9-10, the average of the ratio of collusion fine and collusion cost is only 0.1059, which indicates that the collusion fine only accounts for about 0.1 times the collusion cost.

In the collusive process, the conspirators will be subject to a fine only when the collusion is discovered. However, conspirators are negotiated in secret, and it isn't easy to find. Therefore, when the supervision is not stronger before the conspirators make decisions, the first consideration is the size of the collusion cost. From a psychological point of view, if the conspirators are willing to pay the collusion cost, and if the regulatory authorities discover the collusion in the later period, they only need to pay a lower fine and the probability of being found is extremely low. More bidders are willing to participate in the collusion. From figure 5, the penalty is only 0-0.5 times the collusion cost, so when the supervision is not strict, more bidders are more inclined to participate in collusion. This study believes that the fines at this stage are lower and do not reach the deterrent effect.

The relationship between collusion fine and collusion cost was discussed using 103 CiB cases. It can be judged that the ratio will fluctuate with the changes in the

institutional environment and the stage of economic construction, but the overall is maintained at a level. When considering the broader or more national institutional environment and economical construction stage, it can be estimated that the ratio of the collusion fine and the collusion cost varies. Still, the overall level will remain at a certain level. The main reason is that society always has standards for specific violations or behaviours. Another reason is that collusion fine and collusion cost are positively related to the winning bid price. Therefore, this requires policymakers to pay attention to creating an excellent institutional environment, paying attention to the issue of penalty intensity standards when the punishment for collusion. This research was filling the latest evidence for the study of the relationship between the collusion fine and collusion cost.

CONCLUSION

This research attempts to explore the models of collusion cost and collusion fine in bidding. Regression analysis results show that as the winning bid price increased, the collusion cost and fine continued to increase, and the predictability of collusion cost and fine were given. When discussing the relationship between winning bid price and the ratio of collusion fine and collusion cost, it was found that the average of the ratio was always between 0 and 0.5, which means that the fines at this stage are lower and do not reach the deterrent effect.

The research findings contribute to providing a new perspective on the construction industry towards collusion cost and fine's linear analysis. Meanwhile, the research findings reveal the changing rules of collusion cost and collusion fine, it guides the construction industry to understand the negative impact of collusion fully and also provide decision support for relevant government departments in bidding supervision, formulating anti-collusion strategies and related punishment measures. In addition, the ratio of collusion fine and collusion cost can be used as a research benchmark, which will help to later study the collusion cost and the intensity of punishment in the anti-collusion behaviours.

Despite these contributions, this study has its limitation. This research gives the prediction models of collusion costs and fines from the perspective of economics. However, these models cannot be directly applied to collusion monitoring, and can only provide a theoretical foundation for subsequent collusion research.

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DOES P3 FAVOUR LARGE COMPANIES? FROM EQUITY FINANCING TO SOCIAL EQUITY

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Ensuring equity in contracting participation is of critical concern to transportation agencies. In the US, federally funded projects have goals of participation from firms owned by socially and economically disadvantaged individuals, and the initiative is the Disadvantaged Business Enterprise (DBE) program. While the requirements apply to any delivery methods, public-private partnership (P3) - often featuring a big size Design-Build (DB) contract, equity financing, and a long concession period - has received particular attention. There is an argument that P3 disproportionately benefits large companies compared to other delivery methods. Admittedly, limited design in the procurement stage creates challenges in enlisting specific DBEs in the proposal. Promoting DBE participation, on the other hand, is DBE performance plans, which many agencies require as a bid submittal to ensure adequate commitments and good faith efforts. Thus, whether P3 makes a difference in the execution of the DBE program warrants an empirical evaluation. This study examined 134 contracts from the US Major Transportation Project Database on four metrics: DBE goal, DBE commitment, DBE attainment, and DBE performance. The Kruskal-Wallis tests were performed on both DBE goal and DBE performance. The mean DBE goals are significantly larger for P3 and DB/Construction Manager at Risk (CMAR) than Design-Bid-Build (DBB). However, there is no significant mean difference for DBE performance among DB/CMAR, DBB, and P3. Among the different types of P3, DBFOM shows the greatest good faith efforts, due in part to the developer's high-level involvement. The authors recommend using a graphical tool called DBE envelope to help visualize DBE efficacy and performance.

Keywords: disadvantaged business enterprise, PPP, equity, performance

INTRODUCTION

Addressing disparity surrounding race, gender, and ethnicity is of critical value to governments (Ricucci 2009). Increasing economic diversity fosters innovation (Stirling 1998) and workforce stability, among other benefits (Myers 2011). Hence, government procurements, especially of transportation projects, have embraced social equity, whose initiatives range from environmental justice in minority and low-income populations and equal employment opportunity to equitable contracting opportunity (Sanchez *et al.*, 2003). One of the programs tackling social equity in contracting is the Disadvantaged Business Enterprise (DBE) program of the US Department of Transportation. The DBE program originated from Title VI of the Civil Rights Act of 1964 and, through a series of laws, executive orders, and

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regulations, has developed into its present form (Gendell *et al.*, 1990). The Surface Transportation and Assistance Act of 1982 officially created the federal program to ensure at least 10% of the federal funds be allocated to minority-owned firms (Brown 1990). In 1987, the Surface Transportation and Uniform Relocation Assistance Act added women-owned businesses into the 10% aspirational goal. To support federal compliance, state transportation agencies (STAs) administer their own DBE programs.

Although the DBE requirements apply to any delivery methods, public-private partnership (P3) has received particular attention. P3 is an integrated delivery approach where the private sector firm performs a combination of services involving design, construction, finance, operation, and maintenance for a specified concession period (Perez 2016). P3 has embraced popularity in the US. As of August 2018, 36 states, plus the District of Columbia and Puerto Rico, have passed P3 authorizing legislations (FHWA 2018a). Because P3 usually entails a sizable Design-Build contract and a long concession period, it may seem that P3 favours large companies. The claim is not without merit, considering the contract documents on which proposals are based have only minimal design. Hence, it is difficult for the proposers to identify enough DBE subcontractors with binding quotes upon awarding the prime contract. However, the potential shortfall of DBE participation can be made up with the help of DBE performance plans detailing compliance strategies. There is no published literature on the impact of delivery methods on DBE participation, which this paper intends to investigate.

DBE PRACTICE REVIEW

DBE goal setting

The US Department of Transportation administers its DBE program in accordance with Title 49 Code of Federal Regulations (CFR) Parts 23 and 26 (FHWA 2018b). The regulations require an STA receiving federal-aid funds to set triennially an overall goal that is reflective of the DBE availability of the state. In some cases (usually for megaprojects), an STA may set up a project goal that is calculated and monitored separately from the overall goal. Additionally, if an STA finds that the overall goal cannot be met through exclusively race-neutral means, the agency may use a contract goal. The race-neutral measures, as delineated in 49 CFR § 26.51, represent customary acquisition procedures - such as providing technical and management assistance - that foster DBE participation in prime contracts. Subcontract awards to DBE firms in excess of the overall goal or on prime contracts without a DBE goal also constitute race-neutral participation. Race-conscious participation, in contrast, involves the use of contract goals and, in rare cases, set-asides for socially and economically disadvantaged firms (Keen *et al.*, 2015). STAs should be cautious about using contract goals arbitrarily, in light of the Ninth Circuit decision in *Western States Paving Co. Inc. v Washington State Department of Transportation* [2005], where the court ruled the use of the contract goal inappropriate. The decision prompted FHWA to call for a suspension of the use of contract goals for the STAs in the Ninth Circuit until evidence supporting the existence of a discriminatory market can be furnished (FHWA 2018c). Another seminal case, *City of Richmond v J. A. Croson Co.* [1989], established the strict scrutiny standard to assess the constitutionality of a race/gender classification program authorized by state and local governments. The strict security test validates the use of contract goals to the extent that statistical and anecdotal evidence of disparity can be demonstrated between the utilization and availability of minorities. In *Adarand Constructors, Inc. v. Peña* [1995], the court extended the strict scrutiny standard to the DBE program.

Setting overall goals typically involves two steps. Step 1 calculates the value-weighted relative availability of DBEs that are ready, willing and able to perform. Step 2 is the adjustment of the Step 1 base figure considering past DBE participation, evidence from disparity studies, the ability of DBEs to get financing, bonding, and insurance, etc. (FHWA 2014). Then, the public is asked to provide comments on the draft goal-setting methodology. Contract goal setting involves identifying the portion of the contract that can be subcontracted to DBEs before contract letting (Brown 1990). When developing contract goals for projects using alternative contracting methods, incomplete information of work items due to incomplete design is a challenge. Other sources of complexity include proper adjustment of the goal for concurrent projects in the region, the long duration of the DB contract, aligning request for proposal language with the goal, and conveying the DBE program expectations to bidders (Keen *et al.*, 2015; Amekudzi-Kennedy *et al.*, 2016). Consequently, some STAs require a DBE performance plan detailing the contractor's/developer's will and ability to engage DBEs in the bid submittals. Such a plan typically includes specific DBEs for design activities, potential subcontracting opportunities for DBEs, a schedule to identify those DBEs, and procedures entailing commercially useful function validation, termination of DBEs, and prompt payment of subcontractors, etc. And the plans are sometimes scored in the evaluation of the proposals. Also, setting subgoals (e.g. isolating design from construction), unbundling work packages to create subcontracting opportunities, and more communication between the DBE staff and the project planner are best practices bolstering DBE utilization while related to goal setting (Ashuri *et al.*, 2019). For Construction Manager at Risk (CMAR) projects, goal setting can wait until the award of the construction contract (Keen *et al.*, 2015). It is worth noting that states are different in terms of setting one or two goals for design and construction in a DB project or the DB portion of a P3 project. There are only a handful of states that set DBE goals for the operation phase of a P3 (Smith *et al.*, 2019).

DBE commitment

The FHWA (2018b) encouraged agencies and proposers of contracts using alternative contracting methods to conduct meaningful (not pro-forma) outreach to and training for DBEs. Agencies' outreach allows early identification of DBEs for pre-award professional services and a larger pool for potential DBEs of different construction trades. Contractors can use the pool to find suitable DBEs quickly. Kyle *et al.*, (2013) reported that agencies' outreach to and one-on-one consulting with DBEs are the most effective strategies to promote DBE participation. These resources and activities help bidders submit - upon or immediately after contract award - a list of DBEs to be included in the contract. This list, along with documentation in support of efforts enlisting DBEs, becomes DBE commitment. For this research, DBE commitment is the percentage of contract value that the winning bidder says would be apportioned to DBEs relative to the value of the prime contract. If a bidder cannot identify enough DBEs to meet the contract goal, they must show good faith efforts to solicit DBEs.

Good Faith Efforts

Furnishing the documentation required to show earnest solicitation of DBE subcontractors is the core of pre-award good faith efforts. The idea of pre-award good faith efforts is a balance between fostering DBE participation and Adarand's spirit of surviving the strict scrutiny, which effectively sets an upper bound for goals (Bruce *et al.*, 2015). Post-award good faith efforts relate to terminations and substitutions of

DBEs. Contractors/developers who committed to contract goals cannot terminate a DBE subcontractor barring a good cause and a proper notice. When substituting a terminated DBE, the contractor/developer should exercise good faith efforts to find another DBE to perform at least the same amount of work. Monitoring and documenting good faith efforts are necessary to hold accountable the contractor/developer making DBE commitment. Federal regulations (49 CFR§ 26.53) require the contractor/developer to provide sufficient documentation showing that good faith efforts were spent to meet the contract goal.

DATA AND METHODS

This research aims to examine the performance of the DBE program through evaluating at the contract level four metrics. A DBE goal is the DBE share of the contract value that the agency expects to achieve on the contract. The goal may or may not be a contract goal. DBE commitment is what the winning bidder committed to achieving upon or immediately following contract award. DBE attainment is the actual DBE participation at project completion. This paper introduces a fourth metric - DBE performance. The metric is the growth of DBE participation from what is committed to the actual achievement, hence, a measure of post-award good faith efforts. Mathematically, DBE performance is the quotient of DBE attainment and DBE commitment minus one ($\frac{\text{DBE Attainment}}{\text{DBE Commitment}} - 1$). The data collection is part of the research team's effort to build the US Major Transportation Project Database, which houses detailed project life-cycle data ranging from cost and schedule to change orders and claims. The database collects DBE goal data from requests for proposals or invitations for bids. If a project has separate design and construction DBE goals, then only the construction DBE goal is taken into account, because design DBE goal is a proportion of the total design contract value, which is not available. DBE commitment is the committed DBE participation that appears in construction contracts or public-private agreements. The percentage, if not reported, is taken the same value as the DBE goal for the purpose of the analysis. For P3 projects, the authors consider only the design and construction portion since few projects have DBE goals for the operation phase. One project that reports DBE goal and commitment for operation and maintenance work is Transform 66 - Outside the Beltway in Virginia. However, the actual DBE participation was reported in the early stage of construction, thus not a valid DBE attainment datum. In fact, 37 federal-aid projects from 13 states have valid data for DBE attainment. Another 97 projects have only DBE goal and DBE commitment data. Thus, a total of 134 prime contracts representing 22 states comprise the dataset for analysis. Project size ranges from \$2.7 million (I-74 Iowa-Illinois Corridor Reconstruction Project Phase 2 - Iowa Ramp and Mainline Storm Sewer) to \$3.1 billion (Tappan Zee Bridge Replacement in New York), with a mean of \$365.3 million and a median of \$120.4 million. The numbers of projects for DB, CMAR, Design-Bid-Build (DBB), Design-Build-Finance (DBF)/Build-Finance (BF), Design-Build-Finance-Maintain (DBFM), Design-Build-Finance-Operate-Maintain (DBFOM), and Design-Build-Maintain (DBM) are 25, 2, 76, 4, 2, 17, and 8, respectively. The numbers of projects with all three metrics - DBE goal, DBE commitment, and DBE attainment - are 11, 1, 12, 1, 11, and 1 for DB, CMAR, DBB, DBF/BF, DBFOM, and DBM, respectively.

The authors compared the averages of DBE goal, DBE commitment, DBE attainment, and DBE performance among DB/CMAR, DBB, and P3, and among the different varieties of P3. Since the metrics are all ratios that depend on contract values, two

types of means were considered: simple average ($\frac{1}{n} \sum_{i=1}^n z_i$) and value-weighted average ($\frac{\sum_{i=1}^n x_i}{\sum_{i=1}^n y_i}$), where $z_i = \frac{x_i}{y_i}$. Besides, the authors subtracted from a DBE goal the overall goal when the DBE goal was set to isolate the state effect. The resulting difference is called adjusted DBE goal. The authors were able to find the historical overall goals for 91 contracts. Group means of adjusted DBE goal and DBE performance were compared with respect to the delivery method. By the Levene's test, the group populations of adjusted DBE goal have the same variances at the 0.05 level of confidence ($F = 1.506$, $p = 0.002$). The Kolmogorov-Smirnova test suggests that the residual for adjusted DBE goal is not normally distributed ($KS = 0.094$, $p = 0.045$). Upon examining the residual's kurtosis, the z-score is 2.86, hence more evidence of non-normality. Therefore, the Kruskal-Wallis test is proper to check the mean ranks of adjusted DBE goal. For non-parametric multiple comparisons, it is customary to use the Dunn's test with the Bonferroni correction. Similarly, for DBE performance, the variances in the three groups are equal (Levene's $F = 2.242$, $p = 0.122$), but the residual distribution is not normal ($SW = 0.912$, $p = 0.006$). Again, the Kruskal-Wallis test was performed on DBE performance (Lomax and Hahs-Vaughn 2013).

FINDINGS

Without adjusting for the overall goal, DBB has the smallest DBE goal in terms of both the simple average (8.0%) and the value-weighted average (10.0%), compared to DB/CMAR (simple average = 12.7%, value-weighted average = 12.0%) and P3 (simple average = 10.0%, value-weighted average = 10.3%). The simple and value-weighted averages of adjusted DBE goals have the same ranking - that DB/CMAR (1.0%, 1.1%) is larger than P3 (-0.9%, -0.6%), which is larger than DBB (-3.9%, -3.5%). Further, for adjusted DBE goal, the mean ranks of DB/CMAR (62.97) and P3 (54.75) are significantly larger than DBB (35.25), as shown in Table 1. An explanation is that for alternative project delivery methods, there are few pre-award contracting opportunities for professional services due to the agency's minimal design, and those contracts could have gone to DBEs. To compensate for the lost DBE participation, STAs tend to aim for higher contract goals for DB, CMAR, and P3, relative to DBB. Figure 1 plots the DBE goals of the 134 projects with respect to the delivery method and the contract value.

Table 1: Mean rank comparison result for adjusted DBE goal

Kruskal-Wallis Test			Dunn's Multiple Comparison Test		
N	Chi-Square	p		Statistic	p
91	15.278	< 0.001	DBB - P3	-19.542	0.008
			DBB - DB/CMAR	24.375	0.003
			P3 - DB/CMAR	4.833	1

For DBE performance, the Kruskal Wallis test result ($\chi^2 = 0.447$, $p = 0.8$) suggests that the mean ranks are not statistically different among DB/CMAR (18.08), DBB (18.17), and P3 (20.62). In the 37 projects with DBE attainment data, P3 is the largest in terms of both simple average (26.3%) and value-weighted average (32.8%). The second in the rank is DBB by the simple average (21.5%) and DB/CMAR by the value-weighted average (10.3%). Consequently, the simple average has DB/CMAR (8.7%) third in the rank, and DBB ranks third by the value-weighted average (4.8%). The reason why DBB ranks lower by the value-weighted average is that the contract

size tends to be smaller for DBB, considering the mean contract values are \$729.3 million, \$178.2 million, and \$1.2 billion for DB/CMAR, DBB, and P3, respectively. Figure 2 shows the distribution of DBE performance by the delivery method. It is comforting to know that, on average, DBE goals were satisfied for all three groups. More importantly, developers in P3s spend no less good faith efforts in retaining DBEs than do contractors in the other delivery methods. This is due in large part to DBE performance plans and the continued documentation and periodic reporting of the good faith efforts, which help meet the goal. Another explanation is that because the developer signed up for a long-term relationship with the STA, they are more motivated to impress the owner by demonstrating good faith efforts.

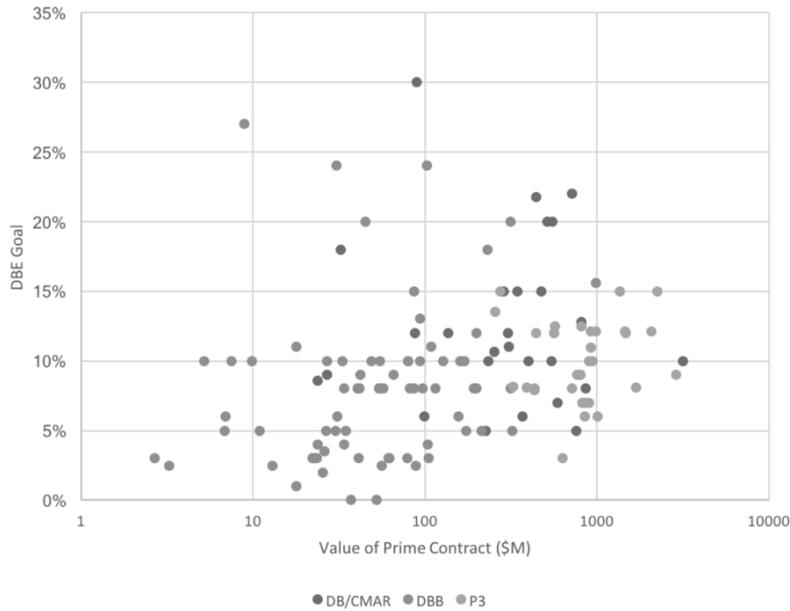


Figure 1: Distribution of DBE goal

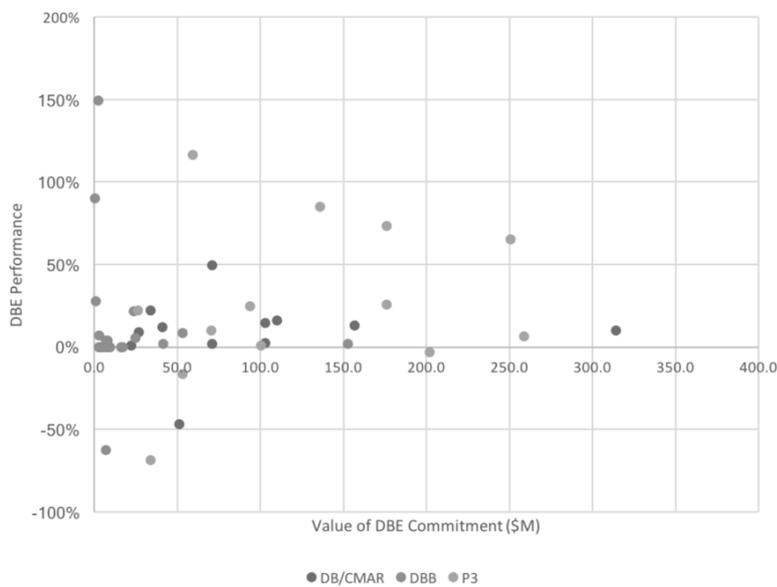


Figure 2: Distribution of DBE performance

To better understand and characterize a DBE program, the authors developed a visual tool called the DBE envelope. This radar plot shows the goal, commitment, and

achievement of DBE participation. An equilateral triangle means that the contracts have committed exactly to the goal and accomplish exactly what had been committed. Figure 3 suggests that DBFOM (10.9%) and DBM (10.9%) are larger for the DBE goal than DBF (7.9%), which has only one project - the iROX in Florida. The DBE goal for iROX is lower than the overall goal (8.12%) when the project was put out for bid and the value-weighted average DBE goal for all P3 projects (8.6%) in the state, which uses 100% race-neutral measures. The gradient of the right boundary represents the DBE performance, i.e., post-award good faith efforts. The slope of the left boundary embodies the efficacy of the program - defined as $(\frac{\text{DBE Attainment}}{\text{DBE Goal}} - 1)$. DBE efficacy captures both the pre-award and post-award good faith efforts. The level of post-award good faith efforts - calculated using the value-weighted average - is the greatest for DBFOM (37.2%), followed by DBM (0.8%), then DBF/BF (-68.4%). So is the steepness of the right boundary in Figure 3. Similarly, the ranking of the mean DBE efficacy from high to low is DBFOM, DBM, and DBF/BF. It is not surprising that DBFOM relates to the greatest post-award good faith efforts because the developer has the most involvement in this type of contract. The fact that DBE performance is overall - albeit not significantly - larger than DB/CMAR and DBB suggests that the level of involvement could play a role. Although the rankings of the mean DBE goal and the mean DBE performance are not representative of the populations, DBE performance carries more weight because it has, by definition, accounted for the DBE availability.

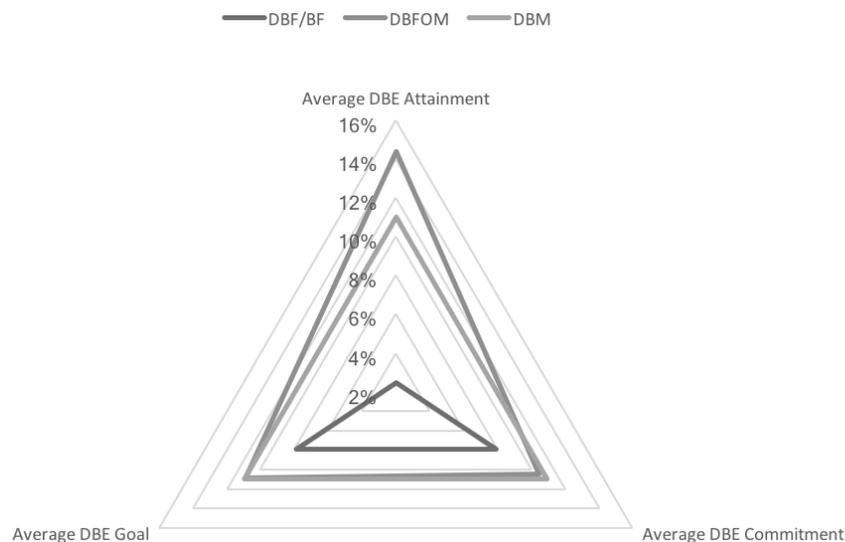


Figure 3: DBE compliance for different P3 types

It is reasonable to rid the metrics of the state effect when comparing contracts from different states. Such is the case with the DBE envelope in Figure 4, where a comparison of DBE participation between DB/CMAR and P3 among three states was made. In terms of value-weighted average DBE goal, Texas (12.1% vs. 12.8%) and Florida (8.6% vs. 15.0%) are lower for P3 than DB/CMAR. P3 also underperforms DB/CMAR for Texas (10.8% vs. 12.8%) and Florida (8.6% vs. 15.0%) for the simple and value-weighted average DBE commitment. The DBE attainment value-weighted averages are larger for P3 than DB/CMAR for all three states in the comparison: Texas (18.8% vs. 14.6%), New York (12.5% vs. 11.0%), and Florida (10.7% vs. 8.0%). P3 is also consistently larger than DB/CMAR for the value-weighted average DBE performance in Texas (74.3% vs. 14.3%), New York (24.7%

vs. 10.0%), and Florida (25.2% vs. -46.7%). These results follow the previous observations that - despite trivial difference, P3 is associated with lower goals and greater post-award good faith efforts than DB/CMAR. This finding is clear of the effect of DBE availability, a component of the state effect. Another component is the agency's approach to using contract goals for alternative project delivery methods. Procedures differ in such areas as the inclusion of the DBE language in the request for qualifications, the timing of commitments, and the use of DBE performance plans (Keen 2015).

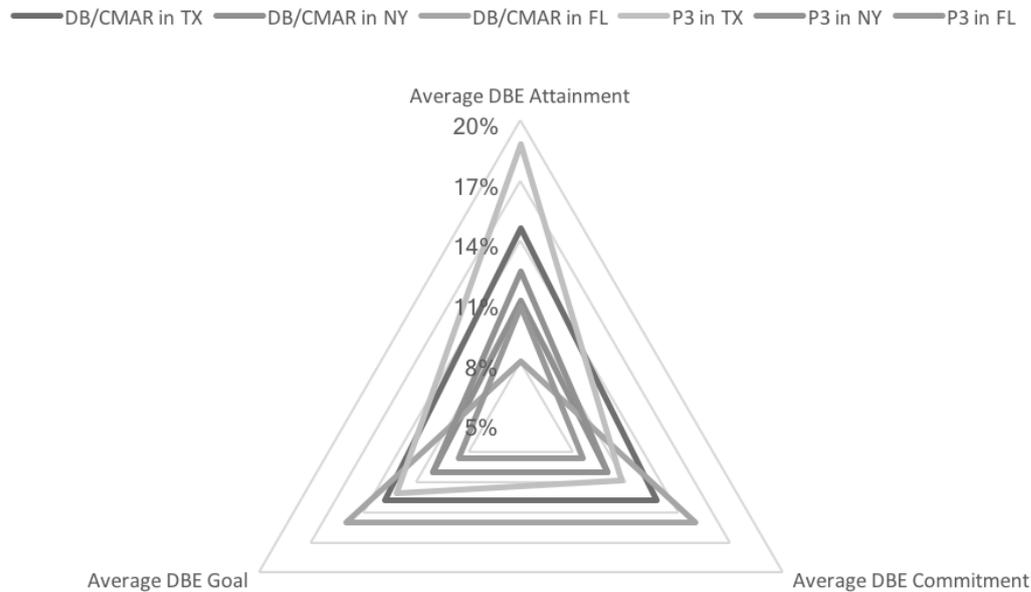


Figure 4: State DBE compliance for DB/CMAR and P3

CONCLUSION

While P3 has garnered increasing interests among transportation agencies in the US, opponents raise suspicion that taxpayers' money goes disproportionately to large companies in the P3 market, compared to other delivery methods. This paper provides empirical evidence on whether P3 discourages the participation of minority firms, which concerns race-classification programs. The DBE program under the US Department of Transportation regulates how federal-aid funds are distributed to certified DBEs through race-neutral and race-conscious measures. The former relies on customary contracting procedures to meet the overall goal, whereas the latter refers to compliance requirements when contract goals are involved. A P3 - due to its large size - bears vast significance in terms of DBE participation and can be treated differently when setting a goal. Despite challenges such as design uncertainties that render a complete DBE list improbable, state agencies have devised such strategies as creating sub goals for design and construction and requiring the use of DBE performance plans.

The authors collected data on three metrics - DBE goal, DBE commitment, and DBE attainment - from the US Major Transportation Project Database. A fourth metric, DBE performance, was calculated to measure the level of post-award good faith effort. The dataset contains 134 contracts, in which 37 have DBE attainment data. The dataset was processed to find if the project delivery method affects the DBE goal and DBE performance. It turns out that the mean DBE goal is larger for P3 and DB/CMAR than DBB at a significance level of 0.05. Comparatively, there is no

significant mean difference in DBE performance for the three delivery method groups. DBFOM shows greater good faith efforts compared to other P3 types, due in part to the developer's high-level involvement. The results refuted the claim that P3 favors large companies. When comparing the averages, the authors found the DBE envelope handy to visualize DBE efficacy and performance, which defined the slopes of the left and right boundaries.

Despite a small dataset, this research is exploratory in asking the question and produce valid results that the extant literature fails to report. Future research could use more data to validate these findings and perform a regression analysis to identify more predictors that influence the DBE goal or DBE performance. Moreover, an investigation of the federal regulations governing the DBE program in relation to DBE performance is intriguing and promising.

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BUILDING FOR THE COMMON GOOD

INTEGRATED PROJECT DELIVERY (IPD): PROJECTING A COMMON GOOD TO KEY PARTICIPANTS AND THE PROJECT

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Construction project efficiency is enhanced when the success of key participants is related to the project. This depends on the project delivery method chosen. However, Integrated Project Delivery (IPD) often results in improved project efficiency. There is however an extensive literature on IPD but there is a dearth of research that seeks to provide evidence on its potentials in projecting a common good. Therefore, the aim of this study is to identify the potentials in IPD towards projecting a common good to key participants and the project. The study employed quantitative research approach and used structured questionnaires for data collection. A total of 127 respondents representing 56% response rate out of a sample of 229 participated in this study. This includes construction site supervisors, engineers, quantity surveyors, architects, project managers and managing directors in the construction industry. A pilot study was conducted to determine the validity and reliability of the survey instrument. Assessment of factors in the questionnaire was based on a five-point Likert scale. The scores were transformed to importance indices using Relative Importance Index (RII) to establish the significance of both contractual and behavioral principles of IPD including the significance of early involvement and collaboration of key participants in a project delivery towards projecting a common good. The study provides empirical evidence and significant insight into how IPD has the potential to project a common good to key participants and the project. It is the first of its kind to explore the common good that is inherent in the implementation of IPD in construction project delivery. However, a further research is recommended to build on the current study by considering a case study to further establish the extent of a common good of key participants in implementing an IPD project in the construction industry.

Keywords: common good, IPD, key participants, project delivery

INTRODUCTION

The project delivery method chosen significantly influences the efficiency of the project (Hamzeh *et al.*, 2019). It also determines the success of the project. There are many project delivery methods in use in the construction industry. However, the Traditional Project Delivery (TPD) methods which includes Design Bid Build (DBB), Design and Build (D&B) and Construction Manager at Risk (CM@R) are the widely used methods across the world (Harper *et al.*, 2016; Mesa *et al.*, 2016; Nawi *et al.*,

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2014). These methods have proven not to project the common good of key participants (owner, designers and constructors) due to lack of collaboration or integration throughout the project particularly at the design stage which often leads to project inefficiency (Harper *et al.*, 2016; Mesa *et al.*, 2016; Nawi *et al.*, 2014).

Common good as used in the context of this study refers to the satisfaction of all key participants (owner, designers and constructors) in relation to the success of the project. This is based on the principles of integration and collaboration in IPD. However, Argandoña (1998, p. 1095), defined common good as “everything that is good to more than one person, that perfects more than one person, that is common to all”. Garay (2015, 46-47) also defined the term as “the attainment of material conditions for the development of a joint activity or the coordination of actions so that the result of the joint activity is achieved including each member's own personal development” based on an earlier definition by Finnis (2011).

Integrated Project Delivery (IPD) on the other hand has the potential of reducing the weaknesses in the TPD methods, leads to improved project performance (Mesa *et al.*, 2016), and ensures better collaboration and integration between participants (Hamzeh *et al.*, 2019; Fish, 2011; Raisbeck, Millie and Maher, 2010). A good collaboration has the potential of projecting a common good of key participants and ensuring project success. It is on this premise that IPD was born into the construction industry (El-Asmar, Hanna and Loh, 2013; AIA and AIACC, 2007).

However, despite the broad range of literature on IPD, there is a dearth of research that seeks to provide evidence on the potentials of IPD in projecting a common good. Therefore, this study sought to provide empirical evidence and significant insight into the potentials of IPD towards projecting a common good to key participants and the project. The relevant literature review is presented in the next section.

LITERATURE REVIEW

The widely used project delivery method in the construction sector is the TPD methods, which have been widely criticized in the industry for lack of integration or collaboration to project delivery (Harper *et al.*, 2016; Mesa *et al.*, 2016; Nawi *et al.*, 2014). In defining these TPD methods Mesa *et al.*, (2016) and Fish (2011) indicated that with “DBB”; the owner enters into separate contracts with the designer and the contractor while with the “DB”; a single contract is signed by the client with the design-builder who is a single firm that performs design and construction. With the “CM@R”; the construction manager is hired early in the process to deliver an early cost commitment and to manage issues of schedule, cost, construction and building technology (AIA and AIACC, 2007). This is similar to IPD but lacks the extent of collaboration and integration (Mesa, *et al.*, 2016; Fish, 2011).

These delivery methods do not project the common good of key participants therefore has consequences of projects being completed behind schedule, to poor quality and over cost (Mesa *et al.*, 2016). Others include project reworks, lack of communication and coordination, wastages, conflicts and misunderstanding between project participants (Nawi *et al.*, 2014; Nawi *et al.*, 2012; Kamar and Anuar, 2011; Nawi, Lee and Nor, 2011). Therefore, efforts towards improving the processes involved in the project cycle to enhance efficiency are very paramount in project delivery. There is the need for process and team integration throughout the project since these are key drivers of change necessary for the industry to become more successful (Nawi *et al.*, (2014).

There are numerous definitions for IPD however, American institute of Architects (AIA) and American Institute of Architects California Council (AIACC) define it as a “project delivery approach that integrates people, systems, business structures, and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction” (AIA and AIACC, 2007, p.1). El-Asmar, Hanna and Loh (2013) also defined it as a project delivery method distinguished by a multi-party agreement with an early involvement of key project participants. IPD offers improvements over existing TPD methods since it promotes a more collaborative or integrated approach between project participants (Hamzeh *et al.*, 2019; Fish, 2011; Raisbeck, Millie and Maher, 2010). It contributes significantly to the success of a project and enhances integration (Nawi *et al.*, 2014). It has the potential to provide better performance to meet owners’ expectations (Mesa *et al.*, 2016). A key reason for which IPD was introduced into the construction industry is because the TPD methods suffer because participant success and project success are not necessarily related (AIA and AIACC, 2007).

In IPD, project participants have an interest in the success of the project and will do what is in the interest of the project (Fish, 2011) thereby projecting a common good. IPD comprise a multidisciplinary team of professionals bound together by alternative forms of agreement that require team members to share risk and reward, contribute equally, and employ alternative processes and technologies, aimed at improving project efficiency (Ilozor and Kelly, 2012). This concept generally begun from the US in which the project participants collaborate to develop a project from the initial concept to the handing over (Nawi *et al.*, 2014). The “Big Room” concept which is a core aspect of IPD allows key participants to collaboratively work in the same room to discuss, define and plan the sustainability and cost goals for the project (Jones, 2014).

An IPD project allows key participants to all sign one contract (multi-party contract) with the aim of eliminating separate motives and contracts that exist within the TPD methods (Becerik-Gerber and Kensek, 2010; AIA and AIACC, 2007). This principle drives the key participants to work towards a set of common goals (Nawi *et al.*, 2014) by tying their success to project success (Jayasena and Senevirathna, 2012; AIA and AIACC, 2007) thereby achieving a common good. The level or degree of collaboration in an IPD project renders it as a philosophy or as a delivery method (Jayasena and Senevirathna, 2012; NASFA, COAA, APPA, AGC and AIA, 2010). IPD as a philosophy is when integrated practices are applied to TPD approaches without a multi-party contract. On the other hand, IPD as a delivery method is when a multi-party contract is signed and employing the full structure of IPD (Jayasena and Senevirathna, 2012; NASFA, COAA, APPA, AGC and AIA, 2010).

Embodied in IPD is contractual and behavioral principles; Contractual principles include key participants bound together as equals; shared financial risk and reward based on project outcome; liability waivers between key participants; fiscal transparency between key participants; early involvement of key participants; jointly developed project target criteria; collaborative decision making. Behavioral principles include mutual respect and trust; willingness to collaborate; and open communication (Jayasena and Senevirathna, 2012; NASFA, COAA, APPA, AGC and AIA, 2010). These principles are the driving force of an IPD project. Critical decision making is improved due to the knowledge and expertise of all key participants (Thomsen *et al.*, 2010) at an earliest practical stage (Jayasena and Senevirathna, 2012). This results in enhancing project efficiency. The common good is ensured by using economic

incentives, encouraging collaborative behavior and creation of an environment that reinforces teamwork through moral and social incentives (O'Connor, 2009). There is also an emphasis on the bonds developed between key participants and their conduct (El-Adaway, 2010).

IPD has high potential of becoming an international standard in the industry due to its substantial benefits and characteristics (Jayasena and Senevirathna, 2012). However, despite its numerous benefits, there are significant barriers to its implementation in the construction industry. A study by Kahvandi *et al.*, (2019) on analysis of the barriers to the implementation of IPD and an earlier research by Becerik-Gerber and Kensek (2010) all identified capital; organizational; and environmental factors as barriers to IPD implementation. Others are legal issues (appropriate contract structures); financial (shared risk and reward); cultural (trust and teamwork); and technological (interoperability between participants).

Notwithstanding the significant barriers to IPD implementation, it has the potential of improving the efficiency of a project delivery. It emphasizes collaboration and integration of key participants from an earliest practical stage of a project and encourages the use of economic incentives. However, there is a dearth of research that seeks to provide evidence on the potentials of IPD in projecting a common good despite the broad range of literature that exist. Therefore, this study sought to provide empirical evidence on the potentials of IPD towards projecting a common good to key participants and the project. The next section presents the research methods.

RESEARCH METHODS

The study employed quantitative research approach due to its positivist nature especially in the use of predetermined and highly structured questionnaire (Saunders *et al.*, 2016). The focus of the questionnaire is to collect factual data in order to critically assess the potentials in IPD towards projecting a common good (Creswell and Creswell, 2017; Saunders *et al.*, 2016). It identified the significance of contractual and behavioral principles in IPD. It provided an effective means of data collection and gave each respondent the opportunity to respond to the same set of questions (Saunders *et al.*, 2016). A five-point Likert scale was used to assess factors in the questionnaire and respondents were asked to score each factor on a scale of 1 to 5 where Not Significant was rated as 1, and Highly Significant rated as 5.

Data analysis was based on the Relative Importance Index (RII) of the factors. According to Holt (2014, p. 6), the most frequently used RII formula in construction management literature is; $RII = \frac{\sum W}{A \times N}$

RII is significant in understanding the importance of different factors in construction management. It was used by Zeng, Tian and Tam (2005, p. 684) in identifying factors affecting design quality and by Ribeiro and Fernandes (2010, p. 170) in exploring agile methods in construction. Therefore the scores from the questionnaire in this study were transformed to importance indices using this formula where RII = Relative Importance Index; W = weight given to each factor by respondents on a scale of 1 to 5 with 1 implying the least and 5 the highest; A = highest weight (5 in this case); and N = total number of respondents. Five important levels were transformed for RII which are; High (H) ($0.8 \leq RII \leq 1$); High-Medium (H-M) ($0.6 \leq RII \leq 0.8$); Medium (M) ($0.4 \leq RII \leq 0.6$); Medium-Low (M-L) ($0.2 \leq RII \leq 0.4$); and Low (L) ($0 \leq RII \leq 0.2$). RII value has a range from 0 to 1 and the higher the value, the more important the factor.

The questionnaire was in five (5) sections; Section A contains demographic information; Section B and C contains contractual and behavioral principles of IPD in improving the efficiency of project delivery respectively; Section D contains factors on early involvement and collaboration of key participants in a project delivery; and Section E makes provision for comments and additional factors from respondents. This study was carried out with professionals in the Ghanaian construction industry and identification of respondents was purposefully carried out through contacts, and LinkedIn. Data collection was done online through emails, LinkedIn and what-sup with a sample size of 229 composed of site supervisors, engineers, quantity surveyors, architects, project managers and managing directors. According to Saunders *et al.*, (2016), a minimum sample size of 30 or more for statistical analyses is acceptable for a study. A purposive sampling technique was used to identify the selection of professionals only as respondents in order to achieve the research aim (Saunders *et al.*, 2016). A total of 127 participants responded representing 56% response rate.

The privacy, anonymity and confidentiality of all respondents were duly assured in their voluntary participation in the research. In ensuring validity and reliability of the questionnaire, a pilot study was conducted with professionals in the industry to test the variables; detect ambiguities and to provide opportunity for additional comments. The next section contains results and appropriate discussions.

RESULT

The results of the questionnaire survey including appropriate discussions are presented in this section based on a total of 127 responses. The role and years of experience of respondents in the construction sector are presented in table 1 and 2 respectively with corresponding frequencies and percentages of participants.

Table 1: Role in the construction sector

Role in the Construction Sector	Frequency	Percent
Foreman	24	18.9
Engineer	36	28.3
Quantity Surveyor	27	21.3
Architect	13	10.2
Project Manager	19	15
Managing Director	8	6.3
Total	127	100

Table 2: Years of experience in construction

Years of Experience in the Construction Sector	Frequency	Percent
1yr - 5yrs	20	15.7
6yrs - 10yrs	36	28.3
11yrs - 20yrs	46	36.2
21yrs - 30yrs	17	13.4
31yrs - 40yrs	8	6.4
Above 40yrs	0	0
Total	127	100

The educational level of respondents was paramount in this study hence presented in figure 1. Majority of respondents were HND, 1st degree and Masters Graduates therefore had a sound knowledge in the field of the study.

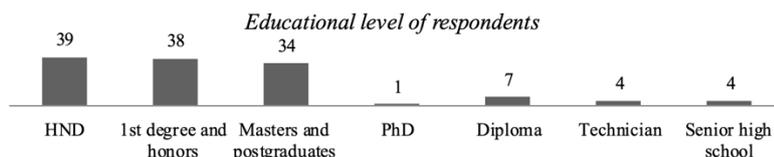


Figure 1: Educational level of respondents

The survey composed of 34 variables out of which 12 were contractual and 7 were behavioral principles of IPD in improving the efficiency of project delivery. A group

of 15 factors were on early involvement and collaboration of key participants in a project delivery.

Contractual Principles of IPD in Improving the Efficiency of Project Delivery

Table 3 presents the RII, ranking and Importance level (IL) of contractual principles of IPD. The RII of 9 contractual principles falls within $0.8 \leq RII \leq 1$ which indicates high importance level. Hence these principles are very significant in ensuring an efficient project delivery towards projecting a common good.

Table 3: RII of Contractual Principles of IPD

S/N	IPD Contractual Principles	RII	Ranking	IL
1	Early involvement of key participants in the project.	0.89	1	H
2	Early contributions of knowledge and expertise by participants.	0.88	2	H
3	Making Collaborative value-based decisions.	0.85	3	H
4	Key participants bound together as equals.	0.85	4	H
5	Jointly and early developed project target criteria.	0.84	5	H
6	When the success of key participants is tied to project success.	0.84	6	H
7	Key participants jointly accountable for any errors in design.	0.83	7	H
8	Sharing financial reward (compensation) based on project outcome.	0.80	8	H
9	Sharing financial risk among key participants.	0.80	9	H
10	Utilization of new technologies and approaches.	0.77	10	H-M
11	Waiving liabilities between key participants.	0.77	11	H-M
12	When there is fiscal transparency between key participants.	0.77	12	H-M

Early involvement of key participants is important in a successful project delivery (El-Asmar, Hanna and Loh, 2013). It enhances process and team integration which are key drivers for the success and common good of a project and participants (Nawi *et al.*, (2014). Early contributions of knowledge and expertise by participants is important to ensure pro-activeness (Jayasena and Senevirathna, 2012). It improves critical collaborative value-based decision making (Thomsen *et al.*, 2010) by enhancing jointly and early developed project target criteria that leads to project success (Fish, 2011). Key participants are bound together as equals by signing a multi-party contract before starting the project (Becerik-Gerber and Kensek, 2010; AIA and AIACC, 2007) hence enhances integration (Nawi *et al.*, 2014). The common good of the project and participants is enhanced when the success of key participants is tied to project success (Nawi *et al.*, 2014; Jayasena and Senevirathna, 2012; AIA and AIACC, 2007). This is also achieved when key participants are jointly accountable for any errors in design (Fish, 2011).

Sharing financial reward (compensation) based on project outcome and sharing financial risk among key participants was rated high. This is consistent with a study by Ilozor and Kelly (2012) with emphasis on risk and reward sharing including equal contribution of expertise. Jayasena and Senevirathna (2012) posited that motivation is very paramount for the success of IPD hence incentives are needed to enhance the process (Raisbeck, Millie and Maher, 2010; O’Connor, 2009).

Behavioral Principles of IPD in Improving the Efficiency of Project Delivery

Table 4 presents the RII, ranking and Importance level (IL) of behavioral principles of IPD. The RII of 6 behavioral principles falls within $0.8 \leq RII \leq 1$ which indicates high importance level hence these principles are very significant in ensuring an efficient project delivery towards projecting a common good.

Behavioral principles are very important in projecting a common good in IPD projects. Key participants having mutual respect and trust for each other enhances good relationship and conduct (El-Adaway, 2010) and promotes working towards a set of common goals (Nawi *et al.*, 2014). Another important principle is willingness to collaborate and effective collaboration as key participants. This is consistent with studies by Hamzeh *et al.*, (2019), Nawi *et al.*, (2014) and Raisbeck *et al.*, (2010).

Table 4: RII of Behavioral Principles of IPD

S/N	IPD Behavioral Principles	RII	Ranking	IL
1	Key participants having mutual respect for each other.	0.88	1	H
2	Willingness to collaborate as key participants.	0.88	2	H
3	Effective collaboration as key participants.	0.86	3	H
4	Having mutual trust for each other.	0.85	4	H
5	Open communication among key participants.	0.85	5	H
6	Open information sharing among key participants.	0.81	6	H
7	Ensuring transparent processes throughout the project.	0.78	12	H-M

Early Involvement and Collaboration of Key Participants in a Project Delivery

Table 5 presents the top 12 factors on early involvement and collaboration of key participants out of 15 variables used. These factors fall within $0.8 \leq RII \leq 1$ indicating high importance level. Therefore, they are very significant in ensuring an efficient project delivery towards projecting a common good.

Table 5: RII of Early involvement and collaboration of key participants

S/N	Early Involvement and Collaboration of Key Participants	RII	Ranking	IL
1	Key participants understanding of the owner’s desired outcomes is enhanced and strengthened.	0.87	1	H
2	Effective collaboration by all participants improves the quality of design documentation.	0.83	2	H
3	There is a more timely and informed understanding of the design.	0.83	3	H
4	Improvement in cost control, budget management and financial performance.	0.83	4	H
5	Providing an opportunity for adequate pre-design and design planning.	0.82	5	H
6	Providing an opportunity for strong pre-construction planning.	0.82	6	H
7	An improvement in the quality of the project.	0.82	7	H
8	Provides early and pre-construction anticipation and resolution of design-related issues.	0.81	8	H
9	Improvement in financial performance during the construction phase.	0.81	9	H
10	Early visualization of construction sequencing prior to commencing project.	0.81	10	H
11	There is the provision of adequate budget estimates to inform design decisions.	0.81	11	H
12	An increase in the level of effort by key participants during design phases results in reduced documentation time.	0.80	12	H

The study confirms that key participants understanding of the owner’s desired outcomes is enhanced and strengthened in an IPD. However, the “Big Room” concept facilitates the process (Jones, 2014) and drives key participants to work toward a set of common goals (Nawi *et al.*, 2014). Early involvement and collaboration enable a more timely and informed understanding of the design. It enhances critical decision making (Thomsen *et al.*, 2010) and improves cost control, budget management and financial performance. It provides an opportunity for adequate pre-design, design and pre-construction planning (AIA and AIACC, 2007). This is consistent with a study by Mesa *et al.*, (2016) that IPD has the potential to reduce the weaknesses in the TPD methods and can provide improved performance. However, the study identifies that effective collaboration by key participants improves project quality and ensures integration (Hamzeh *et al.*, 2019; Fish, 2011; Raisbeck, Millie and Maher, 2010).

The ranking of contractual and behavioral principles of IPD including variables on early involvement and collaboration of key participants presents the significance of these factors in ensuring an efficient project delivery. These however emphasize the potential of IPD towards projecting a common good to both the project and key participants. The next section presents conclusion and appropriate recommendation for future research.

CONCLUSION

When the success of key participants is not related to the success of the project, both suffers. Therefore, in ensuring an effective project delivery, the success of the two must be related (AIA and AIACC, 2007). This is the basis of IPD hence the potential of projecting a common good in a project delivery. There is an enhanced collaboration and integration (Hamzeh *et al.*, 2019; Nawi *et al.*, 2014; Fish, 2011; Raisbeck *et al.*, 2010) with better performance that meets participants expectations in IPD (Mesa *et al.*, 2016) when key participants success is tied to project success. IPD projects a common good to key participants and the project by improving construction productivity (AIA and Construction, 2007) particularly when a multi-party agreement is signed thereby eliminating separate motives that exist within the TPD methods (Becerik-Gerber and Kensek, 2010). These principles drive the key participants to work toward a set of common goals (Nawi *et al.*, 2014).

A total of 34 variables on IPD were synthesized for the study. This consists of 12 contractual and 7 behavioral principles respectively including 15 variables on early involvement and collaboration of key participants in a project delivery. The RII of 9 contractual and 6 behavioral principles recorded high importance level including 12 variables on early involvement and collaboration of key participants in a project. This indicates the significance of these variables in ensuring an efficient project delivery that seeks to promote a common good of key participants and the project by tying their success together.

Respondents commented that construction plays a vital role in the world; hence the identified points in the survey are very relevant for projecting a common good in construction. It was also indicated that effective planning of projects is necessary to ensure value for money in construction. Finally, there should be a good team build up where all parties involved will be willing to execute their duties and roles to avoid blame game.

This study presents valuable data to industry practitioners and academics in understanding the inherent potentials in IPD towards projecting a common good to key participants and the project. It presents the significance of contractual and behavioral principles of IPD including variables on early involvement and collaboration of key participants in improving the efficiency of project delivery. It provides an empirical evidence and pragmatic data to expand knowledge on IPD in projecting a common good, a field that has not received adequate research in previous studies. A further research is therefore recommended to build on the current study by considering a case study to further establish the extent of a common good of key participants in implementing an IPD project in the construction industry.

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EFFICACY OF VALUE MANAGEMENT SYSTEM IN BUILDING PROJECTS: A UK PERSPECTIVE

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The main purpose of using Design and Build (D&B) procurement method is to ensure client's satisfaction is maximised, which is in full concordance with the main purpose of using Value Management System (VMS). VMS is considered as a useful tool for enhancing functions, improving quality, and reducing cost and time in construction projects. This synergy has laid the foundation for this research to investigate the measures that are used in practice to adopt VMS for medium-sized D&B building projects in the UK. Eight building and construction professionals from different backgrounds having significant experience in using D&B procurement system were recruited through purposive sampling method and participated in the data collection using semi-structured interviews. In-depth qualitative analysis has identified key benefits in adopting VMS in D&B projects. However, some of these benefits were squandered due to the lack of systematic VMS practice in place. The research concluded that raising clients' awareness of VMS and its benefits, using the VMS techniques, and appointing a value facilitator are of paramount importance yet still widely overlooked by practitioners in the construction industry. This paper makes key recommendations for/on how these shortcomings could be addressed.

Keywords: design and build, procurement, value management system

INTRODUCTION

Building projects output in the UK generates more than £110 billion per annum and contributes 7% of GDP distributed into three main sub-sectors: Commercial and social (approximately 45%); residential (approximately 40%); and infrastructure (approximately 15%). Approximately 60% of construction output is new build, whilst 40% is refurbishment and maintenance (Government Construction Strategy, 2011). In 1970, the Value Management System (VMS) was first employed in construction industry to help practitioners focus on not only saving money but also balancing quality with cost.

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This system is typically embraced by practitioners in big building projects. However, clients of small to medium sized projects are more preoccupied with what they perceive as additional cost and managerial effort of employing VMS compared to the small budget of the project (Gidado, 2000). A report by the Chartered Institute of Building in 2010 revealed that traditional procurement is the most efficient and appropriate method for building projects of less than £5m, while D&B procurement is often selected for medium-sized building projects of up to £50m (CIOB, 2010).

In construction project management, VMS has goals, methods, processes, and techniques. The main goal of the system is to increase value and functionality with optimum cost (Nasir *et al.*, 2016). The other goals include improving communication, improving project management structure and system, enhancing design choice considerations, saving time, and making quicker decisions during the development process (Yeo and Lee 2018).

Takim *et al.*, (2013) analysed six case studies in D&B projects in Malaysia that identified VM and value engineering (VE) as among the key processes that bring improvements in construction. Other processes include partnering, constructability, benchmarking, total quality management (TQM), sustainability management and safety management. They proposed a conceptual framework integrating VM, VE and Partnering as a unified process improvement solution. Park *et al.*, (2017) suggested to embed VE into the Building Information Modelling (BIM) and presented meticulous examples into how that can be done to improve the idea generation process, save time, cost and resources during the VE workshop. The aim of the study is to investigate the critical success factors that make the application of value management in D&B medium size building projects effective.

LITERATURE REVIEW

Yeo and Lee (2018) argued that before fully adopting VM in building projects, there are different obstacles that must be borne in mind, namely: The heavier implementation liability of the VM concept, the diverse - and sometimes adversarial - nature of the design team, the lack of an established approach to functional analysis, and the lack of specific cost modelling approach. They suggested that the VM team and design team should work closely together to achieve the best project outcomes. Notwithstanding, coordination appears to be a clear weakness within the D&B system especially during the design stage of the project where the contractors' early involvement is expected to have a major influence on the effective achievement of the project objectives (Mohamed and Coffey 2010). Another weakness within the D&B projects is the lack of clear guidelines identifying not only the implementation steps of the VM but also the extent of projects to which it should be applied. It is only assumed that VM should mainly be used in complex and big projects that have high potential of restoring the investment made.

Atabay and Galipogullari (2013) argued that the implementation of VM has a convoluted cost, therefore it is best implemented in projects big enough to meet the associated cost and obtain profit above the desired threshold. It is worth noting that Atabay and Galipogullari (2013) did not specify exactly how big the project should be in order for the implementation of VM to be economically, strategically and practically viable. This can be argued that it might be a cause of unnecessary ambiguity deterring clients and practitioners alike from considering VM systems. In most projects, the implementation of VM is simple and straightforward. It simply involves the selection of the optimum option bearing the highest value, quality and

functionality but with the lowest cost, risk, time and environmental footprint. However, the selection process tends to become tedious especially for complex projects requiring the use of numbers and matrixes to choose the best solution among several alternatives in a multi-dimensional consideration. In this case, a simple VM implementation is inadequate, and it is often necessary to use sophisticated models or techniques. There is numerous modelling software that can help find the best solution, but the burden of framing the selection criteria and success factors lies always on the operator of such models. There is a certain degree of ambiguity in distinguishing between the factors leading to success and the indicators of performance measurements, so it is necessary to define those terms in detail.

Performance measurement in the context of VM studies is about quantifying the efficiency and effectiveness of VM workshops (Lin and Shen 2007). Performance indicators are parameters used to quantify the efficiency and/or effectiveness of a past action (Neely *et al.*, 2002). Thus, the Key Performance Indicators (KPIs) are classified as core elements of any performance measurement framework. On the other hand, Critical Success Factors (CSFs) were defined by Sanvido *et al.* (1992) as factors predicting the success of projects in the context of construction field. The identification of CSFs, which describes how an objective of VM studies can be measured and achieved, is important in performance measurement (Lin and Shen 2007). A careful performance measurement of the VM workshop is likely to improve the success of the project (Surlan *et al.*, 2016).

A variety of factors can determine the success of VM. A clear understanding of these factors will be instrumental in overcoming constraints caused by the higher demands of clients (Shen and Liu 2003). Each CSF should have a few KPIs that can be measured and quantified (Lin *et al.*, 2011). Surlan *et al.*, (2016) explained that CSFs were introduced as a means of measuring client value system. In addition, CSFs were used to steer the project brief in a direction that will maximise the desired expectations of the client. Kulatunga *et al.* (2005) considered CSF in specific construction project settings and argued that assigning values to particular CSF and quantifying client priorities through the pre-brief VM workshop can substantially impact the brief. However, CSFs can also be used for the assessment of whole life performance, as suggested by Park (2009).

There is a myriad of studies that investigated the performance indicators of VM and their identifications and classifications. For instance, Male *et al.* (1998) highlighted 10 CSFs for VM. These factors were reviewed by Shen and Liu (2003) who introduced 15 CSFs affecting the success of VM, which were categorised under four different clusters namely VM team requirements, clients' influence, facilitator competence, and relevant department's impact. Later on, Lin and Shen (2007) identified 23 different CSFs factors under four different groups depending on the stage of implementation within the project. The researchers evaluated the importance of these CSFs by surveying experienced VM practitioners, but they did not identify performance indicators that link to these CSFs at an operational level.

Chen *et al.*, (2010) have produced a model to measure the performance of VE workshops highlighting the importance of the composition, capability and participation of the VE workshop team. They have named the CSFs as primary Performance Assessment Criteria (PACs) under four Performance Assessment Aspects (PAAs). The researchers used factor analysis to extract the assessment criteria, which were then further grouped and weighted using the Analytic Hierarchy

Process (AHP). The assessment criteria were calculated using the Simple Additive Weighting Method (SAWM). The conducted quantitative study showed that the eight most important PACs are: Constructability of recommendations; integration and coordination ability of team leader; team leader’s ability to control job plan and schedule; completeness and clarity of recommendations; team leader’s conformance to the six-phase job plan; communication, coordination and consensus level during VE workshop (VEW); Professional level of VE workshop team members; and Team leader satisfaction with workshop goal. Lin *et al.*, (2011) defined 18 indicators out of potential 47 of highly ranked CSFs. They grouped these indicators under three categories: Predicting, process performance, and outcome performance. The outcomes of all these studies are summarised in Table 1.

Table 1: CSFs for Effective VMS Application

N	Critical Success Factor	Male <i>et al.</i> (1998b)	Shen and Liu (2003)	Wilson (2007)	Chen <i>et al.</i> (2007)	Lin <i>et al.</i> (2011)	Counts
1	Availability of multidisciplinary team	*	*	*	*	*	5
2	VM facilitator skills and qualifications	*	*	*	*	*	5
3	Structured VM process	*		*	*	*	4
4	Understanding of relevant information before the VM workshops	*	*	*		*	4
5	An implementation plan for the VM workshop outcomes	*	*			*	3
6	Clear objective of VM workshops		*		*	*	3
7	Interaction between VM workshops participants		*		*	*	3
8	Senior management support and commitment for applying VM	*	*	*			3
9	Use of VM function analysis techniques	*	*				2
10	Participants knowledge and experience in VM	*	*				2
11	Project scope/assumptions clarified				*	*	2
12	Timing of VM workshops (studies)		*		*		2
13	The job plan of five phases must be implemented			*	*		2
14	Decision-makers participation in VM workshops	*				*	2
15	Client’s objectives clarified					*	1
16	Client’s participation					*	1
17	Client’s satisfaction					*	1
18	Client’s support					*	1
19	Constructability of recommendations				*		1
20	Controlling the VM workshops (studies)		*				1

21	Identifying and clarifying the client’s requirements		*	1
22	Improving the project quality		*	1
23	Knowledge and experience of VM team in their own disciplines	*		1
24	Number of recommendations		*	1
25	Participants personalities	*		1
26	Primary function identified		*	1
27	Quality of the VM workshop output report		*	1
28	Recommendation supports of designer		*	1
29	Relevant departments’ support		*	1
30	Representing level of designer		*	1
31	Sufficient time for VM workshops	*		1
32	The commitment of VM team members		*	1

The aforementioned studies considered all types of projects in determining the CSFs regardless of size and procurement type used. However, this study will focus primarily on D&B medium-sized building projects in the UK to determine the CSFs that directly affect the performance and effectiveness of VE and VM.

METHOD

This research selected exploratory research design to achieve its objective that is to investigate the items that make VM effective in medium-sized D&B building projects in the UK building and construction industry. A qualitative methodology using semi-structured face-to-face interviews has been conducted to investigate the items that should be considered in implementing VM in D&B medium-sized building projects. It is intended to identify the items that make VM an effective system from the perspective of senior practitioners who have extensive expertise in D&B building projects. Therefore, one of the main objectives of this interview is to gain information from experienced practitioners about the effective implementation of VM during the life cycle of the project based on their current and past experience in managing D&B medium-sized building projects. The interviews also included the determination of: Whether the project size is key to implementation of VM; the effect of appointing VM facilitator; the use of VM techniques during the VM workshops.

Table 2: Participants Profiles

Organization type/Participant role	Y	Organization type/Participant role	Y
1. Private Consultancy/ Senior Designer	24	5. Principal Contractor/ Senior Project Manager	25
2. Private Consultancy/ Senior Designer	29	6. Principal Contractor/ Senior Project Manager	16
3. Private Consultancy/ Clients Consultant	25	7. Principal Contractor/ Commercial Manager	14
4. Principal Contractor/ Senior Project Manager	25	8. Private Consultancy/ Clients Consultant	22

A total of eight face-to-face interviews were carried out. The interviewees comprised three representatives from different sectors of the building industry including client’s consultants, principal contractors, and designers. The participants role, nature of their organization and work experience are summarised in Table 2. The selection of participants was performed by expert sampling (purposive sampling) in order to get data based on their past experience to describe the situation. Thus, the main selection

criterion of the participants was their current and previous experience in managing D&B building projects mainly in the UK. Due to time and budget constraints, all interviewees were chosen from the South East of England. Transcripts were collected and the contents were analysed on the basis of contextual themes. The qualitative analytical tool, NVivo 12, was used to analysis the interviews.

FINDINGS

The analysis of the interviews revealed several key CSFs that make the VM implementation effective in the D&B construction projects in the UK. In total, 11 critical success factors (CSFs) have been defined by practitioners, as shown in Figure 1. It is evident that there is almost complete unanimity among interviewees that satisfying clients by achieving their needs is the most important item that enhances the effectiveness of the VM system. Also, the interviewees indicated that the client is the main driver and supporter for updating and implementing the VM system. As clients play paramount role in achieving effective VM, the participants stated that clients need to be empowered and constantly engaged to participate in the VM processes. They need to be educated about the VM importance and benefits. Participant (1) stated that

the [client] is doing now 160 units, which is pretty massive, that is close to £50 million, so it is a large project, but we still do not do [VM] because it is not the client mindset ...

This means that even in a rather big D&B projects, the VM system is still not implemented just because of the lack of interest or understanding from the client towards the VM system and its benefits.

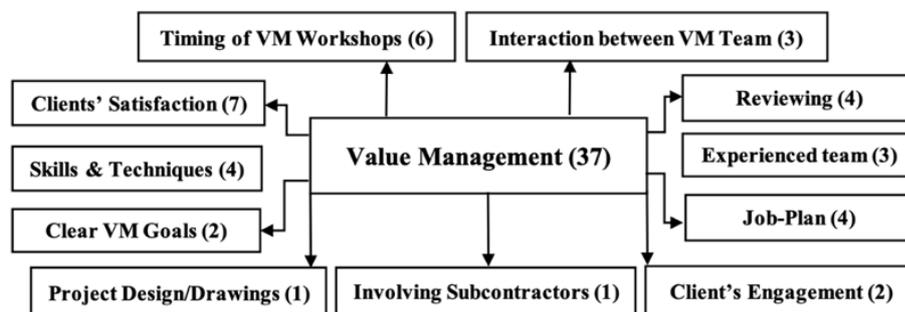


Figure 1: Thematic Diagram of CSFs for VM in the UK medium-sized building industry

Timing and Attendances of VM Workshops

The second most critical CSF to consider is the importance of timing of VM workshops during the project life cycle. The participants highlighted that changes in any construction project have greater effects before the construction phase starts, which indicates the importance for VM to be considered in the preconstruction phase. This phase would also be ideal for integrating VM with any other management systems such as risk management (RM) and environmental management (EM). Therefore, in this phase a full team including VM, RM and EM experts, among others, should jointly attend the workshop due to the overlap of the different management systems; whereas VM and RM both aim at reducing risk, VM and EM both aim at reducing environmental footprint. In addition, stakeholders including contractors and subcontractors should be present. Participant (6) mentioned that in the D&B projects the risks are typically transferred to principal contractors who then distribute them among subcontractors, thus there is a necessity for subcontractors to appear in all VM workshops. In this particular point, there was a disparity in the definition of

stakeholders who should be present in VM workshops. The consensus of three sectors representatives is that the interaction between participants in VM workshops is important in making VM effective due to the exchange of their experiences and knowledge. Therefore, it is important to run VM workshops involving all parties.

Three project managers from large principal construction companies in the UK emphasised the importance of using VM techniques. When they were asked about the types of such techniques, the responses showed that brainstorming is the only technique used with complete absence of any modelling/mathematical software tools that may help optimise the selection process for the best option with the highest value. Participant (7) presented a detailed explanation on how VM workshops are typically performed in the UK. The participant perceived the VM workshop as a tool to merely test the best option mainly in terms of cost among several available alternatives, whereas in reality it should be more about enhancing functionality, performance, value (not cost) and delivery time with lowest possible risk and environmental footprint.

The different participants expressed positive and confident response when using the brainstorming at the innovation phase, i.e., the third of the seven stages of the Job-Plan. However, among the participants there appeared to be a lack of confidence in using VM models in selecting the optimal solution among several alternative scenarios. The absence of this skill indicates that in any complex setting, where the knowing-how of VM models is essential, “poor” practice of VM is inevitable. Furthermore, none of the client representatives mentioned the importance of using VM techniques or setting up job-plans, which clearly indicates that clients and their consultants “do not care much about VM” as one interviewee put it. This is fully consistent with what has been mentioned in the literature about the importance of engaging and educating the clients about the benefits of VM. In addition, Participant (3) stated that there are no specific VM workshops or available VM facilitators in construction projects. This emphasises the lack of any true VM implementation in the UK construction industry, which means that the VM benefits are largely wasted.

There is a clear consensus among all participants on the importance of experienced team. However, the responses from all participants indicate that there is no dedicated person for VM or VE on their projects. Participant (4) assigned managing the cost (not value) to the quantity surveyor. On the other hand, Participants (1, 6, and 8) assigned the responsibilities for VM or VE to the project manager. However, Participant (7) stated that the project manager is only concerned with delivering projects on time while the cost manager is only interested in reducing expenses and that is why conflicts always arise between the two. This is a clear management problem.

Participant (5) stated that managing the value is “a team work really, and it is not necessarily specific. It is actually done as a whole team, which includes obviously the architect, engineer and MNP designer and D&B managers and the commercial manager ...”. The different responses related to who is in charge of managing the value within any D&B project highlights clearly that the construction industry does not value VM or VE systems from practical point of view because these systems are perceived as wasting time and costing money unnecessarily. For instance, Participant (1) stated: “The thing with the medium-sized building project [is that VM] takes time and costs money, nobody wants to spend that ...”. It is clear that the different interviewees equated VM to cost management (CM). However, VM is different from

CM as VM is focused on functionality and balancing between cost, quality, risk, and environmental benefits. It is worth highlighting Participant's (2) response: "When you meet the client, they want everything green and when you start to work on cost and identify things that cost more generally, they drop them away and then pulled back to the cheapest options." Furthermore, Participant (3) stated: "I think the value management is commonly seen as purely a cost management exercise by generally construction teams and all project managers."

This proves the lack of understanding of VM within the practitioners in the building industry in the UK who have cost-oriented mentality instead of value-oriented mentality. For instance, Participant (5) stated: "[when proposing] renewable energies [to clients] and we recommend that it is going to save them ... around 100,000 pounds a year less than other bids [using conventional energy] but the other bids are cheaper and the client decided to go for the cheap bid even though they could be paying more ...". This emphasises the decisive role of the client to adopt and implement VM. Therefore, clients need to be educated about the benefits of the VM. Furthermore, a simple and clear tool/framework/process need to be created to enable them to use VM accordingly. Clarity was emphasised by Participant (6), a senior construction manager at one of the biggest international contractor company, who stated: "So, the only way to make effective value management is to ensure that you have clear information from client (clarity of intent). In any D&B contract the client gives us a Design Intent ...".

CONCLUSION

Expert practitioners (principal contractors, client's consultants, and design consultants) that have significant experience in VM studies helped in identifying 11 key CSFs that influence the effective and efficient application of VM practice for medium-sized D&B building projects in the UK. Amongst these, the most important CSFs that can enhance the effectiveness of the VM system are: Achieving clients' needs and regular client's engagement; timing of and attendance in VM workshops; setting-up job-plan and use of relevant skills and techniques; regular reviewing; and availability of experienced team. The research concluded that without the client's approval and awareness of VMS, the D&B project will not harness the full benefits of VMS.

Thus, it is critical to raise client's awareness of/about the advantages of VMS in enhancing value and quality while reducing risk, time and environmental fingerprint. This could be enhanced by integrating the VMS with the management systems used for managing risk and environment. This research, therefore, recommends the integration of VM, Risk Management (RM), Environmental Management (EM) into a single framework, which must be user friendly both practitioners and clients as a key solution. Furthermore, the research concluded that the ideal timing for the implementation of VMS is in the preconstruction phase, which is also ideal for integrating the VMS with RM and EM in one workshop attended by all stakeholders across different fields. Finally, the research concluded that appointing a value facilitator is of paramount importance yet still widely overlooked by practitioners in the construction industry. The participants mentioned the availability of a multi-disciplinary team on each construction project that regularly meets to review the progress of the project. This already available team can be a great driver to adopt and implement any new integrated system led by a dedicated facilitator.

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QUALITY MANAGEMENT IN UK SOCIAL HOUSING PROJECTS: ADDRESSING THERMAL PERFORMANCE

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Construction defects in the domestic sector, especially those occurring in the building fabric, are acknowledged to contribute to the mismatch between the energy use as predicted at design stage and as measured in the building operation. Despite the number of quality management procedures put in place in social housing projects, defects affecting the thermal performance of dwellings are still a major issue to be managed. Within this context, this study investigates how Project Quality Plans related to thermal performance of dwellings are defined and implemented in the UK social housing projects. The analysis of evidence collected from five social housing case studies suggests that in the majority of the projects, the deployed quality management procedures focuses on visual quality issues, allowing defects with the potential to impair the thermal performance of the dwellings to remain uncorrected. Despite a range of quality control procedures administered by the projects' stakeholders, they did not systematically appraise such defects neither during preconstruction phase, nor during the construction stage. This study identifies the main challenges posed to the development and implementation of Project Quality Plans with focus on the thermal performance of dwellings. In addition, recommendations focused on offsetting the identified challenges are proposed as means to mitigate the quality issues affecting the thermal performance in social housing projects.

Keywords: quality management, defects, thermal performance, social housing

INTRODUCTION

In the UK, social housing associations (HA) are independent non-profit organisations who rely partially on government funding and partially on private finance to fund the construction of new dwellings (McManus *et al.*, 2010). HA play an important role in the UK housing sector, as well as being an essential part of the country's social security net, providing affordable letting to a substantial portion of the population.

In line with the objectives undertaken in the Climate Change Act 2008 (HMG, 2008), in the recent years the UK social housing sector has engaged in a large-scale effort to reduce carbon emissions, mitigate fuel poverty and increase the comfort level for their tenants (NEF, 2016). In fact, in 2016 the social housing sector presented higher average of SAP ratings (67), against the average of both private rented and owned occupied dwellings (61) (MHLG, 2018). However, recent studies on actual energy

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consumption indicate that the energy savings intended from the thermally efficient retrofits and new-built homes are falling short of their targets (NEF, 2016). This mismatch between the energy performance as predicted at design stage and as measured once the building is in operation is known as the buildings' energy performance gap (Zero Carbon Hub, 2014, de Wilde, 2014). Unless consistent measures are taken in the social housing sector aiming to help projects to achieve expected thermal performance levels (i.e. targeted fabric u-values and air tightness), the reductions of energy demand and CO₂ emissions aimed by the Climate Change Act 2008 (HMG, 2008) will not be met.

Among a wide number of contributing factors to the energy performance gap, poor quality management and the occurrence of defects in buildings' fabric have also been acknowledged (Gorse *et al.*, 2012, de Wilde, 2014). It is broadly claimed that the origins of these root causes are related to the "traditional construction model", encompassing poor teamwork across design and construction processes and inadequate technical literacy on thermal related quality issues (Tofield, 2012, Zero Carbon Hub, 2014).

As stated by researchers such as Hopkin *et al.*, (2016), HA are seeking ways to improve their Project Quality Plans (PQP) and to learn from recurring defects. However, they recognize that they are lacking a clear understanding of the best practices which would lead them to attaining the desired quality standards and thus achieving desired thermal performance targets (NEF, 2016). This paper aims, firstly, to identify the challenges faced in UK social housing projects in relation to the definition and implementation of PQP with a particular focus on thermal performance of dwellings; and secondly, to propose recommendations to overcome the identified challenges.

Globally, buildings are acknowledged to play a large role in the current energy use worldwide, being responsible for 40% of primary energy consumption and thus for 40% of the total amount of CO₂ emissions (IEA, 2016). In 2017, the domestic sector in the UK accounted for approximately 28% of final energy consumption (DBEIS, 2018a), 63% of this energy was used for space heating (DBEIS, 2018b). Therefore, to achieve the carbon emission targets it is pivotal to reduce the heating energy use in the sector by upgrading the thermal performance of the existing housing stock and building new energy-efficient dwellings.

In this regard, in 2008 the UK government committed to a legally binding target of reducing by 80% the 1990 carbon emissions levels by 2050 (HMG, 2008). This initiative was entailed by a number of mandatory and voluntary standards and codes for sustainable design and construction of buildings, aiming to increase the energy efficiency in the domestic sector. The Approved Document Part L1a (HMG, 2013) is part of UK Building Regulations and defines standards of energy use and carbon emissions, setting requirements of heat gains and losses in new dwellings.

The occurrence of quality defects in construction industry can potentially impact negatively in several dimensions of projects' performance, such as programme, budget, reputation, customers' satisfaction, health and safety, as well as the thermal performance of buildings (Alencastro *et al.*, 2018). Although there has been an ongoing effort to improve building quality through the implementation of quality programmes, the task of quality management in construction projects often proves itself to be challenging (Karim *et al.*, 2005). Construction projects are often one-offs, built in unique circumstances with transient organizations formed by multiples

stakeholders with diverse backgrounds and objectives (Briscoe *et al.*, 2004, Gorse *et al.*, 2012).

Historically, quality management in construction projects has adopted managerial practices developed in manufacturing industries translated into standardised Quality Management Systems (QMS), following the principles of quality management devised by authors such as Kanji and Wong (1998) and Deming (2000). However, due to the fragmented nature of construction sector, authors such as Karim *et al.*, (2005) and Jraisat *et al.*, (2016) have questioned the compatibility of QMS such as ISO 9001 (BSI, 2015) with the construction sector. The authors claim that these QMS does not present the desired flexibility to encompass the particularities and uniqueness of projects, resulting in unnecessary bureaucracy.

Karim *et al.*, (2005) and Harris *et al.*, (2013) suggest that the principles of quality management should be employed in frameworks that can be tailored for individual projects. PQP should be negotiated project by project, encompassing technical characteristics, as well as stakeholders' managerial background. Nevertheless, the successful implementation of PQP are dependent on two key aspects: the definition of specific quality requirements and assessment of necessary resources.

The definition of the quality objectives entails the recognition of the relevant functions and performance attributes of the resulting building that should be pursued by the PQP (Harris *et al.*, 2013). In that sense, the identification and understanding of the clients, occupants, statutory authorities and regulators' requirements are key to develop and implement quality plans which help to deliver the expected quality standards (Jraisat *et al.*, 2016). In addition, it is equally important that compliance procedures are aligned with the quality objectives, establishing unambiguously the evidence necessary for the compliance with quality standards (Karim *et al.*, 2005, Gorse *et al.*, 2012).

Quality resources assessment explores the identification and provision of essential resources to develop and implement PQP (Juran, 1993, Harris *et al.*, 2013). It is also necessary to establish the roles and responsibilities among the projects' participants in terms of who is responsible to undertake and exert the authority over each of the stages of the implementation of the quality program. In that sense, the capability of those involved, the financial resources and external support required must be assessed.

The existing knowledge establishes a sound theoretical basis for the development of quality management frameworks in construction projects, highlighting the importance of recognising quality objectives and making available the necessary resources for the implementation of PQP. However, there is a shortage of studies and sufficient information to provide a full understanding on the fact that despite the number of quality assurance procedures put in place in UK HA's projects, defects affecting the thermal performance of dwellings are still a widespread occurrence.

METHODOLOGY

This study adopts a qualitative approach by means of an explanatory design where empirical data was collected and analysed to explore in detail the established phenomena (Bryman, 2012). For this purpose, five case studies of new-built UK social housing projects were selected to investigate the challenges to the development and implementation of PQP with focus on thermal performance.

The methods of data collection and analysis were devised based on Grounded Theory (Corbin and Strauss, 2008). In order to organise the data collection and analysis

which enabled constant comparison across case studies and existing knowledge, a conceptual framework was developed (Bryman, 2012) containing two of the main areas of PQP: (1) Definition of quality requirements and (2) Quality resources assessment.

Empirical investigations must rely on multiple sources of data in order to avoid biased conclusions (Bryman, 2012). In that sense, the main data collection procedure used was semi-structured interviews with key stakeholders: housing associations (i.e. project managers) and contractors (i.e. project and site managers). In total fifteen interviews, three per project, were undertaken. Additional data was collected by means of: (i) quality management documentation (quality policy and plan, checklists, etc.); (ii) observations during projects' management team meetings and construction site visits focusing on the implementations of PQP; and (iii) construction defects identification surveys undertaken by the researcher during the construction process. These additional sources of information were used to confirm or to challenge the findings emerging from the semi-structured interviews. In total, five case studies were selected (Table 1) and their original denominations were substituted by Case study 1 to 5 in order to ensure confidentiality.

Table 1: Summary of the case studies included in this research

	Case study 1	Case study 2	Case study 3	Case study 4	Case study 5
Location	Cornwall	Cornwall	Devon	Devon	Wiltshire
Number of units	28	39	67	72	40 (121) *
Contract value (£)	3,100,000	4,000,000	8,300,000	10,000,00	5,000,000
Energy performance target	Part L1a	Part L1a	Part L1a	Passivhaus	Part L1a

* This case study is a developer led project of 121 housing units where 40 dwellings were acquired by the HA.

The data was collected from December 2015 to February 2018, and key findings were grouped into the two main areas to PQP. In order to assess the validity of the results, three focus groups were undertaken with the participation of experienced professionals of similar projects, such as project managers, site managers, consultants, building surveyors, building control approved inspectors and academics. The main goal was to verify if the challenges identified in the case studies were also experienced by the focus groups' participants, and therefore the study's results could be generalised to other similar social housing projects.

RESULTS

In terms of the general quality approach adopted by the investigated HA, it was observed that HA have a genuine interest in improving the levels of energy efficiency and thus an intent of reducing fuel poverty and energy bills of tenants, as well as the environmental impact such as carbon emissions. However, as explained by the project manager of the housing association in case study 1, due to financial constraints led by cuts in social renting values and limited funding, the adoption of more ambitious thermal performance targets has been suspended since 2015. As a consequence, four out of five case studies only adopted the compliance to Part L1a of Building Regulations as the ultimate quality goal in terms of thermal performance. The exception was case study 4 where the adopted thermal performance targets were the Passivhaus standards.

The analysis of collected data made evident that in all case studies a clear definition of the quality objectives was provided by the housing association or developer in the

early stages of the project, via "employer's requirements" (e.g. project toolkit and technical specification). These objectives were part of tendering documentations and contractual requirements. It is important to state that specifically in Case study 5, the HA's business model was predominately focused on buying housing units from the open market developers instead of commissioning the construction of their new assets. Consequently, little input was provided in terms of the definition of the quality requirements. However, the HA would only acquire new assets providing they met the Building Regulations requirements as a minimal standard.

In Case studies 1, 2, 3 and 5 the challenge posed to the achievement of the quality objectives regarded to thermal performance was that the defined compliance process did not encompass the quality assurance procedures undertaken by neither the housing associations nor the contractors. The ultimate quality compliance requirement was to obtain statutory approval, where the quality control and compliance confirmation was assigned to a third party, i.e., building control bodies (BCB). Thus, the establishment of this compliance process defined the approach of the PQP developed and implemented by HA and contractors, especially in the allocation of resources and the emphasis applied on the quality control procedures.

In terms of formal procedures, in most case studies quality control procedures focusing on defects with potential to impact on thermal performance of the buildings were defined and implemented by BCB. Although the quality control procedures applied by BCB used a standard approach, only five key stages of the construction process were established for quality inspections (i.e. foundations, drainage, superstructure, pre-plaster and pre-handover). It is also important to acknowledge that from the five inspections stages, two of them (i.e. drainage and pre-handover) offered very few, if any, opportunities to identify quality issues affecting the thermal performance of the dwellings through visual identification. Moreover, BCB inspectors also had an extensive amount of quality attributes to check related to other parts of Building Regulations. Moreover, the process of appraising quality relied mostly on their experience and awareness rather than the use of a structured quality checklist as guidance.

Summarising, the majority of the case study results suggests that quality objectives related to the thermal performance were defined following the specifications of the UK Building Regulations as the minimum standard. Therefore, the ultimate quality control and compliance procedures concerned to the thermal performance were assigned to building control parties. Consequently, no formal quality compliance method was defined and implemented by the HA and contractors. Because the ultimate compliance procedure for the quality objectives related to thermal performance were assigned to the BCB, the HA had no control over the process of assessing and reporting quality compliance. Thus, the definition of the necessary evidence for quality compliance and resources applied in the process of quality control were neither tailored to the project, nor aligned to the housing associations' long-term objectives.

The findings suggested that multiple layers of quality control procedures were resourced, and roles and responsibilities were assigned in order to ensure the achievement of the desired quality requirements. However, as mentioned the ultimate authority in terms of awarding the final quality compliance concerning to the quality objectives related to thermal performance was given to BCB, in exception of Case study 4. Therefore, in the majority of the case studies an imbalance between quality

control efforts put in place in different stages of the construction process was observed. Quality appraisal procedures put in place by HA and contractors were intensified in the practical completion stage of the construction process. For instance, in cases studies 1, 2, 3, and 5, contractors' interviewees explained that during certain stages of the construction process the effectiveness of the quality control procedures were compromised due to the lack of appropriate allocated time and human resources. In Case study 4 where Passivhaus accreditation was required, a dedicated quality officer was assigned in addition to the usual managerial team to monitor specific building elements where defects were likely to occur.

In respect to the quality control required to achieve UK Building Regulations approvals, approved inspectors were appointed by the contractors/developers to inspect the sites in all case studies. The findings revealed an issue related to resources constraints within BCB. The number of approved inspectors were mentioned to be insufficient and often they were not available to undertake inspections whenever project's dwellings reached a defined key stage for quality check. As a result, a number of housing units were not inspected in certain key stages of construction due to the fact that subcontractors did not want to be penalised for programme delays in case of having to wait for the availability of the BCB inspector. The lack of resources and time constraints also impacted on the regime of inspection. The available time slot for the site inspection did not always allowed the appraisal of all the dwellings expected for each visit, leaving some dwellings unassessed. Anecdotally, a BCB's surveyor, participant of one the focus groups, confirmed the scarcity of resources, stating that quality control regime of assessing all housing units of the surveyed project is not being followed as it should. The surveyor revealed that building control activities are being undertaken through sampling due to lack of human resources.

In terms of resources deployed for upskilling and to increase awareness of quality requirements and the impact of defects on the thermal performance of the dwellings, the results revealed that similar approaches were adopted in the case studies, in exception of case study 4. As relevant quality objectives were embedded in contractual and design documentation, the HA did not formally require that additional activities were undertaken with the workforce on-site. Thus, in the majority of the case studies, apart from the initial site inductions, no other initiatives could be identified in terms of upskilling or increasing awareness of the site operatives. Moreover, it was apparent in case studies 1, 2 and 5 that the only formal induction provided to the operatives was mostly regarded to Health and Safety issues. In fact, the site management held meetings with the subcontractors' supervisors on a weekly basis, however the main focus was the planning and the achievement of construction programme milestones. In Case study 4, there was a concern about the level of technical knowledge across the supply chain and site managerial team jeopardising the achievement of the thermal performance targets. It thus led the contractor to deploy training courses ran by the Passivhaus consultant. The site managerial team and subcontractors' supervisors received technical training and were made aware of the potential quality issues which could undermine the ultimate thermal performance of the dwellings.

In conclusion, in the majority of the case studies the ultimate quality compliance related to the thermal performance of dwellings was assigned to BCB. As a consequence, housing associations and contractors concentrated their efforts and resources to undertake quality control procedures mostly on the final stages of the construction process. At that phase, defects affecting the thermal performance of the

dwellings were enclosed within the building fabric and could not be detected through the deployed procedures. It was identified in case studies 1, 2, 3 and 5 that the deployed resources for the quality control procedures compromised the administration of the PQP, undermining the ability of the defined procedures to detect defects and thus, impacting on the achievement of the quality objectives. In the majority of the case studies it was observed that the only formal activity with the purpose of increasing workforce's awareness were health and safety inductions. Training sessions and upskilling activities aiming to develop technical knowledge and capabilities, as well as increasing the levels of awareness toward the projects' quality objectives were only observed in case study 4.

DISCUSSIONS

As evidenced by the results, the main challenge posed to the achievement of quality objectives related to the thermal performance of the investigated projects is the fact that the ultimate quality compliance was assigned to third parties, i.e., BCB. This approach reduced the drive and motivation of PQP implemented by HA and contractors, undermining their ability to address quality defects impacting on thermal performance of the dwellings. The quality control procedures devised and implemented by BCB presented inadequate structure in terms of providing guidance for the identification of thermal building defects. Moreover, resources put in place were deemed insufficient, impacting negatively on the implementation of the devised quality control procedures.

The inefficacy of BCB on assessing the achievement of quality objectives, although granting statutory approval, is something of great concern also manifested in other studies. For instance, the National Energy Foundation's report on energy efficiency of UK social housing projects (NEF, 2016) shows that 33% of the 48 projects investigated presented external walls' u-values failing to meet the Building Regulations' threshold, even though all the projects were awarded with statutory approval. Moreover, reviewing the tragedy of the Grenfell Tower fire (BBC, 2018), the Hackitt report indicates that the UK's regulatory system suffers from an inadequate oversight and enforcement tools (Hackitt, 2018). Hackitt (2018) highlights the weaknesses of the current structure of BCB in terms of scarce resources and the inspectors' inability to undertake quality control activities. Moreover, the report mentions the conflict of interest of BCB between using the enforcement methods and fear of losing long-term businesses. This statement was also manifested by the head of development of the housing association in one the case studies, denoting the lack of credibility of the current arrangement.

It is equally important to acknowledge that construction projects are mostly one-offs, built by a temporary group of participants, using different construction methods (Briscoe *et al.*, 2004, Gorse *et al.*, 2012). In that sense, HA must be able to adjust quality objectives and compliance procedures to the particularities of projects in regard to their construction methodology and sequencing. In addition, the use of PQP is more suited to accommodate the particularities of each project, rather than the inflexible standardised QMS. Karim *et al.*, (2005) also stated that the success factor to the development of quality assurance procedures are down to the project level and not linked to standardised QMS.

The findings also suggest that contractors and subcontractors should be made fully aware by the HA of what is expected from them in terms of the quality requirements, but also how and when evidence of quality compliance should be reported. The

compliance procedure must be designed to determine that the contractor is responsible for providing evidence that the workmanship is undertaken at the desired level, where specific building elements are free from the defects highlighted at the stage of risk assessment. It is fundamental that these requirements are embedded in contractual documentation where the contractor is legally bound to deliver the expected quality standards. The compliance procedure should ensure that building elements are compliant with the technical drawings and the specifications of the project (Gorse *et al.*, 2012).

In this respect, HA have a vested interest in the uptake of PQP that enable the delivery of thermal performance translated into quality objectives. HA are the institutions that are responsible for commissioning and maintaining social housing and most importantly promoting the wellbeing of social tenants through the delivery of energy efficient dwellings. Therefore, it is reasonable that HA should participate actively not only on the establishment of quality objectives but also the definition of quality compliance procedures to be assigned to contractors, even when only statutory approval is required. Researchers such as Briscoe *et al.*, (2004) and Karim *et al.*, (2005) claim that active client participation in the process of establishing quality objectives and compliance is vital to drive the process of quality assurance, as well as to increase contractors' levels of awareness towards the risks involved to achieve the desired standards of quality.

As stated by researchers such as Feigenbaum (1991) and Josephson *et al.*, (2002), the resources applied in quality management of construction projects are usually concentrated in three main areas: prevention, appraisal and correction. The findings demonstrated that most of the resources put in place in the investigated case studies were concentrated in the appraisal and correction activities. Very little was invested in prevention, through upskilling activities focusing on technical capability and awareness. The results presented a similar trend to what is experienced in the construction industry, where very little resources are allocated on the prevention of quality issues (Josephson *et al.*, 2002, Tofield, 2012). The lack of focus and awareness towards quality issues, in this study impacting on the dwellings' thermal performance, converge with studies of Brooks and Spillane (2016) and Atkinson (2002). In fact, the lack of awareness of the quality objectives not only compromises the delivery of the expected standard of quality but also undermines the workforce's motivation and pride.

For the achievement of quality objectives focusing on increasing living standards in the UK social housing through the delivery of energy efficient dwellings, an important shift in quality management approach is required. It is pivotal that PQP provide more focus towards prevention, instead of correction. Channelling resources to prevention activities, such as upskilling and increase of awareness, enables the empowerment of the workforce, promoting motivation and pride in delivering quality first time, thus reducing correction costs. In addition, this approach promotes collaboration between the many stakeholders where quality goals are shared and are well known, shifting construction culture to a no-blame philosophy.

CONCLUSION

This study's main contributions to knowledge is the recognition that the sole adoption of statutory approval as the ultimate quality compliance related to the thermal performance objectives is not sufficient to achieve the set quality goals. Firstly, this approach reduced the drive and motivation of PQP undertaken by housing

associations and contractors. Secondly, the quality control procedures put in place by BCB proved inefficient. The findings demonstrate that the PQP were devised and resourced mainly to mitigate visible quality defects which were likely to be identified by tenants and thus become complaints to be dealt with. In most of the case studies, resources for quality appraisal procedures were concentrated in the final stages of the construction process, where defects affecting the thermal performance were already enclosed within the building fabric, remaining undetected and uncorrected. In order to promote the achievement of quality objectives aiming to improve energy efficiency, social tenants' living standards as well as the decrease of carbon emissions a shift in the quality management approach is required. It is recommended that change of culture must be achieved that promotes collaboration and participation, encompassing a clear definition of quality compliance and empowering the workforce to deliver the expected quality standards. Quality management practices related to prevention, i.e., upskilling and increase of awareness, should be prevalent over the correction of defects, thus reducing the cost of rework and promoting the achievement of quality goals.

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RENOVATION OF THE JAPANESE CONSTRUCTION INDUSTRY: EVALUATION OF I-CONSTRUCTION FROM THE PERSPECTIVE OF CONSTRUCTION MANAGEMENT

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Japan's population is both decreasing and aging. The abundant labour force that has supported the economy will continue to decline, and improving productivity is becoming a challenge. The "i-Construction" initiative, which aims to drastically improve productivity in all construction production processes from survey to design, construction, inspection, maintenance and renewal, is an important measure, and the i-Construction Report was compiled by the Ministry of Land, Infrastructure, Transport, and Tourism in April 2016. Based on the rapid development of satellite positioning technology and Internet of Things, the report summarizes viewpoints for advancing i-Construction in three categories: "Turning construction sites into advanced factories", "Introduction of advanced supply chain management at construction sites", and "Regulation of construction sites, breaking stereotypes, and continuing "Kaizen"". As overarching policy from these 3 perspectives, "full utilisation of ICT (ICT earthwork)", "optimal overall deployment" and "levelling of construction time" were set. The main characteristic of this policy is that it lists the items to be tackled for each category. In addition, as a mechanism for promoting i-Construction, the development of a national promotion system, establishment of a public-private partnership consortium, utilisation of big data, collaboration with other outdoor industries, and overseas expansion is proposed. This study evaluates and analyses Japan's efforts from the viewpoint of construction management research and examines how construction management research is utilised in the policy practice carried out in Japan, and what is considered for the feedback from policy to research. In this paper, we re-evaluate Japan's i-Construction efforts from three perspectives, (1) the relationship between construction management methodology and i-Construction; (2) the relationship between i-Construction and the interdisciplinary and comprehensive nature of construction management; and (3) the relationship with digital platforms. In recent years, digital platforms have played an important role in dramatically improving consumer market access, and it is desirable to identify the key to their success, and to verify the points of attention that contribute to both practical use and research.

Keywords: i-Construction, Japan, project management

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INTRODUCTION

The population of Japan is both aging and declining. The abundant labour force that has supported the economy will continue to decline and improving productivity has become a challenge. The Ministry of Land, Infrastructure, Transport and Tourism (MLITT) compiled the i-Construction Report in April 2016 with the aim of drastically improving productivity in all construction production processes, such as research, survey, design, construction work, inspection, maintenance, and renewal. The i-Construction initiative has been a major means of solving the problems that the construction industry has faced since productivity improvement was taken up as a Japanese national policy. This includes: (1) Turning construction sites into advanced factories based on the rapid development of satellite positioning technology and Internet of Things (IoT); (2) Introduction of advanced supply chain management at construction sites; and (3) Regulation of construction sites, breaking of stereotypes, and continuation of “Kaizen” which is mainly aimed at improving awareness. This not only includes the utilisation of advanced technology, but also the improvement of existing awareness technological possibilities.

The opportunity to improve productivity at this time is attributed to the sluggish productivity caused by an excessive number of workers. After the bursting of Japan’s economic bubble in the 1990s, construction investment continued in order to support the economy and minimize the economic downturn. As a result, public work projects designed to help the unemployed hired a large number of people, thereby creating a labour surplus. Therefore, improvements in productivity at construction sites, which lead to labour saving efficiencies, were postponed, and work at construction sites has been carried out manually since the late 1990s.

In contrast, it is estimated from statistics that over the next 10 years, 1.1 million workers will leave their jobs owing to the aging of society and other factors, and skilled workers will disappear from the construction industry over time. Few young people want to work in the construction industry, and construction workers aged 29 years or below account for only 10% of the total workforce. This is also evident from the graph of changes in the number of skilled workers. In the graph showing the age of construction business licensees, 30% of construction industry workers are aged 55 or over, and 10% are aged 29 or under. Despite the decrease in the number of older workers entering the workforce, young people are reluctant to work in such occupations.

In Japan, the civil engineering industry has depended on public investment. However, this public investment has decreased to a level of about 60% of its peak in 1996, and the business environment has not been stable, making it difficult for the construction and civil engineering industries, as a whole, to break away from public works. The focus of this report is the field of earthwork, where productivity improvement is currently lagging, and Japan's labour productivity is only about 80% compared with that of the United States.

Over the past 50 years, the mechanisation of tunnel construction has advanced and productivity has increased by a factor of ten. In contrast, there is still scope for improvement in earthworks and concrete works that have relied on human resources, where productivity is still constant or declining. The construction industry is destined to receive orders on a case-by-case basis. Before starting production, they receive orders for unique products and produce them at fixed prices. In addition, because the requirement to work outdoors is inevitable and the products to be produced are

attached to the site, it is sometimes necessary for the labour force to be located there. In the past, the cell production method had been promoted in the manufacturing industry because of the characteristics of labour-intensive production. This method should be incorporated into IoT technology to improve the productivity of the manufacturing industry now that innovation has made it easy to introduce IoT technology outdoors.

The research methods used in this paper were developed by listening to those who are actually promoting i-Construction through discussions at five seminars on system sciences of i-Construction held at the University of Tokyo, and by exchanging opinions among researchers on their position in construction management research. Therefore, in this paper, we first explain i-Construction, and then link it to previous research on construction management.

I-CONSTRUCTION VIEWPOINT

The i-Construction report aims to (1) make the construction site similar to a state-of-the-art factory; (2) introduce i-Construction, automatic operation, and mechanisation into the supply chain, including the procurement of materials, transportation of earthworks, and transportation of soil; and (3) break through the two Kisei (official regulations that are followed in practice) and make continuous improvements at the construction site, following the Plan-Do-Check-Act (PDCA) cycle, in order to incorporate i-Construction into the next site in an improved way. However, in addition to these three aims, it is also necessary to pay attention to the following caveats.

The first caveat is the improvement of safety. The construction industry still accounts for 40% of fatal labour and work-related accidents. Second, flexible measures should be taken to promote the introduction of rapidly advancing new technologies into the field. Existing technologies that were not introduced owing to regulations should be reviewed and the introduction of such technologies should be actively promoted. Third, overseas expansion should be considered with international standardisation of the i-Construction package, and its export. This also includes studying ways to better integrate concurrent engineering and front-loading bidding contracts.

Concerning point (1) above, specifically, various cutting-edge “Information Communication and Technology (ICT)”-enabled construction equipment, including drones, are being introduced in research, surveying, design, and construction work stages. It is a great advantage that one person can speedily perform a wide range of labour-intensive work with improved accuracy. Through the introduction of these devices, we hope to eventually turn the construction site into a state-of-the-art factory that will attract young people.

Regarding point (2), we aim to introduce an efficient supply chain that uses a flexible and integrated approach at all stages: research, survey, design, construction work, inspection, and maintenance. By utilising i-Construction, productivity will improve, the work site will become cutting-edge, and each process will not be divided, but rather introduced after integration.

Viewpoint (3) will be discussed later.

In terms of safety, which is a critical aspect, the number of fatal accidents in the construction industry is double that in other industries. The number of accidents caused by contact with construction machinery is second only to motor vehicle

crashes. The introduction of ICT in this area, to detect people and reduce fatal accidents by preventing their contact with dangerous equipment, is highly desirable.

Overall Optimal Deployment (Standardisation of Concrete Work Standards)

The introduction of overall optimisation is explained using the standardisation of concrete work standards as an example. First, regarding overall optimisation, there is a problem in applying the optimum design method and construction method. This involves the fact that concrete work is undertaken outdoors and is easily affected by weather conditions. In particular, it is stipulated that cast-in-place concrete, which is transported to the site, assembled with reinforcing steel and the concrete cast in a particular form, should be placed in an environment where the temperature is between 4 °C and 25 °C. Therefore, work during summer and winter is restricted, and it is also affected by rain. As a result, planned construction becomes difficult, and extra time is required for completion. In addition, there are problems such as the fact that a bridge requires work in high places and involves danger, and that the work environment and conditions are different for each construction site. The combination of factors is very complicated. Thus, skilled workers engaged in these activities also require different levels of a variety of skills.

On the other hand, there is a method of construction using ready-made concrete, called precast, which is manufactured in a factory. This can be produced more cost-effectively by standardizing products of the same size in large quantities. However, the opportunity to use these products in large quantities is currently very limited, and economies of scale that equalise the operation of these plants are unlikely to occur. The current problem is that it is difficult to reduce costs because the inventory produced at such plants becomes dead stock.

In addition, as standards for superior construction methods and new technologies have not yet been established, even if proposals for new construction methods are received, they are unlikely to be adopted. This is another current challenge. To solve these problems, the i-Construction report states that we are beginning with what can be implemented in the present circumstances and what may be implemented in the future. Based on the above problems, to improve the productivity of the entire concrete work process, the current positive characteristics are extracted, optimised, and incorporated into the stages of the supply chain.

It is necessary to develop innovative technologies and establish a mechanism to promote the full-scale introduction of overall optimisation, but it is very difficult to implement such methods through the initiative of the client. In contrast, the government encourages a shift to a system that may realise the concept of front-loading by utilizing private technologies that were not conceived before, such as receiving orders and holding technical competitions. Successful cases can be effectively distributed nationwide. At the same time, the standardisation of precast products and generalisation of technical elements are being considered. For overall optimisation, particular standards and parts are optimised to the maximum possible extent. For this purpose, the concept of civil engineering structures and design guidelines must be revised. As it is impossible to supplement the field standards and field requirements through pre-casting, the guidelines for civil engineering structure design should be reviewed first. In addition, quality regulations should be reviewed such that better-quality products can be delivered to the field. Specifically, the guidelines aim to standardise materials, indoor work for factory manufacturing of

items, the introduction of new technology, and especially the rationalization of quality inspection for items made in factories.

After improving each of these processes, we consider introducing supply chain management. This aims to introduce the concept of concurrent engineering and to improve each process of production, transportation, procurement, and assembly.

Levelling Construction Time

Levelling the construction time is also known as levelling the ordering period. This is mainly a target of the orderer and is basically the same as the standardisation of the construction time. Standardizing the construction time considers the weather conditions and the conditions required for laying the concrete such that an established construction period ends at the end of the fiscal year. This is largely the responsibility of the orderer, as the construction period is limited to the end of the fiscal year for the convenience of the orderer. (In Japan, a single fiscal year rule is followed, and orders are often placed at the end of the fiscal year to utilise the remaining budget). In particular, 70% of local governments that have a large gap in their busy schedules place orders for all public work projects. Even if only the MLITT is standardised, an overall optimisation would not be achieved unless the local government ordering procedures are standardised. To this end, a regional orderers council has been established, and the national government, local governments, and other ordering agencies work together to standardise construction periods and orders through the Ministry of Internal Affairs and Communications as necessary.

In addition, efforts are being made to ensure that construction need not be completed by the end of the fiscal year. Levelling is attempted by prolonging the construction period. Construction companies that are responsible for disaster response and maintenance in the region are expected to have a sustainable business environment in the future. To this end, projects should be constructed over a two- or three-year period, improving on the existing procurement mechanism of the single-year principle. In other words, a multi-year procurement mechanism should be considered to ensure a sustainable business environment. To reduce the number of construction projects scheduled for completion at the end of the fiscal year, the concept of a 2-year long project and a longer 10-year project are being implemented. Construction projects to be ordered from now on will be revealed to the industry such that management can continue to keep the future requirements in perspective. Standardisation is being carried out in a planned manner, with a view to formulate plans for the maintenance and renewal of infrastructure, placing detailed orders based on regional characteristics, and medium- to long-term standardisation.

Academic Evaluation of Construction Management

Next, we would like to provide an evaluation of i-Construction in Japan from an academic viewpoint of construction management. This is based on three viewpoints. The first aspect is the relationship between construction management methodology and i-Construction. The PDCA, a known engineering method, is used as an analytical method for construction management. This is an inductive extraction of technology in the field and part of the methodology is an accumulation of empirical knowledge. Furthermore, the methodology of business management advocated by Iriyama (2019; Page 788) is not unique to that field, and the argument that the analysis of business management using the methodology of economics, sociology, and psychology is mainstream in modern business management is also basically applicable to construction management. As claimed by Dainty and Leiringer (2019), new

directions are being explored in the study of construction management and economics (Koskela, 2017; Ivory, 2017; Bröchner, 2018; Volker, 2019). Koch *et al.*, (2019) also explored the application of various methodologies in social science. On a more unusual note, Tutt and Pink (2019) are exploring the application of ethnography to construction management. The positioning of i-Construction in Japan in the methodology of construction management, which is an interdisciplinary field, can be regarded as the combination of various management methods. In particular, dynamics based on academic consistency will not be sufficient in the course of policy formation; hence, it is important to re-evaluate them from an academic perspective in order to modernise construction management in Japan.

We have reviewed and further deconstructed the i-Construction report from a construction management perspective. Specifically, the i-Construction report is an excellent summary of the efforts so far to put productivity at the centre. However, it is different from the system and position used in construction management study. Therefore, compared to the textbooks (e.g. Pellicer *et al.*, 2014; Sherratt, 2015), there is a particular emphasis on productivity improvement perspectives, which can be seen from the fact that there is a chapter of the report entitled “Perspectives”, and productivity improvement standpoints are always in mind when organizing efforts in the field. In contrast, in the two textbooks above, the former carefully explains the model and theory of project management, while the latter analyses the field, but due to its nature as a textbook, it lists in detail the points of caution for discussion on production management. These are aspects that are not mentioned in the i-Construction report. Furthermore, the two textbooks and the i-Construction report also emphasize a very forward-looking perspective, reminding us that construction management is a discipline of practice. However, this has advantages and disadvantages, and construction management research does not have its own methodology, but rather borrows methodologies from economics, sociology, management, and engineers. While this is something that construction management as a practical science cannot escape, it must be understood that the type of research presented in this report that firmly summarizes existing efforts is also important.

The second aspect is the relationship between i-Construction and the interdisciplinary and comprehensive nature of construction management. From a methodological point of view, i-Construction is a collection of various experience values; however, to date, interdisciplinary and comprehensive knowledge of construction management has been utilised. Specifically, Hiroshi Komiyama, a distinguished engineer and the president of Mitsubishi Research Institute, Inc., served as the chairperson of the committee for the planning of i-Construction. Two of the five members of the committee, Kazumasa Ozawa, a professor at the Graduate School of Engineering, the University of Tokyo, and Kazuyoshi Takeyama, a professor at the Faculty of Science and Engineering, Ritsumeikan University, were joined by academic researchers in construction management to complete the report for our study. This was beneficial in order to compile the experience of the interdisciplinary and comprehensive nature of construction management researchers. In addition, as pointed out in the aforementioned papers by Dainty and Leiringer, construction management has immense practical research potential. However, although the research results of construction management are not directly applied to i-Construction, the findings to date have been generated from the viewpoint of improving productivity, introducing total optimisation, and levelling construction timings (Hegazy and Saad, 2014; Lindblad and Guerrero, 2020). Among these, the need to change consciousness in the

construction industry is pointed out from the viewpoint of construction management as a significant contribution in the process. These are important achievements in construction management research and will provide momentum for further research. The emphasis is evident in the analysis of the text of the i-Construction report. We used simple text mining to analyse the i-Construction report. The list of the top 20 extracted words from the Japanese text mining is shown in Table 1.

Table 1

Word	English	Frequency
1 建設	construction	158
2 生産	production	111
3 現場	site	102
4 施工	actual working	72
5 技術	technology	71
6 向上	improvement	62
7 導入	introduction	58
8 i-Construction	i-Construction	58
9 必要	necessary	55
10 IT	IT	54
11 設計	design	45
12 活用	practical use	41
13 管理	management	41
14 労働	labor	39
15 工事	construction work	36
16 データ	data	35
17 維持	maintenance	30
18 基準	standard	30
19 検査	inspection	28
20 作業	work	28

Figure 1 shows a diagram of this co-occurrence network, in Japanese as well as English. This is a visual presentation of what i-Construction aims to achieve and what is needed to achieve it in relevant terms. Particularly prominent terms, such as ‘site’, ‘improvement’, typically indicate that it is an organized report referring to actual construction implementation.

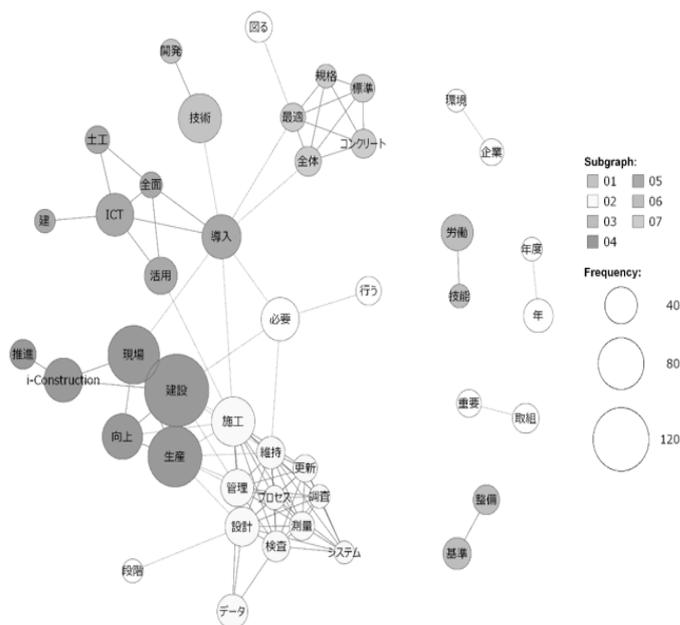


Figure 1

This can also be seen in the use of terms such as ‘construction work’ and ‘work’. Parallel to this, the terminology of ‘technology’, ‘introduction’, and ‘practical use’,

which is geared towards increasing productivity, is conspicuous, and vividly illustrates that the purpose of this report is to increase efficiency. It is also noteworthy that it specifies the conditions for productivity improvement, such as ‘necessity’, ‘ICT’, and ‘standard’. The third aspect is the relationship with digital platforms. In recent years, digital platforms have played an important role in dramatically improving consumer access to the market and to business activities in the market. Relationships with Google, Amazon, Facebook, and Apple (GAFA) cannot be ignored in the construction industry, so we need to consider how we should leverage data. To date, there has been little research in construction management on improving the transparency and fairness of transactions on digital platforms (except for Lavikka *et al.*, 2018). However, it is also necessary to consider how to implement better measures based on the voluntary and proactive efforts of digital platform operators. For example, now that construction without Google Maps is no longer conceivable, it is necessary to think about how to respond to the further shift to a data society and how to channel the market.

From this point of view, ICT utilization and data linkage have been focusing on i-Construction in particular in recent years. MLITT established a plan to develop a “National Transport Data Platform” in May 2019, which would link a large amount of data held by the MLITT with data from the private sector. The aim is to improve the efficiency of operations, improve the sophistication of MLITT's policies such as smart cities, and create innovation through collaboration between industry, academia, and government. In this context, a platform is being built to link data on national land, and to utilize data on national land, data on economic activities, and data on natural phenomena such as weather.

CONCLUSION

In this paper, as Japan's population composition is an issue of increasing concern, we showed that i-Construction, which drastically improved productivity in all construction production processes such as research, survey, design, construction work, inspection, maintenance, and renewal was an important measure, and examined the i-Construction report compiled by the MLITT in April 2016 from the viewpoint of construction management.

In i-Construction, based on the rapid development of satellite positioning technology and IoT, the areas for advancing i-Construction were organised into 3 categories: “Turning construction sites into advanced factories”, “Introduction of advanced supply chain management at construction sites”, and “Regulation of construction sites, breaking stereotypes, and continuing ‘Kaizen’”. As top-ranking policies from these three perspectives, “Full utilisation of ICT (ICT earthwork)”, “Optimal overall deployment (Standardisation of concrete work standards)” and “Levelling of construction time” were set. The characteristic of these policies was that they listed the items to be tackled for each perspective. In addition, as a mechanism for promoting i-Construction, it was proposed to establish a national promotion system, establish a public-private partnership consortium, utilise big data, collaborate with other outdoor industries, and expand overseas. After the compilation and publication of this report, the government created a road map each year since 2017, and progress was steadily advanced for each item, such as the utilisation of 3D data, levelling of construction time, open innovation by open data, and strengthening of the system through public-private cooperation.

This study evaluated this effort in Japan from three viewpoints. The first was the relationship between construction management methodology and i-Construction. The positioning of i-Construction in Japan in construction management methodology was seen to be an arrangement of various management methods in the engineering discipline. The second point of view was the relationship between the interdisciplinary nature and integrity of construction management and i-Construction. The interdisciplinary nature and integrity required in i-Construction was based on the knowledge of construction management to date in terms of human contribution and individual application cases. The third point was the relationship with digital platforms. The relationship with GAFAs is not negligible in the construction industry, and it is necessary for construction management to examine ways to utilise data. The main contribution of this research is that it is the first introduction of i-Construction in construction management research in Japan. It presents an evaluation and positioning of i-Construction and helps to provide material for future construction management research based on this knowledge. However, the limitation of this research is that only an introduction of the case in Japan is presented. It is also important to understand the situation further based on regional and temporal perspectives.

From the empirical perspective as seen in this paper, we have found that the business environment and companies that are built there make good use of the principle for the common good in construction. A different national context would also create opportunities to learn about and contrast approaches to governance, economic models, and the role that the construction industry plays in society. It is expected that this analysis will contribute to the progress of construction management research for the common good in the field of construction.

Postscript

Before concluding this paper, we would like to briefly describe the efforts of the construction-related departments of the MLITT of Japan in relation to new corona infections (COVID-19) as well as a review by the construction management research industry. It may not be directly related to the efforts of the Japanese construction industry to improve productivity, which is the subject of this paper. However, at this point, a paper that does not address this topic is not only meaningless but may also be called irresponsible.

The Government of Japan recognizes that countermeasures against the new coronavirus infection are a critical issue in terms of crisis management. In addition, it has promoted the implementation of basic infection control measures, such as the thorough avoidance of the "three densities", the maintenance of human-to-human distance, the wearing of masks, and hand hygiene, such as hand washing (hereinafter referred to as "the cluster"). On April 7, 2020, a state of emergency was declared. Subsequently, on May 25, 2020, the Government of Japan declared the state of emergency to be lifted. A certain transition period was established to gradually increase the level of socio-economic activity, while easing requests for self-restraint on going out and restrictions on the use of facilities. In this case, it is assumed that the "new lifestyle" to prevent the spread of infection, as described below, would take root and that the guidelines for the prevention of the spread of infection, etc., formulated for each industry, would be implemented.

The construction industry is beginning to see a downward trend in sales and orders due to a drop in private investment and the suspension of construction work by some

general contractors. The construction materials business is gradually improving with the resumption of domestic plant operations in China. Some general contractors have begun to resume construction at the end of May, after consultation with the clients.

It is considered that the information provided here will be updated and compiled as appropriate till the time of the report presentation.

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CONSTRUCTION PROFESSIONALS' COMMITMENT TO THE ORGANISATION, WORK-LIFE BALANCE, AND WELL-BEING

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This theory-driven literature review aims to examine how work-life balance and emerging research in positive psychology may inform our understanding of the underlying mechanisms that affect the organisational commitment of construction professionals. Based on the review, we propose that work-life balance, well-being (i.e. sense of purpose and positive emotions) are linked to construction professionals' organisational commitment. From this we offer a research model and eight research propositions postulating that work-life balance directly affects organisational commitment via promoting sense of purpose and positive emotions. Furthermore, we propose two additional paths where positive emotions mediate the relationship between work-life balance and organisational commitment, and between sense of purpose and organisational commitment.

Keywords: work-life balance, well-being, sense of purpose, commitment

INTRODUCTION

Work-life balance (WLB) and organisational commitment (OC), constructs that are well established in the occupational stress literature, have drawn considerable attention from scholars and researchers in different disciplines in recent decades, because they significantly affect important organisational outcomes such as staff turnover, absenteeism, and organisational citizenship behaviour (see Dwivedula *et al.*, 2016; Riketta, 2002; Timms *et al.*, 2015). Furthermore, the two constructs have been found to influence one another (Sethi, 2015).

Construction contractors are typically unaware of the nature and level of occupational stress experienced by their construction project managers (Love and Edwards, 2005). The dearth of theoretical and empirical research on occupational stress within the industry has contributed to this situation (Haynes and Love, 2004; Love and Edwards,

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2005), and only in recent years have researchers turned their attention to this important topic (Lingard and Francis, 2009; Dainty and Loosemore, 2012; Bowen *et al.*, 2014; Leung *et al.*, 2015; Cattell *et al.*, 2017).

WLB is generally regarded as the balance that an employee needs between the time allocated to work and other aspects of life (e.g. family). OC is about employees' psychological and emotional attachment to their organisations. In the construction literature, the importance of WLB and OC is well recognised. For example, Lingard and Francis (2004; 2009) identified that long working hours, weekend work and excessive workloads, characteristics typical of construction industry jobs, negatively affected the WLB of construction professionals. Poor WLB has been found to be positively associated with employee burnout, mental health issues, substance abuse, and diminished family functioning (Lingard *et al.*, 2007).

Majid (2010) identified OC as an important factor in getting a safety culture embedded into the organisational culture of construction firms. However, despite the research into WLB and OC previously undertaken in the construction industry, little is known about the relationships between the two constructs, or the underlying mechanism driving the relationships. Bridging this knowledge gap could enable the industry to develop more effective and evidence-based interventions and advance theory building of both constructs in the construction context. This paper aims to narrow the knowledge gap by conducting a theory-driven literature review which examines how WLB and certain aspects of well-being may affect the OC of construction professionals. The paper extends other overviews of OC research (e.g. Rose and Muthuveloo, 2005) to specifically look into the construction context and consider how theoretical advances in WLB theory and the positive psychology theory of well-being (i.e. positive emotions and sense of purpose) can inform our understanding of potential mechanisms that affect OC. In particular, construction professionals' WLB is proposed to directly affect their OC. Such a relationship is mediated by sense of purpose and positive emotions. Figure 1 illustrates the hypothesised model that potentially explains "the how" between WLB and OC.

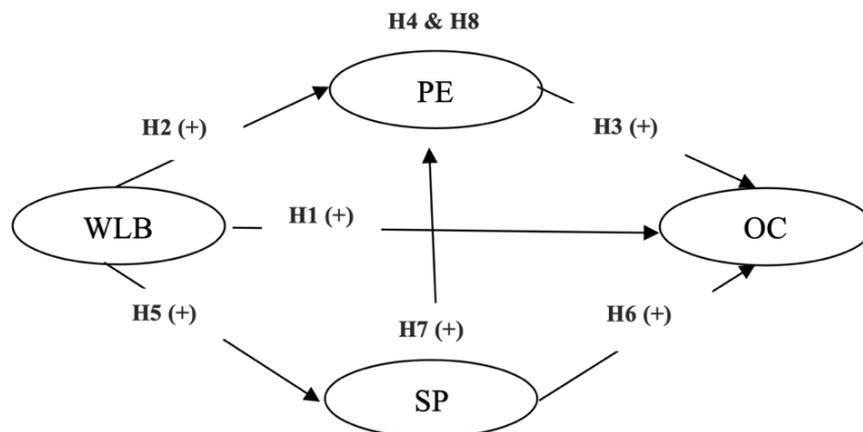


Figure 1: The hypothesised model

The arguments and associated hypotheses will be presented in the following sections in a concept-by-concept manner.

LITERATURE REVIEW

Organisational Commitment

Mowday et al.'s (2013, p.27) definition of OC - "the relative strength of an individual's identification with and involvement in a particular organisation" - is adopted in this paper, but it is noted that OC has also been conceptualised as an exchange between organisations and employees, where employees' involvement is offered with the expectation of rewards and benefits (Hall and Mirvis, 1996). Meyer and Allen's (1991, p.67) conceptualisation is broader, regarding OC to consist of three elements, namely: Affective commitment: An employee's emotional attachment to, identification with, and involvement in the organisation; continuance commitment: An awareness of the costs associated with leaving the organisation; and normative commitment: A feeling of obligation to continue employment.

OC has been associated with a range of business outcomes such as lower turnover intent of the employees (Harrel *et al.*, 1986), lower absenteeism (Blau and Boal, 1987), higher job satisfaction (Ricketta, 2002), and higher productivity (Wright and Bonett, 2002). Similar findings were obtained in relation to construction. For example, Du *et al.* (2006) concluded that construction managers with high levels of organisational commitment have lower turnover intentions. Because of the benefits of enhancing OC, various research studies (e.g. Leung *et al.*, 2008) have examined the antecedents of OC in order to better understand the underlying mechanism of building it; for example, project assignment and acceptance, membership maintenance, job involvement, WLB, and performance feedback and workplace well-being (e.g. Leung and Chan, 2007; Brunetto *et al.*, 2012; Siegel *et al.*, 2005). However, the majority of those studies were conducted in a non-construction context. This paper aims to narrow this knowledge gap specifically for construction professionals.

Previous literature has acknowledged the importance of work context in influencing the cultivation of OC (e.g. Camilleri, 2006; Chih and Lin, 2009; Dwivedula *et al.*, 2016). In this context, construction work, characterised by outsourcing and "flexible firms" (Dainty and Loosemore, 2012), and the project-based mode of its execution, is different from non-project-based work such as manufacturing, because construction projects are usually frenetic, non-repetitive and temporary. Additionally, construction professionals need to perform their work in a dynamic and changeable work environment filled with uncertainties (Asquin *et al.*, 2010) and are thus more likely to work under stressful conditions (Lingard and Francis, 2004). High levels of job demand in construction have been linked to the burnout attributes of cynicism and emotional exhaustion (Pinto *et al.*, 2014). The unique features of construction work justify further empirical investigation into whether, and to what extent, the OC theories and practices found in other disciplines are applicable to construction management in general, and to construction professionals in particular. In fact, lack of knowledge about what influences the level of OC of construction professionals has possibly led to missed opportunities for organisations to develop and implement effective and evidence-based interventions to build OC, and thus enhance construction professionals' performance.

Maxwell and Steele (2003) summarised the antecedents of OC into four categories, namely: personal characteristics; job or role characteristics; work experiences; and organisational structure. The antecedents chosen in this paper fall into the category of job or role characteristics (i.e. work-life balance) and work experiences (i.e. well-being, positive emotions, and sense of purpose) because these categories encompass

characteristics over which construction project managers arguably have the most influence in managing their teams. Therefore, job or role characteristics and work experiences may be more influential in cultivating the OC of construction professionals.

Work-Life Balance

Work-life balance is a frequently used term, but it has been subject to a variety of definitions (Kalliath and Brough, 2008). Sirgy and Lee (2016) proposed an integrated definition of WLB that comprised three elements: (1) balanced role commitment; (2) reduced role conflict; and (3) the absence of social alienation. The presence of these three elements gives rise to WLB, which then results in a bidirectional transfer of net positive emotions between work and nonwork roles, increasing or decreasing life satisfaction overall. To achieve WLB, individuals need to commit across the multiple life domains that are important to them by spending time and energy on each and deriving satisfaction from them equally (Sirgy and Lee, 2016). Lingard *et al.* (2007) define WLB for construction sector employees in terms of the extent of control and flexibility given to employees over how they do their work, the reasonableness of workloads, and the supportiveness of the work environment.

An overarching condition in the industry, though, is that construction professionals typically work very long hours as “an explicit component of the role” (Turner and Mariani, 2016, p. 248). Consequently, it has been found that they encounter WLB issues (Lingard and Francis 2004, 2009). WLB is difficult to attain because the demands of the work role are frequently incompatible with the demands of the family and other life domain roles (Sirgy and Lee, 2016). Supportive organisational policies such as alternative work schedules, telework, wellness programs, and support for child/elder care, as well as personal support systems such as spousal support, reduce work-life conflicts leading to higher levels of life satisfaction, which then yield higher levels of OC (Sirgy and Lee, 2016).

The connection between WLB and OC could be made by viewing WLB through the lens of Self-determination Theory (Ryan and Deci, 2000). In particular, WLB requires autonomy, sense of purpose, and mastery. First, autonomy supports employees to take advantage of the available work flexibility programs, which allow employees to decide when and where to work. Autonomy also informs and supports the employees to establish goals across the multiple life domains which they deem important, while supporting their allocation of time and resources to attain those goals. This flexibility is key to WLB and, for example, was found by Eaton (2003) to be a significant predictor of OC among employees of highly competitive biotech firms. Lingard and Francis (2002) similarly found from their sample of construction industry employees that the job characteristics of long hours and schedule inflexibility - both negatively associated with OC - caused burnout, which led to lower OC. WLB initiatives introduced by the firms of these employees were found to enhance OC. Similarly, an investigation into the effects of the introduction of a compressed working week on a dam project revealed that the resultant improvement in flexibility had a positive effect on WLB (Lingard *et al.*, 2007), although such schedule changes may not be generally acceptable to all construction industry employees (Lingard *et al.*, 2008; Townsend *et al.*, 2011). Notwithstanding findings that work-life experiences do not appear to affect the sexes differently, Lingard and Francis (2002) surmise that this may be due to the underrepresentation of women in the construction sector, where survey samples typically involve far more men than women. In a subsequent study of

women working in the construction sector, Lingard and Lin (2004) argued that OC would be improved by the introduction of career development opportunities and just reward allocation processes. Second, sense of purpose for the employee supports their ability to develop their goals across multiple life domains and align resources appropriately to those goals.

Finally, mastery is supported by the sense of satisfaction attained through accomplishing their goals across multiple life domains; competencies arising from success across multiple life domains also support a sense of mastery in other life domains. Better WLB yields positive emotions which spill over into other life domains and, in turn, benefits WLB (Timms *et al.*, 2015). Insufficient WLB across multiple life domains causes distress for the individual, resulting in conflicted or reduced commitment to the organisation as well as adverse personal consequences to the employee such as burnout (Keeton *et al.*, 2007). Therefore, it is hypothesised that:

H1: Construction professionals' work-life balance (WLB) positively affects their organisational commitment (OC).

Well-Being

Well-being at work is a core construct in positive psychology. It comprises two elements: A eudemonic element (e.g. sense of purpose) and a hedonic element (e.g. positive emotions) (Robertson and Flint-Taylor, 2008). Eudaimonic well-being incorporates variables such as “meaning and purpose in life, supportive social relationships, and feelings of mastery” (Diener *et al.*, 2017, p.134) and in the workplace this is apparent in people who derive a sense of purpose from their work activities (Arnold *et al.*, 2010). Hedonic well-being involves positive emotions, which effectively cause an “upward positive spiral” leading to augmented emotional well-being (Arnold *et al.*, 2010, p.452; Fredrickson and Joiner, 2002, p.172), whereas hedonic well-being is enhanced by an overall sense of purpose (Arnold *et al.*, 2010; Fredrickson *et al.*, 2003). Conceptualising positive psychological well-being as comprising elements of both net pleasure and purpose fits well with the organisational context, since it suggests that part of the experience of well-being originates in positive feelings arising from work activities that are regarded as “worthwhile” (Arnold *et al.*, 2010; Robertson and Flint-Taylor, 2008). In the construction literature, WLB was found to have a positive association with well-being (Rowlinson *et al.*, 2009) and a negative association with mental problems (Kotera *et al.*, 2019). To further demonstrate how construction professionals' well-being could influence the relationship between WLB and OC, the following sub-sections divide well-being into positive emotions and sense of purpose.

Positive Emotions

As mentioned above, to achieve WLB, construction professionals need to have clear goals (purpose) and values to determine what roles are important in what life domain and to be able to align their personal resources, accordingly, thereby deriving satisfaction from each domain. Their satisfaction could lead to positive spill over (Sirgy and Lee, 2016), which includes: positive emotions from different domains “spill over” into other domains; experiences and skills from one domain transfer to and enhance other domains (role enrichment); and role integration or low role conflict across multiple role domains.

According to the Broaden-and-Build Theory (Fredrickson, 2001), positive emotions build people's physical, social, intellectual, and psychological resources, thereby

building resilience and higher levels of life satisfaction (Cohn *et al.*, 2009). It also expands our attention to broader perspectives, helps us generate more creative ideas and actions, supports more inclusive teams, and promotes more flexible mindsets (Cohn *et al.*, 2009) - all of which are essential to enhance OC.

Interestingly, while research on the OC of employees was initially studied to reduce costly attrition in organisations because it predicted intention to stay, OC has also been found to contribute to performance outcomes in organisations (Meyer and Allen, 1991). Findings from research by Herrbach (2006), using a sample of 365 engineers, suggest that positive emotions support an approach response rather than an avoidance response, and that net positive emotions are linked to beneficial outcomes for the employee and their organisation. Herrbach (2006) confirmed his hypothesis that affective commitment is at least, in part, the result of experiencing positive emotions: “affective organizational commitment was related to experiencing a higher frequency of positive affect at work, even when controlling for dispositional affect.” (p.638). Herrbach goes on to suggest that a virtuous cycle may result in which more positive emotions yield greater affective commitment, which, in turn yields more positive emotions at work.

Therefore, it is hypothesised that:

H2: Construction professionals’ work-life balance (WLB) positively affects their positive emotions (PE);

H3: Construction professionals’ positive emotions (PE) positively affects their organisational commitment (OC); and

H4: Construction professionals’ positive emotions (PE) moderates the effect of work-life balance (WLB) on their organisational commitment (OC).

Sense of Purpose

As noted above, to achieve WLB, construction professionals need to have a clear sense of purpose (SP) and some level of autonomy (Eaton, 2003) in order set goals by life domain and align resources equitably among them to assure satisfaction across all life domains. Because employees need to distribute focus across domains rather than singularly focusing on the one domain in order to obtain WLB, WLB supports SP and thus leads to higher OC. Furthermore, resolution of role conflict reduces stress, thereby increasing the net positive emotions experienced by the individual (Sirgy and Lee, 2016). However, misalignment of values, goals and resources across multiple life domains gives rise to inter-domain stress which diminishes the employee’s ability or perception of their ability to act with purpose, actions congruent with their values. This misalignment may reduce the net positive emotions experienced by the employees, thus building the virtuous spiral and diminishing OC. Therefore, it is hypothesised that:

H5: Construction professionals’ work-life balance (WLB) positively affects their sense of purpose (SP);

H6: Construction professionals’ sense of purpose (SP) positively affects their organisational commitment (OC);

H7: Construction professionals’ sense of purpose (SP) positively affects their positive emotions (PE); and

H8: Construction professionals' positive emotions (PE) moderates the effect of sense of purpose (SP) on their organisational commitment (OC).

CONCLUSION

Managing OC represents a major challenge for organisations today, specifically in construction organisations and professional practices where the resources are finite, and the nature of employment is often temporary, contract-based, or specific to a particular project. As a result, motivating the employees to deliver quality project performance and retaining them becomes a daunting task. Therefore, we need to understand the antecedents and mechanisms that lead to OC. However, these facets have not been widely studied in the construction literature. This paper aims to narrow this knowledge gap by presenting a conceptual model based on WLB literature and emerging research in the field of positive psychology. The model proposes that WLB directly affects OC via promoting well-being (i.e. sense of purpose and positive emotions). Furthermore, positive emotions is seen to mediate the relationship between WLB and OC, and between sense of purpose and OC.

The implications of this study are manifold. Scholastically, this study addresses the limited research done in exploring the antecedents and mechanisms of OC in the construction industry context. In addition, given that organisations today need to deal with the problems of job hopping and employee attrition, this study will be able to reveal the type of work experience or condition (i.e. WLB, positive emotions, and sense of purpose) that is most important in cultivating the OC of construction professionals. Finally, this research throws light on interventions that can be applied to make work more attractive and thus better retain project professionals in the same organisation.

A key objective of future research in this area would usefully be to gain a fuller understanding of how recent advances in positive psychology could inform our understanding of what factors, and by which mechanisms, the development of OC in construction professionals may be facilitated. More specifically, the aim will be to empirically examine if WLB and well-being could influence the OC of professionals working in high-risk industries like construction. This focus would allow comparison across industries to be conducted so as to understand whether the proposed model works differently in different high-risk industry settings. Following this line of thought, articulating the multi-level nature of such a model according to job titles would be particularly relevant, for example, the level of comparison between construction professionals and construction workers. A survey-based approach is proposed for the collection of the necessary data to test the proposed model and concomitant hypotheses using structural equation modelling.

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CAPACITY BUILDING FOR TANZANIAN PUBLIC-PRIVATE PARTNERSHIPS (PPPS) PROJECTS: CHALLENGES AND ADVOCATED SOLUTIONS

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Despite the popularity of public-private partnerships (PPPs) as a means of alleviating social housing and infrastructural needs and improving service delivery in both developing and developed economies, the lack of capacity remains one of the major problems in implementing PPPs particularly in developing economies. Empirical studies around capacity building for PPPs are also limited. To address the identified knowledge gaps, this study seeks to examine the challenges impacting the capacity building for the Tanzanian PPP projects, as well as explore the strength of interactions between challenges. Questionnaire survey approach was used to collect data from 81 PPP Tanzanian practitioners who were purposely targeted. Response data was subjected to descriptive statistics, parametric and non-parametric tests to examine the differences in the perception of the identified capacity building challenges, and inherent relationships amongst them. Ensuing descriptive and empirical analysis demonstrated a disparity in the ranking of the 8 challenges among those with and without PPP experience, with 4 having statistically significant differences. Based on the overall sample, the highly ranked seven challenges (mean score > 3.50) in ascending order were: 1) limited local people with experience; 2) lack of resources; 3) lack of successful PPP projects; 4) lack of permanent PPP trainers; 5) higher costs in conducting PPP training; 6) lack of hands-on training; and 7) inadequate qualifications. The least ranked was lack of political will for promoting PPPs. The major finding from the correlation analysis was the existence of the strong and positive correlation between ‘inadequate qualifications’ and ‘lack of hands-on training’. Suggested solutions were nested within the training and education, lessons learnt through PPP project exemplars, benchmarking of PPP projects through local and foreign visit categories. The results of this study foster a better understanding of the different mechanisms for overcoming the capacity building challenges.

Keywords: developing countries, Tanzania, capacity buildings, solutions, PPP

INTRODUCTION

According to the United Nations Development Programme, (UNDP), (2009), strong capacity, locally generated and sustained, is essential to the success of any development enterprise. However, despite the Tanzanian National Development

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Vision 2025 which encourages the Government to seek private sector investments in infrastructure and services development, a number of capacity-building related challenges continues to hamper the PPP implementation efforts by the Tanzanian stakeholders. Likewise, most Governments in developing countries, the Tanzanian government has established PPP Units and associated teams in the Ministry of Finance focusing on skills in PPPs with the public administration. Notwithstanding the importance of capacity building programs in developing countries, studies have shown that capacity building support tended to be directed more towards the countries with higher existing capacity (Umemiya *et al.*, 2020).

The World Bank report (2018) has also suggested that capacity building for other government entities must be undertaken by the PPP units. However, within the Tanzanian context, despite these units (PPP finance Unit, and PPP coordinating unit) being responsible for the assessment, approval as well as the coordination of all PPP projects, studies such as Kavishe *et al.*, (2018) have found these PPP units as being ineffective and underutilised.

This supports Mourgues and Kingombe, (2017) study that mere creation of PPP units is not enough to make them successful. More so, whilst PPPs have been suggested as a strategy to deliver infrastructure and affordable housing in emerging economies, its [PPPs] still a relatively new concept (World Bank, 2016), and lack of capacity particularly remains one of the major problems in implementing PPPs. However, the synergies and the role of capacity building in facilitating the PPP implementation success are acknowledged in literature (World Bank, 2016; Trebilcock and Rosenstock, 2015; Osei-Kyei and Chan, 2018). For instance, Trebilcock and Rosenstock (2015) identified institutional capacity as a key determinant of PPP success.

Capacity building and training have been acknowledged to enhance local practitioners' skills and knowledge in delivering PPPs projects (Osei-Kyei and Chan, 2018). There also been renewed calls and classification of 7 research themes for more research on PPP (Akintoye and Kumaraswamy, 2016), and Cui *et al.*, (2016) identified the need for more research on 'government supervision of PPP projects', and 'knowledge management methods for PPP projects' clearly indicates a need for more PPP empirical studies. The studies reviewed recommend further research on the identification of practical solutions to challenges affecting the capacity buildings around PPP housing projects.

Therefore, a need to explore the capacity building challenges and subsequent advocated solutions with PPP housing projects associated with developing countries such as Tanzania becomes relevant. The present study is aimed at filling the knowledge gap by conducting a survey among the Tanzanian PPP stakeholders. Its aims are twofold. Firstly, identify and rank the challenges impacting the capacity building for the Tanzania public-private partnerships (PPPs) projects. Secondly, it aims to propose ways of improving the PPP capacity building and offer some advocated solutions. The following is an overview of the conceptualisation of capacity building and capacity development. A brief summary of discussions is provided on the extant literature on the challenges affecting the capacity building for implementing PPPs, and the knowledge gap. This is followed by the methodological approach adopted, a discussion of the findings and implications of the study. Some advocated practical solutions for managing the challenges are also suggested. The final section concludes with recommendations and conclusions drawn.

Conceptualisation of Capacity Building and Capacity Development

To facilitate the examination of the challenges impacting the capacity building for the Tanzanian PPP projects, the concepts of “capacity building” and “capacity development” needs to be defined as a number of different definitions for capacity building exists (Ferrero *et al.*, 2019; UNDP, 2009) and contradictions or consensus over the actual definitions of “capacity building” or even “capacity” (Ridge *et al.*, 2018). According to Ferrero *et al.*, (2019), capacity building is defined as a multi-level learning process, and training is one of its components. In contrast the UNDP (2009) defines capacity building as “a process that supports only the initial stages of building or creating capacities and assumes that there are no existing capacities to start from” whereas ‘capacity development’ is defined as ‘the process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time. “Capacity” and “organizational readiness” have also been used in the same context (Spaulding *et al.*, 2017).

According to Manu *et al.*, (2018), capacity building and development is also conceptualised as having three strands of capacity - individual, organisational and national (i.e. enabling national environment). However, this study focuses more on issues pertaining to the individual and organisational facets. Other studies such as Nanfosso (2011) have conceptualised capacity as referring to an acquired or developed knowledge which enables an individual to succeed in a physical or intellectual activity. Within the context of Municipals capacity building, Plummer (2002, pg. 6) offers the following definition: The term ‘capacity building’ includes a broader understanding of capacity that includes human resource development, organisational development and the regulatory framework. ‘Municipal capacity building’ refers specifically to organisational and human resource development (HRD) issues, and those regulatory issues that are within the scope of municipal government. Therefore, drawing upon the review of the definitions as provided, and particularly, that of Nanfosso (2011) which further states that capacity building covers three activities: professional enhancement, procedures improvement and organisation strengthening, the exploration of the capacity building challenges for the Tanzanian PPPs projects, our study is designed to view those challenges from both the organisational and human resource development (HRD) issues, and the areas where capacity is expected to be grown such as an enabling environment, in organizations and within individuals (UNDP, 2009).

LITERATURE REVIEW

The identified studies were selected using a mini scoping review. According to Grant and Booth (2009), this type of review is used for preliminary assessment of potential size and scope of available research literature, with no formal quality assessment required. The SCOPUS database was used, and the following search string of TITLE-ABS-KEY was used: “Capacity building”; “Capacity development; “Public-private partnerships”; “PPPs”; AND developing; countries; housing; projects. This initial search retrieved 3923 articles for the subsequent refinement. These comprised 997 from open access and 2926 from other sources. The scope was further narrowed with the following revised string search: (TITLE-ABS-KEY (“Capacity building” AND challenges) AND PUBYEAR > 2008 AND PUBYEAR < 2020) AND (PPPs). This resulted in 18 document results with the final selected 11 studies identified through reading the abstracts with key focus on the identified keywords.

RESEARCH METHODS

To examine the challenges impacting the capacity building for the Tanzanian PPP projects, as well as explore the strength of interactions between challenges, and propose some practical solution for managing these challenges, an explanatory empirical research was undertaken in the study.

Table 1: Summary of supporting literature on capacity building challenges in PPP projects

No.	Challenge	Supporting literature
1.	Limited local people with experience	Chileshe and Kikwasi (2014); Danish Institute for International Studies (DIIS), (2015); World Bank (2016); Kikwasi and Escalante (2018)
2.	Lack of resources	UPND (2009); Ika and Donnelly (2017)*; Mourgues and Kingombe, (2017)
3.	Lack of successful PPP projects	Plummer (2002); UNDP (2009)
4.	Lack of permanent PPP trainers	Plummer (2002), UNDP (2009); Danish Institute for International Studies (DIIS), (2015); World Bank (2018);
5.	Higher costs in conducting PPP training	Ika and Donnelly (2017); Janssen <i>et al.</i> (2016),
6.	Lack of hands-on training	UNDP (2009); Osei-Kyei and Chan (2018); Ferrero <i>et al.</i> (2019); Mourgues and Kingombe, (2017)
7.	Inadequate qualifications	Plummer (2002), World Bank (2016)
8.	Lack of political will for promoting PPPs	Nanfosso (2011); Voordijk (2012); Danish Institute for International Studies (DIIS), (2015); Kwofie <i>et al.</i> (2016); World Bank (2016); Jansen <i>et al.</i> (2016); Ika and Donnelly (2017); Almarri and Boussabaine (2017); Kavishe <i>et al.</i> (2018); UNDP (2009)

Notes: Drawing upon Umemiya *et al.* (2020), capacity building support in the context of this study means financial and technical assistance in the form of international development projects, aimed at building and strengthening the PPP implementation approaches capacity in developing countries, and using Tanzania as a case study; * Ika and Donnelly (2017) identified financial resources among the structural conditions necessary for measuring capacity building.

Measurement instrument: The questionnaire was comprised of the following 2 distinct sections related to findings as: (1) demographics; and (2) challenges impacting the capacity building process. For section 2, the respondents were asked to rate their perceptions on the 8 challenges impacting PPP capacity building using a five-point Likert-scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree).

Survey administration: A cross-sectional research design was adopted whereby the targeted population included PPP consultants, local authority officers involved in PPP projects, World Bank PPP facilitators and private sector trainees who were attending PPP Training of Trainers (TOT) held from 7th -18th October 2019 at Bagamoyo Beach Hotel in Bagamoyo, Tanzania.

Population and data collection method: As acknowledged by Ferrero *et al.*, (2019), capacity building is a multi-level learning process, and training is one of its components. Therefore, to equip the Tanzanian stakeholders with PPP knowledge, a total of nearly 120 participants from various regions of the country attended the PPP training of trainers organized by the World Bank, Tanzania Country Office. A sample size of 100 potential respondents was estimated with questionnaires prepared and distributed to all the willing participants. Out of 100 distributed, a total of 81 questionnaires were returned on the same day at the end of the training session, of which one was incomplete thus resulting in 80 useable for the final data analysis.

Data analysis: Drawing on methodological justification, including rationale, explanation of null hypothesis of Kavishe *et al.*, (2018) study, quantitative data were analysed using the IBM Statistical Package for Social Sciences (SPSS) version 25. Four methods were employed: 1) Parametric tests were undertaken to measure the significance of the 'challenges'; 2) Descriptive statistics tests such as measures of

central tendencies and frequency analysis enabled further ranking analyses to obtain relative importance of the capacity building challenges; 3) Kendall's concordance analysis and 4) Pearson correlation analysis was used to examine the interaction, strength and direction of relationships among identified challenges.

RESULTS

Reliability analysis: The reliability and internal consistency of the survey instrument comprising the eight challenges as itemised in Table 1 were examined using the Cronbach's α 's coefficient. According to Cronbach (1951), this is one of the most popular reliability statistics which is aimed at determining the internal consistency or average correlation of items in a survey instrument to gauge its reliability. The Cronbach α was found to be 0.807 (F-statistic = 5.261, sig = 0.000) for the challenges instrument thus indicating a high reliability of scales (Nunnally, 1978).

Agreement and consistency of responses: To establish whether there were any agreement and consistency of responses around the eight challenges, Kendall's concordance analysis at a pre-defined test value of 0.05 was undertaken (Osei-Kyei and Chan, 2017, Kavishe and Chileshe, 2019). The results for the test statistics for Kendall's coefficient concordance showed that, the W value obtained for the "challenges" was 0.305, with significance values of 0.000. As suggested by Kavishe and Chileshe (2019), Osei-Kyei and Chan (2017), the χ^2 was used for the pitfalls than the computed W values due to the number of attributes (i.e. challenges) exceeding seven. From the results obtained, the critical value of the χ^2 was 14.08 and less than the computed value of 57.585 with degrees of freedom (df) of 7 thus confirming that there was agreement in the levels of consensus in the scoring of the challenges among the respondents.

Stage of PPP projects: The survey respondents were asked to indicate the stage of the current PPP projects that they were working on. Out of the 80 respondents, only 76.25% (n =61) responded to this question. The results showed that the majority 47 (70%) of the PPP practitioners were currently working on PPP projects which were in the feasibility stage, followed by identification and screening (11.3%, n = 9), procurement (3.8%, n = 3), and operational (2.5%, n = 2). The early stages of the PPP projects or life cycles have been identified as being prone to a number of challenges (Soomro and Zhang, 2013; Kavishe *et al.*, 2018; World Bank, 2018; Jayasuriya *et al.*, 2019). For example, Kavishe *et al.*, (2018) study aimed at identifying and ranking the challenges influencing the delivery of the housing public-private partnership (HPPP) in Tanzania established that the majority of these challenges were more prevalent in the "Procurement phase" followed by the "Preparation phase" with 6 (31.58 per cent). This highlights the need of building capacity around activities associated with these stages. Likewise, financial management challenges have been found to be associated with the early stage of the PPP projects (Soomro and Zhang, 2013; Jayasuriya *et al.*, 2019).

Table 2 presents the descriptive results of analysis for 8 challenges affecting the capacity building of PPPs in Tanzania. Table 2 also presents the results of one-sample t-tests of challenges affecting the capacity building of the PPP projects according to respondent's experience and will now be discussed in some further detail. As shown in Table 2, the mean scores for 8 challenges range from 4.32 (limited local people with experience) to 3.46 (lack of political will), suggesting differences amongst perception of respondents. The CoV of the challenges also ranged between 21.71 and 34.51 percent illustrating the different levels of agreement amongst the respondents.

Results show that the 4 highly ranked ‘challenges’ impacting the capacity building of the PPP housing projects are statistically significantly different ($p < 0.05$) in Tanzania. For ease of discussion, only the top quartile ranked significant challenges factors as well as the least ranked are included in these discussions.

Limited local people with experience: According to the UNDP (2009), the capacity building needs to be developed using the local knowledge, structure and processes. However, the lack of skill amongst the professions in development countries is well documented.

Table 2: Ranking of capacity building challenges

Code	Capacity building challenge	Test value ($\mu = 3.5$)	Sig. (2-tailed)	Mean ^a	Std. Dev	CoV	Rank
CBC1	Limited local people with experience	7.714	.000*	4.32	.938	21.71	1
CBC2	Lack of resources	2.526	.014*	4.12	1.131	27.45	2
CBC3	Lack of successful PPP projects	2.956	.004*	3.86	1.060	27.46	3
CBC4	Lack of permanent PPP trainers	2.308	.024*	3.80	1.143	30.08	4
CBC5	Higher costs in conducting PPP training	1.302	.197	3.65	1.120	30.68	5
CBC6	Lack of hands-on training	1.181	.241	3.59	1.116	31.09	6
CBC7	Inadequate qualifications	1.042	.301	3.53	1.208	34.22	7
CBC8	Lack of political will for promoting PPPs	-.288	.774	3.46	1.194	34.51	8

Notes: ^aMean score based on valid $n = 76$ (list wise), ^bMS = mean score of capacity building challenge where 5= strongly agree; 4=agree; 3=neutral; 2= disagree; 1= strongly disagree. The higher the mean score the more critical the challenge; COV = Coefficient of variation; R = Rank, $df = \text{degrees of freedom}$, *Significant at the 95 per cent level ($p < 0.05$)

Using Tanzania as an example, Chileshe and Kikwasi, (2014) identified project management skills as faced by the contractors, clients and consultants. Likewise, Kikwasi and Escalante (2018) identified ‘inadequate management and human resource skills’ among the number of challenges facing contractors. From the responses, the challenge ‘Limited local people with experience’ (mean = 4.32) was the highest ranked challenge based on the overall sample (mean = 4.70). The lower value of standard deviation (std. dev = 0.938) further reinforces the consensus among respondents in ranking this challenge highly. This challenge was also statistically significant ($t(76) = 7.714, p = 0.000 < 0.05$). The findings are consistent with literature on PPPs. For instance, the World Bank (2016) acknowledges that Tanzania has significant experiences with PPPs, although these have so far produced mixed results.

Lack of resources: ‘Lack of resources’ (mean = 4.12) was ranked second most critical challenge affecting the capacity building in PPP projects in Tanzania. The higher value of standard deviation (std. dev = 1.131) further reinforces the lack of consensus among respondents despite the higher ranking of this challenge. Further examination of Table 2 also shows that this challenge was statistically significant ($t(75) = 2.526, p = 0.0140 < 0.05$). The higher ranking of this challenge is further evidenced by the large mean difference of 1.013. The findings are also consistent with a few earlier studies. Other studies such as UNDP (2009) offer some contradictory viewpoints with the assertion that availability of input resources does not guarantee their contribution to development objectives.

Lack of successful PPP projects: The third overall ranked challenge affecting the capacity building in PPP projects was that of lack of successful PPP projects, (mean = 3.86). Despite the higher value of the standard deviation (SD = 1.060) suggesting the respondents’ lack of consensus around the higher ranking of this challenge, it was nevertheless statistically significant ($t(76) = 2.956, p = 0.004 < 0.05$) and had a

positive mean difference of .3571. Some ways of improving the capacity building were suggested by the survey respondents. Examples and advocated solutions include usage of PPP projects from countries which have similar enabling environment such as Tanzania. This finding is also consistent with the UNDP (2009) which recommended 'experience sharing' through promoting exchange of information and best practices among the countries as a pathway to successful project. Accordingly, the Tanzanian practitioners are of the view that this could be used as case studies for easy understanding and to show how they are successful.

Lack of permanent PPP trainers: According to Plummer (2002), a capacity building strategy should address both skills development and organisational capacity. The World Bank (2016, pg. XV) further acknowledges that a solid training program and public outreach campaign plays an important role in enabling government staff, local governments and the public to understand the rationale for P Likewise, the UNDP (2009) has identified 'expertise on training and learning methodologies' among the indicative activities of capacity building programmes. However, the issue of skilled workforce, and lack of qualified PPP trainers is a significant challenge affecting the emerging economies, and Tanzania is no exception. This further demonstrates why the challenge of 'Lack of permanent PPP trainers' was ranked fourth (mean = 3.80) and assessed as statistically significant ($t(76) = 2.308, p = 0.024 < 0.05$) and had a positive mean difference of .3026. Previous studies further support this finding. For example, the Danish Institute for International Studies (DIIS), (2015), noted that the skills required to identify, assess, procure and implement PPP projects are advanced and in high demand in government and, especially, in the private sector.

Lack of political will for promoting PPPs: According to Mahalingam *et al.*, (2011 *et al.*, cited in Voordijk, 2012), political willingness is a key factor to determining the evolution of the institutional environment. In the lower quartile, "lack of political will for promoting PPPs" was the least ranked (8th) with mean score of 3.46. This challenge was also not statistically significant ($t(76) = -.288, p = .774 > 0.05$) with mean difference of -.0395. The need of an enabling PPP environment and government support as a catalyst for PPP implementation and capacity building is well documented in earlier studies. For instance, Janssen *et al.*, (2016) established that the application of PPPs required local governments to adapt their current working methods. Most functioning of local government in developing countries is associated with the particular Government of the day (or in power), hence any lack of political will would cascade to the functioning of the local government. Similarly, other studies such in developed (Danish Institute for International Studies, 2015); and developing countries (Kwofie *et al.*, 2016; Almarri and Boussabaine, 2017; Kavishe *et al.*, 2018) have identified government commitment as an enabler of PPP implementation process, and 'political support' as a critical success factor which was a good predictor for PPP project performance. For instance, UNDP (2009) Singaporean study demonstrated how strong political will to combat corruption through the introduction of stringent administrative and legal measures to support the anticorruption law could promote capacity building initiatives.

Pearson's correlation coefficient and the coefficient of determination were computed for the eight challenges affecting capacity building for the PPP in Tanzania. As observed by Janssen *et al.*, (2016), the application of PPPs requires local governments to adapt their current working methods, which accordingly amounts to a large impediment to local governments applying PPPs. The results (not shown here) further illustrated the criticality of the challenge of 'lack of resources' as it had a number of

positive, medium and low levels of relationships that has with other challenges such as 'lack of successful PPP projects' ($r = 0.305$); 'lack of permanent PPP trainers' ($r = 0.245$), 'higher costs in conducting PPP training' ($r = 0.245$), 'lack of hands-on training' ($r = 0.237$) and 'lack of political will for promoting PPPs' ($r = 0.232$). The results further revealed that that none of the correlations were of large strength ($r = 0.50$ to 1.0 or $r = -0.50$ to -1.0) as defined by Cohen (1988 cited in Pallant, 2005). In addition, the results also revealed that 15 (53.57 per cent) out of the 28 correlations were significant at $p < 0.01$ and $p < 0.05$ levels with 'inadequate qualifications' and 'lack of hands on training' showing medium strength positive correlations ($r = 0.447$, $n = 71$, $p = 0.000 < 0.01$).

CONCLUSION

In order to gain insights into the Tanzanian stakeholders on the challenges impacting the capacity building for the PPP projects, as well as propose some practical solution for managing these challenges, a quantitative approach comprising questionnaire survey was adopted. Based on the overall sample, the most highly ranked seven challenges in ascending order were: 1) limited local people with experience; 2) lack of resources; 3) lack of successful PPP projects; 4) lack of permanent PPP trainers; 5) higher costs in conducting PPP training, 6) lack of hands-on training; and 7) inadequate qualifications. The least ranked was lack of political will for promoting PPPs. The findings further established that the majority of these challenges were more prevalent in the "Procurement phase" followed by the "Preparation phase". The major finding from the correlation analysis was the existence of the strong and positive correlation between 'inadequate qualifications' and 'lack of hands-on training'. The majority of the advocated solutions were nested within within the training and education, lessons learnt through PPP project exemplars, benchmarking of PPP projects through local and foreign visit categories. This study is significant as it is among the first within the Tanzanian construction and housing-specific empirical studies on the challenges affecting the capacity building for PPPs.

The following important implications are suggested. For government and policy makers, the identification of the 'capacity building' challenges would provide them with an opportunity for the development of appropriate local strategies and coping mechanism specifically conducive for the Tanzanian environment. More so, limited local people with PPP experience and lack of resources ranked 1st and 2nd agrees with Mourgues and Kingombe, (2017) and implies that, the practical local training approach is considered lengthy and leads into another problem of higher costs in conducting PPP training, therefore, the government through the PPP units to design and tailor specific training initiatives associated with capacity building programmes. Secondly, similar to Kavishe *et al.*, (2018), and Plummer (2002) suggestions, the key stakeholders would take part in-house PPP training programmes and enabling environments. The following limitations are acknowledged: Firstly, the survey sample consisted of organisations and PPP stakeholders from one country, namely Tanzania. Evidently, findings may not generalize to other developing countries. Secondly, this study focuses more on issues pertaining to the individual and organisational facets of capacity building, and not the national (i.e. enabling national environment). Therefore, future studies should be extended to empirical coverage of capacity at national level and also in other developing countries.

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AN INTEGRATED APPROACH TO LEARNING FROM PROJECT-RELATED FAILURES

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Project Based Organisations (PBOs) are established to optimise project delivery. Unfortunately, as failures still occur on projects, the anticipated performance enhancements of PBOs have not lived up to expectations to date. This has led to interest in how PBOs learn from project-related failures. Regrettably, despite considerable financial investment on projects, particularly infrastructure projects, there is limited research on learning from project failures. Hence, the aim of this study was to assess the practices and behaviours of project-based actors and organisations towards learning from project-related failures. To achieve that, semi-structured interviews were conducted with construction project management practitioners. Results reveal that systematic attempts to learn from project-related failures are rare. Barriers relate to the temporary and fragmented nature of projects, the negative perceptions around failure, and the fear of being blamed or punished for failure(s). Where such learning exists within PBOs, mechanisms such as project reports and project review meetings are typically used. The cause of project failures ranges from the actions of project actors themselves such as the project manager, designers, contractors and the client, to external events such as financing and technological challenges. The implication for project actors is that instead of relying on ad-hoc learning mechanisms, systemic and sector-wide approaches should be encouraged. This is by integrating the following six facets in the process of learning from failures: structure; culture; psychological; safety; policy; context, and; technology.

Keywords: project failure, PBOs, learning practices, organisational learning

INTRODUCTION

Projects are now ubiquitous in society due to their perceived efficiencies in benefits delivery. This, and the increased use of programs and portfolios in organising activities is being referred to as the projectification and programification phenomenon (Midler, 1995; Maylor *et al.*, 2006; Thuesen and Geraldi, 2016). Unfortunately, projectification has not optimised benefits delivery because 'failures' still regularly occur on projects (Maylor *et al.*, 2006). To counter this, learning from project-related failures is being encouraged in most sectors. Yet, learning from failures in the construction sector is rarely practiced or researched. Consider how the NAO (2020) recently reported on three nuclear projects under the Ministry of Defence (MoD) which are seemingly failing and face an estimated delay of 5 to 6 years and 115% cost

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overruns. Understandably, the NAO (2020) has asked why the MoD has not yet learnt lessons from each of these three projects, or from other nuclear related projects outside the UK. Equally OConnor (2020), observed that the construction sector is failing to learn from past projects with 61% of its clients' programs not reviewing their procurement process in light of lessons from past projects. Perhaps this is a common failing in the construction sector, because learning from failures is easier said than done. This may be due to several barriers including a lack of a standard approach. Instead ad hoc approaches to learning are believed to be more common. Hence the aim of this study was to assess practices and behaviours towards learning from failures with the following objectives being set: (a) review existing PBOs' approaches around learning from project-related failures (b) assess the barriers in learning from failures and (c) suggest a framework for learning from failures that can be adopted by PBOs. Acknowledging the non-agreement on the definition of 'failure', as a guide the study considers project 'failures' as any unintended outcome on a project which could be small or large. These may include cost overruns, delays, poor quality and client dissatisfaction.

Barriers, Practices and Approaches towards Learning from Failures

The regular occurrence of construction project 'failures' continues to generate interest in learning from them. The advantages in doing so are two-fold. First, there is the possibility of avoiding undesirable negative consequences, such as financial losses, environmental and physical damage, or injury/loss of life (Liu *et al.*, 2017). Furthermore, the assimilation of learning from past projects can enhance future performance, and mitigate against future failures (Cannon and Edmondson, 2005; Moore and Price, 2018). Regrettably, there is limited research on learning from failures, and where such studies have been done, they are rarely empirical (Liu *et al.*, 2017). The majority focus on organisational (rather than project-specific) learning and concerns of knowledge management. Such research includes Chan *et al.*, (2005) who looked at organisational learning challenges within a project, whereas Gameson *et al.*, (2008) focused on knowledge management through debriefing. Maqsood *et al.*, (2004) discussed techniques such as project reviews, project audits, after action reviews and post-project appraisals as means of collecting lessons on projects. Research that focuses on learning from failures within construction includes: the theoretical studies by Love *et al.*, (2011) who advocates for the adoption of a systematic approach; Baker *et al.*, (2018) who discusses attitudes and approaches of learning from failure, and; Velikova *et al.*, (2018) who developed a taxonomy of project failure as a way of enhancing learning from it. Use of Information Technology is also latterly being encouraged to assist in this, through automatic learning from construction injuries to using deep learning via artificial intelligence applications (Baker *et al.*, 2019b; 2019a). Barriers affecting learning from failures are identified as the temporary nature of projects, the involvement of a diverse range of professionals within teams, and the emphasis on constraints of the project time and cost targets. A lack of a standard definition of failure and approach to learning within projects and theoretical research have been cited as concerns (Chan *et al.*, 2005; Liu *et al.*, 2017). Cannon and Edmondson (2005) also observed a series of structural (organisational policies, procedures and complex systems) and social-related (senior management behaviour, negative perception and lack of owning failure) barriers. Others identify the poor management of emotions (Shepherd, 2003) and the chaos occurring during failures (Tainter and Taylor, 2014) as additional barriers. Such a

myriad range of challenges signify the need for a comprehensive, integrated approach to address them.

The Proposed Multifaceted Model of Learning from Project-related Failures.

In order to review the learning approaches and behaviour, the study was theoretically informed by organisational learning. Several definitions of organisational learning exist. However, this study uses that provided by Lipshitz *et al.*, (2002, p. 82) who consider it as “a cyclical process involving the evaluation of past behaviour, the discovery of error or opportunity, the invention of new behaviours and their implementation”. Focusing on failures, one deficiency in the extant literature on learning from failure is a failure to address cultural and social factors, by relying on learning mechanism (Cannon and Edmondson, 2005; Carroll and Fahlbruch, 2011). Accordingly, Lipshitz *et al.*, (2002), subsequently supported by Chan *et al.*, (2005), identify five facets necessary for in-project learning. Rejecting a simpler 'two-fold' classification of structure and social systems (see Cannon and Edmondson, 2005), they instead argue that additional, contextual, psychological, cultural, and policy facets should also be considered. Hence, in order to obtain meaningful lessons from failures on projects, an integrated approach, which takes cognisance of the five facets instead of only relying on the learning mechanism, is proposed. This is by building upon the five-facet identified Lipshitz *et al.*, (2002). The five facets, and their relevance to learning from project failures, are as follows:

- A) Structural Facet - which addresses learning mechanisms, and the individuals involved in the detection and correction of the failure, and the organisational sub-systems involved in learning from failures. Mechanisms include post-action-, and project-, reviews.
- B) Cultural Facet - this provides the norms that are needed to create an environment fit for commitment to learning from failures, namely: transparency, integrity, inquiry and accountability. This encourages openness, and a sharing of information regardless of its implication, and assumes responsibility for the whole process of learning.
- C) Psychological Facet - this facet enhances psychological safety, whereby actors take risks that are necessary for learning and sharing information, and lessons from failure achieved by reducing threats while increasing trust.
- D) Policy Facet - this relates to the formal and informal measures put in place by management to encourage learning from failures through rules, budgets, procedures and policies. These are grouped into three: commitment to learning; tolerance for error, and; commitment to the workforce.
- E) Contextual Facet - this reviews the contextual nature of a failure such as its criticality, and its impact, i.e., the costs or losses suffered from a failure event manifesting. The feasibility of getting valid information on a failure is also considered.

Therefore, the rationale considered herein is that these five facets by Lipshitz *et al.*, (2002) create a more favourable environment for capturing and sharing lessons, unlike past studies that simply focus on failure identification, analysis, and learning mechanisms.

RESEARCH METHOD

This exploratory study uses a purposive sampling method, with 7 carefully selected, appropriate construction professionals participating in semi-structured, mixed-mode interviews. In order to improve the quality of responses owing to the small sample size, consideration of the power of information was made by selecting participants with prior information on failure (See Malterud *et al.*, 2016). This was by drawing participants from diverse professions within the construction sector involved in management positions or higher with over 10 years of experience. The participants were also involved in building and infrastructure related projects such as commercial, education and health facilities. These included: 3 directors; 2 project planners; 1 electrical engineer/project manager, and; 1 civil engineer. Five of the interviews were face-to-face while two were telephone interviews in order to reach wide dispersed participants (Bryman, 2012). Due to the nature of the area of study, instead of the naturalised (verbatim) method of transcribing, a denaturalised method (focusing on accuracy instead of transcribing word for word including involuntary vocalisation such as sighs) was used (Oliver *et al.*, 2005). The average length of the interviews was 25 to 48 minutes. Thematic analysis supported by narration was used to analyse the findings which involved identifying the key themes arising from responses and relating them back to the guiding theory (Bryman, 2012). Questions were coded as main themes, whilst responses produced further sub-themes. The facets of organisational learning as proposed by Lipshitz *et al.*, (2002) were also considered as a basis for analysis, and for developing a subsequent framework.

FINDINGS

The main themes from the findings were, as follows:

Causes of Project Failure

In response to questions on the common causes of failures, participants variously advised of a lack of coordination, incorrect information, continuous technological changes, growing project complexities, and the too rushed process of establishing adequate project teams. Inadequate planning, employee turnover, lack of understanding project deliverables and financial problems were other causes variously identified the participants. From this, it was observed that participants tended to externalise the causes of failures. For instance, Participant 6 indicated that “When I took the job, the program was already in place... there was a lot of items missing on the program that wasn't detailed enough. We swallowed up 6 weeks of extra work”. This perhaps reveals reluctance to accept any ownership of failures: instead they are externalised by blaming predecessors or the wider supply chain.

Assessing Current Learning Practices and Behaviour

When asked how organisational learning occurs, most participants cited a use of past project reviews and project 'lessons learnt' reviews involving key project team members. For example, Participant 6 stated that: “We have a lessons learnt meeting... with the director, the project manager, myself, the foreman, the QS team, the designers... got to come forward with our own [thoughts on] why we didn't hand over on time”. Participants 2 and 6 cited the use of intranet portals for uploading lessons from past projects. When asked who should participate in learning from failures, participants used terms such as “everyone” and “top to down[sic]”. Participant 6 supported engaging everyone as this offers every team member an opportunity to say what went wrong which is good for failure analysis. In contrast, Participant 4

favoured only key project members participating (the definition of 'key' being decided based on the nature and size of a project and the failure). Additionally, unlike most cases where PBOs themselves were the focus, Participant 7 included the client. Similarly, Participant 2 argued for the inclusion of project governance bodies (or, indeed, that government) as they also have to learn from failures. Amongst failure-types, similar to the findings by Baker *et al.*, (2018), health and safety related/types of failure were the most frequently referenced as being necessary for learning purposes. Per Participants 2 and 3, this was linked to health and safety management having systems in place for reporting and enforcing within organisations and the sector.

Lack of Cross-Organisational Willingness to Share Lessons from Failures.

Interviews revealed little evidence of sharing failure lessons between organisations. Participation in such cross-organisational or external learning was restricted only to traditional government training programs. However, such learning hinges on the willingness to share failure-related information. Hence, when asked about willingness to share, Participant 5 submitted that it exists but is hindered by external pressures such as political influence, especially on projects funded by government or local authorities. In contrast, Participant 7 reasoned that willingness to share at a personal level is higher than at organisational level, and with bigger firms perceived as being less than willing. A similar unwillingness was observed by Participant 4 between departments within organisations. Such unwillingness to share, as noted by Participant 2, is influenced by the negative impact of failure on the image of an organisation (or a project or a department) while individuals fear any negative repercussions. This is because a common response to failure, as observed by Participants 4 and 5, is the blaming and dismissal of employees. Participants 4 and 6 also noted that 'willingness' is also influenced by individual behaviour, management style and the nature and severity of the failure, all of which can be linked to contextual and cultural facets.

Barriers to Learning from Failures

In response to questions on the barriers to learning from project-related failure, participants variously cited: the lack of an agreed definition of failure; time pressure on projects, and; fast changing technology and teams involving different professions. Participant 7 highlighted the lack of time for adequate reflection and a lack of failures to learn from, which can be associated to unwillingness to share failure information. Others include employee turnover; challenge of new staff accessing information on past failures, and; the non-integration of project information in organisational learning (Participant 4). Participant 4 also observed that punishing and blaming employees, e.g., the PM, for failure(s) often leads to their departure thus depleting an organisations knowledge base. Linked to 'blame', a lack of ownership of failure remains a huge barrier because it is difficult to consider learning from failures without acknowledging them. This 'non-acceptance' issue was revealed by Participant 1 who stated: "its [failure] usually on site as opposed to the design concept ... its usually when you get to site and there is [a] coordination issue with different disciplines.... that's the bit where you tend to find there is a failure". Lack of ownership is also linked to the commercial nature of the industry as "any business open enough to talk about failure in a direct way risks the opportunity of working with that client" (Participant 2). Besides, Participant 5 noted that, low profit of the sector, lack of trust and wanting to just have things done does not afford the time and resources needed for investment in learning. Additionally, institutionalised behaviour or rigid beliefs (i.e.

of not accepting failures) as a barrier was also observed in some of the participants. This was when they externalised failure as being only site-related (Participant 1) or how their organisations (may) have not experienced failure due to having robust risk and PM systems (Participant 2). In both cases, no consideration for learning was apparent.

Enhancing Learning from Failures

In response to a question on how to enhance the process of learning from failures, the need to create an environment with a culture of sharing failure information based on transparency within and across PBOs was highlighted. Participant 6 suggested being proactive and “shouting out” before the project fails. Accordingly, Participant 4 suggested that management and leadership should be open and engaging when handling failure. In addition, Participant 2 stressed the need to allow “room for failing”. Participant 7 also submitted that the industry needs to accept that certain lessons can only come from failures, and from people acknowledging failures. Taking advantage of technological advancement and its opportunities for learning from failures was also identified. For example, Participant 2 suggested use of a portal for submitting project reviews with the possibility of machine-learning and artificial intelligence. Fundamentally, since project-related failures are subjective, instead of taking a universal approach to failure, each organisation should pay attention to the key stakeholders' needs on each project and its overall delivery process (Participant 2 and 4). Participant 1 also stressed the need for inter-discipline learning because it is “dangerous to concentrate just on your expertise”. Thus, with reference to Bakker *et al.*, (2011) the unique, inter-disciplinary and transient nature of projects can be considered as hubs for knowledge creation and learning instead of being barriers. Essentially this calls for a change in culture as echoed by the participants. For instance, Participant 2 submitted that the need to change culture by moving away from a notion of: “we produce deliverables, towards we produce a landscape of information that everyone uses”. Hence, instead of focusing on project outputs and on completing the 'job' alone, consideration should also be given to capturing lessons and allowing for meaningful reflection during project delivery. On that basis the study argues for a systemic and integrative approach as discussed in the following section.

Framework for Learning from Failures and Discussion

Considering Lipshitz *et al.*, (2002) five facets of organisational learning, though measures for enhancing learning from project failures were provided, current practices are ad hoc and isolated with a focus on Structure (learning mechanisms). Evidently, little or no attention is given to the other facets such as: Policy (rules encouraging learning); Culture (support given to allowable failures), and; the Psychological (how safe employees feel to experiment). Consequently, such ad hoc means do not address the social related barriers such as the negative perception of failure, blaming and non-acceptance of failure. To counter that, the study favours an integrative and systemic framework by building upon the works of Lipshitz *et al.*, (2002). Such integration is viewed from two perspectives: the level of analysis (or learning) itself, as from either the organisation, project or individual actors (see Goodman *et al.*, 2011), and; the learning facets/disciplines advocated by Lipshitz *et al.*, (2002). This is in line with Participant 3 who recommended that organisations need to encourage the acceptance of failures among their employees through various possible ways such as organisational culture and policies. Therefore, aligning with Davis and Marquis (2005) and the participants perspective of involving everyone, integration has to be

both at the level of analysis (or learning) and the facets instead of a simplistic approach focusing on one facet. However, from the data analysed, one limitation associated with model by Lipshitz *et al.*, (2002) is that it does not explicitly consider technology which was recommended by Participants 2, 3 and 6. Accordingly, in developing the framework, besides the 5 facets by Lipshitz *et al.*, (2002), the technological facet is included for capturing and sharing failure related information as shown in Figure 1.

	Individual Level			
Sectoral level	Structural	Cultural	Policy	Project level
	Psychological	Contextual	Technological	
Organisational level				

Figure 1: Integrated Framework for Learning from Failure (Adapted from Lipshitz *et al.*, 2002)

From the interview data analysed, though some facets in Figure 1 were highlighted, they were presented or applied singly, and the majority remain unaddressed or lacking in practice. For instance, focusing on the Cultural and Psychological facets, Participant 2 indicates that employees are scared to speak when something goes wrong fearing both being punished, and the negative commercial impact on their business. The Policy facet is equally lacking in practice as only two participants indicated that they have deliberate measures in place for capturing lessons. Participant 4 also indicated that mostly they rely on individual initiative with Participant 1 admitting that “We don't really have anything internally; we don't really do things for that stuff [learning from failure]”. The Contextual facet also received little consideration even though Participant 4 suggests that the nature of failure should dictate who participates in the learning and the willingness to share failure information. Additionally, though organisations argue that it is not possible to learn from other projects and PBOs due to aspects of uniqueness, Participants 5 and 6 indicate that common failures are encountered on similar projects. Hence, based on Figure 1, the Structure facet should encourage cross-organisational learning as advocated by Stead and Smallman (1999). Thus, the four levels of leaning in Figure 1 also serve as sources of failure lessons. This is in order to avoid the myopia of internal (organisational level) learning as discussed by Chan *et al.*, (2005). Similarly, Sydow *et al.*, (2004) advocated for sector wide 'Competence Networks' as a means of learning across organisations or projects.

Therefore, Figure 1 reveals that for PBOs to learn from failures, in addition to the learning mechanisms they should have: A culture committed to learning from failures; policies to support this; participants enabled and encouraged to take meaningful risks; contextualised failures, and; they should take a sector wide perspective. Thus, instead of relying on learning mechanisms solely (structural facet), the study calls for the integration of the six facets in order to mitigate a myriad of barriers associated with learning from failures which in most cases are associated with the cultural and behaviour factors (Cannon and Edmondson 2005; Love and Curtin, 2019).

CONCLUSION

When examined through a lens of organisational learning, and based on the work of Lipshitz *et al.*, (2002) the construction industry, if it engages at all in learning from project failures, relies mainly on the structural' facet. However, failures in projects are complex with varied causes, and there are barriers to capturing lessons from them. Simply relying solely on mechanisms such as post-project and post-action reviews alone will not permit meaningful learning to take place. Besides that, project

environments have seen an increased use of networks and alliances (Davis and Marquis, 2005; Maylor *et al.*, 2006). Therefore, it is imperative that the sector considers cross-organisational learning with practitioners taking a wider view and embracing the idea of a community of learning amongst PBOs supported by all six facets, instead of focusing on only project outputs and relying on ad-hoc learning mechanisms. One immediate limitation of the study recognised is that, owing to the current small sample size, the findings herein cannot be generalised. It is therefore recommended that similar future studies consider these issues, testing them against a bigger sample size.

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A PERFORMANCE BARRIER? CAVITY BARRIER INSTALLATION IN WALL ENVELOPE MAKEUPS

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Fire protection in wall envelope makeups post Grenfell has understandably focused on materials deemed acceptable for use depending on overall building height. Cladding and insulation products have received most attention in the aftermath of the amendment made to Regulation 7 of The Building (Amendment) Regulations 2018 (TSO, 2018). Whilst acknowledging the importance of the amendment to Regulation 7, this paper is suggesting that the area of workmanship related to detail assembly and product or component installation, more specifically cavity barrier installation, deserves equal focus in the drive for improved quality within the sector. The potential for defects in the installation of cavity barriers in ventilated rainscreen envelope makeups has been investigated by employing a mixed method research approach. Qualitative analysis in the form of an exploratory focus group was undertaken with industry professionals to gain a better understanding of potential defects occurring during wall envelope construction. The qualitative data was supplemented by a Failure Mode and Effect Analysis with building control professionals, evaluating the probability of a range of possible defects occurring during installation and the severity of the negative influence of each if they did occur. The results from this study highlight the importance of workmanship in the construction of wall envelope makeups to achieve the requisite standard of fire protection. The paper concludes by highlighting that breaks in the continuity of cavity barriers during on-site installation is an important parameter which requires consideration and proposes a method for assessing the impact of this occurrence in the stated wall envelope makeup.

Keywords: defects, cavity barrier, design management, façade fire, high-rise building

INTRODUCTION

The tragic events at Grenfell Tower in June 2017 led to the publication of The Building (Amendment) Regulations 2018 (TSO, 2018), with a change to Regulation 7, Materials and Workmanship, focusing on material performance classification in relation to fire. This amendment was unsurprising considering the events at Grenfell, and more broadly, the significant fires which have occurred worldwide over the last decade (see Guillaume *et al.*, 2018), many concerning the use of combustible cladding. The amendment to Regulation 7 focused on material performance as opposed to workmanship, with the requirements for the latter clearly stipulated in both the Regulations and Approved Document 7 (HM Government, 2013). For building

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work, the Building Regulations 2010 (TSO, 2010) outline that it should be undertaken “in a workmanlike manner”, with Approved Document 7 stating “Workmanship is such that, where relevant, materials are adequately mixed or prepared and applied, used or fixed so as to perform adequately the functions for which they are intended.”

There is an expectation that workmanship is viewed as being of equal importance to materials in the delivery of a robust built asset which complies with the legislative requirements. However, it should not be assumed that all workmanship results in compliant building detail assemblies. This paper focuses on one specific intricate detail assembly, namely wall envelope makeup in ventilated rainscreen systems, where there is a potential for issues with the as-constructed assembly due to its complex nature. With a focus on building performance from a passive fire protection, building and life safety perspective, the aim of the paper is to identify potential areas of concern relating to in-situ detail makeups and the possible resulting effects.

Workmanship and Fire Protection

As-constructed detail assemblies deviating from approved technical designs, with inadequate workmanship just one of many possible reasons for this, is an issue which has been well documented within the construction sector (Littlewood *et al.*, 2017; Hackitt, 2017; Comiskey *et al.*, 2018; Daly *et al.*, 2019). Research from the Chartered Institute of Building (CIOB) has illustrated issues with the management of quality in terms of workmanship (CIOB, 2018), with the content of the independent inquiries into the Construction of Edinburgh Schools (City of Edinburgh Council, 2017) and the DG One Complex (Dumfries and Galloway Council, 2018) reinforcing this assertion. The importance of good workmanship is widely acknowledged, especially as it can have a significant impact on protection against fire spread (DCLG, 2008). However, there is potentially a lack of awareness amongst unskilled tradespeople on the importance of specific areas of passive fire protection, namely fire and cavity barriers (DCLG, 2008), which could result in non-compliance of key detail assemblies. Others have made the link between on-site workmanship and the potential impact on fire protection strategies. A paper by Daly *et al.* (2019) alluded to issues with supervision and the seemingly oblivious need for installation of critical components, from a life safety perspective, to be exactly as per manufacturers specification. Littlewood *et al.* (2017) echo the sentiment that detail integrity is not assured, with possible shortcomings in the building fabric potentially contributing to the spread of smoke and fire. Decade long research undertaken by Building Research Establishment (BRE) Global identified that, out of approximately 106 fires investigated, 34 had an aspect related to concealed fire spread, and out of these 34, around half mentioned cavity barrier issues, either solely or along with other issues (Shipp *et al.*, 2015).

Cavity Barrier Installation

The potential for in-situ issues with cavity barriers in refurbishment projects was illustrated in expert reports as part of the Grenfell Inquiry (Bisby, 2018; Lane, 2018). Notable observations included some cavity barriers not being fitted as per the manufacturers specification and examples of breaks in the continuity of cavity barriers resulting in what was described as an “interconnected network of connected cladding cavities” (Bisby, 2018). This paper is not speculating on cause, rather, highlighting challenges which can be encountered with in-situ cavity barriers generally, acknowledging that even perfect installation which follows the specification of the manufacturer is not a panacea in all situations. It is recognised that cavity barrier performance in the event of a fire which bypasses the cavity barrier via a combustible

external surface is somewhat irrelevant (Lane, 2018) and in the case of Grenfell, it is unlikely that even if all cavity barriers had been installed exactly as per the manufacturer specification, that this "would have been effective in preventing lateral spread of fire or smoke" (Bisby, 2018). A study by Guillaume *et al.* (2018) further illustrated the ineffectiveness of cavity barriers when the fire is driven by combustible materials as the cavity integrity is not ensured. However, it is important to stress the importance of cavity barriers as part of a well-considered passive fire protection strategy. Colic and Pecur (2020) emphasise their significance in the event of a fire, something illustrated in a study by Giraldo *et al.* (2013), and that on-site installation is critical. In the event of a fire, on-site workmanship and material installation related to key details can play a significant part in helping to reduce the overall impact on the building structure, delaying potentially disastrous situations and providing a window of opportunity for fire and rescue services to intervene.

Workmanship and Inspection

Improving workmanship quality is one area addressed by the CIOB in their 'Code of Quality Management' (CIOB, 2019), with suggestions made in relation to training, incentivisation, supervision and a greater emphasis being placed on those constructing buildings to produce good workmanship. However, this is not a magic bullet. The nature of the industry means there is always the potential for human error during construction resulting in as-constructed detail assemblies not meeting the required regulatory standards. It is also important to acknowledge that, with the majority of buildings which will be around in 2050 having already been constructed (Ford and Gillich, 2018), this means that even with exemplary workmanship standards over the next three decades, there will still be uncertainty over the quality of many built assets. Mindful of this, the focus of this study is to identify potential defects and discuss possible resulting effects in the area of greatest significance, that being already constructed buildings including those which have been refurbished.

Workmanship, inspection, and quality are interlinked and there is huge scope for advances in inspection techniques for quality checking, both during and after construction. Such advances are already taking place in the form of the development of inspection apps (Siderise, 2020), which could be supplemented by the application of existing technologies, such as infrared photogrammetry, or via innovative digital solutions. Daly *et al.* (2019) have already highlighted the potential for inspection of cavity barrier positioning, prior to encapsulation within the building fabric, using point cloud overlay on a project Building Information Model. However, this is a separate area of investigation which is outside of the scope of this paper.

Ventilated Rainscreen Systems

A deficiency in an as-constructed detail assembly poses a concern in any building type, with the significance exacerbated in complex medium and higher rise residential schemes due to the level of human occupancy. Ventilated rainscreen systems are a popular choice of external wall envelope for such buildings, used in both new build and refurbishment settings (Guillaume *et al.*, 2018; Asimakopoulou *et al.*, 2016; Giraldo *et al.*, 2013). A ventilated rainscreen system is essentially a façade assembly made up of an outer panel, a ventilated cavity and an inner leaf. The air flow in the cavity provides several advantages both from an energy and moisture prevention perspective. A process of natural convection can take place in the cavity resulting in a chimney effect. Should a fire occur in the cavity, flame extension can be excessive and become elongated, to between five and ten times the original length (Colwell and Baker, 2013; Asimakopoulou *et al.*, 2016), as oxygen is sought to sustain combustion,

facilitating rapid fire spread through the hidden cavity if the barriers to prevent this are not in place (Colwell and Baker, 2013; Asimakopoulou *et al.*, 2016). The design of the cavity, a concealed space, is considered as a critical detail assembly from both a fire and life safety perspective, with the role of cavity barriers in this assembly playing an important part in the passive fire protection strategy. Workmanship detailing is therefore key in ensuring the cavity has a clear ventilation and drainage channel which, should a fire occur, fully fills to act as a seal, preventing the spread of smoke and fire. Asimakopoulou *et al.* (2016) outlined that much of the literature related to ventilated façade systems has focused on energy performance as opposed to their behaviour in relation to fire, but that in the event of a fire, such systems may contribute to fire spread. As such, additional research is required to fill this knowledge gap.

Cavity Barrier Requirements

This paper focuses on the design requirements of cavity barriers in medium and high-rise residential schemes, more specifically ventilated rainscreen systems. It will refer to Approved Document B Volume 2: Buildings other than dwellings (HM Government, 2019), referred to as ADB in the remainder of this paper, as the reference document providing practical guidance in terms of meeting the requirements of The Building Regulations 2010 (TSO, 2010) and subsequent amendments. It is acknowledged that the devolved regions of the United Kingdom (UK) have their own technical guidance documents related to fire safety; Technical Booklet E in Northern Ireland (DFP, 2012), Building standards technical handbook 2019: non-domestic in Scotland (Scottish Government, 2019) and Approved Document B Volume 2: Buildings other than dwelling houses in Wales (Welsh Government, 2015), and that separate guidance on fire safety is provided by the Centre for Window and Cladding Technology (CWCT) in their Standards for Systemised Building Envelopes publication (CWCT, 2005) and the more recent Technical Note 98 (CWCT, 2017). However, the sole focus of this paper is ADB in England.

Regulation and Technical Guidance Requirements

To comply with the legal requirements of the building regulations, B3 (4) (Building regulations, 2010) states that “The building shall be designed and constructed so that the unseen spread of fire and smoke within concealed spaces in its structure and fabric is inhibited.” Cavity barriers are key in this regard in ventilated rainscreen makeups. For clarity, the definition of a cavity barrier as provided in ADB is a construction within a cavity, other than a smoke curtain, to perform either of the following functions.

- Close a cavity to stop smoke or flame entering
- Restrict the movement of smoke or flame within a cavity

The term should not be confused with similar phrases used in relation to passive fire protection such as cavity closer, fire barrier and fire stopping. In simple terms, in the event of a fire in a ventilated rainscreen makeup the purpose of a cavity barrier is to cut off the supply of oxygen to prevent the chimney effect. It also cuts off potential fuel supplies to a fire in the form of materials above and below, so the fire is contained within a compartment for a time period in accordance with the regulations. In ventilated rainscreen systems, vertical barriers are installed to fully fill the cavity. Due to the need for ventilation, horizontal barriers do not fully fill the cavity. Instead, an intumescent strip is placed on the outer face of the cavity barrier, which, under normal conditions facilitates the required ventilation gap to be achieved. In the event

of a fire, and when a critical temperature is achieved, the intumescent strip activates, expands and fully fills the cavity. Section 12.8 of ADB states that cavity barriers should be provided as set out in Section 9 of the same guidance document, with the key requirements for the area of focus for this study including:

- The provision of cavity barriers around openings and junctions between external cavity walls and compartment floors and walls
- Maximum dimensions of cavities as per Table 9.1 of ADB
- The requirement to provide 30 minutes integrity and 15 minutes insulation
- Acceptable materials for use specified
- The requirement for adequate fixing, with the term "tightly fitted" used
- Guidance on allowable openings, which are limited to few scenarios

With the regulations and technical guidance setting out clear requirements for the performance of cavity barriers and the review of literature highlighting potential workmanship and installation concerns more generally, a research methodology was developed to further investigate the likelihood of deficiencies and their impact.

RESEARCH METHODOLOGY AND DATA COLLECTION

This study is an example of real-world research, as discussed by Robson and McCartan (2016), in so far as it is identifying a current problem and seeking to progress research into the area. To further explore the findings emerging from the review of literature a mixed-method approach was deemed most suitable. This consisted of a two-stage approach, a qualitative analysis in the form of an exploratory group interview, with the findings from this forming the basis for a Failure Mode and Effect Analysis (FMEA) undertaken as part of a focus group. The group interview was undertaken for exploratory purposes, to allow for a better understanding of the topic area, ascertain the feasibility of follow on work and methodological techniques, identify nuances and add precision (Frey and Fontana, 1991 citing Babbie, 1989).

The FMEA was influenced by the work of Dubas and Paslawski (2018) and a combination of the nominal and interacting group models, as described in Adams (2006), was used along with a vignette technique, that being eleven construction defects related to cavity barriers visually represented. Each scenario was presented to members of a focus group, consisting of eight building control professionals, with each member given time to record their individual observations for each scenario should they so wish. This was followed by a group discussion before figures were agreed to give an overall value for which a risk level could be attributed (Table 1). In the case where there was no unanimous agreement, an average figure was taken. The FMEA approach was selected as it collects numerical data which can be analysed, allowing for identification of critical junctures in ventilated rainscreen makeups where risk is greatest. Ethical approval was sought and obtained for the study.

Professional Insight and Analysis

An initial exploratory group interview took place with two industry professionals, both from a leading fire safety engineering consultancy, and focused primarily on on-site inspection processes. This exploratory work was aimed at identifying common defects which had the potential to occur in the construction of ventilated rainscreen makeups, specifically in relation to cavity barriers, based on the industry experience of those being interviewed. The discussion suggested that the potential for incorrect and substandard quality installation of cavity barriers was higher in commercial and larger

scale projects. As highlighted earlier in this paper, reference was made to tradespeople, as opposed to specialist installers, installing cavity barriers on projects, with issues arising requiring the work to be redone several times before installation was deemed as being satisfactory. It was stated that, due to the rapid erection of many larger scale projects, aspects such as this can be easily missed, especially if frequent inspections are not undertaken. The findings from the exploratory group interview formed the basis for the FMEA (Table 1).

Table 1: Failure Mode and Effect Analysis

Probability: 1-extremely unlikely, 2-remote, 3-occasional, 4-reasonably possible, 5-frequent

Severity: 1-no effect, 2-very minor effect, 3-minor effect, 4-critical, 5-catastrophic

Risk Level: < 9 Low, < 12 Moderate, < 15 High, ≥ 15 Unacceptable

Description of Defect	Probability (P)	Severity (S)	Risk (P x S)	Risk Level (RL)
Inadequate installation of fixing brackets, either the number of brackets used not being in accordance with manufacturers recommendations or the installation being defective	3	3.5	10.5	Moderate
Missing cavity barrier, either vertical or horizontal	3	4	12	High
Cavity barrier in place but sagging in the cavity due to issues with the fixing brackets	3	3.5	10.5	Moderate
Vertical cavity barrier installed in a horizontal position	2	4	8	Low
Horizontal cavity barrier installed in a vertical position	2	1	2	Low
Horizontal cavity barrier installed with the wrong orientation i.e. upside down	2	3	6	Low
Gaps between cavity barriers	4	3	12	High
Cavity barrier connection joints not taped in accordance with manufacturers recommendations	4.2	2	8.4	Low
Cavity barrier placed in front of insulation i.e. insulation placed first which is not in accordance with manufacturers recommendations	2.2	4	8.8	Low
Incorrect dimensional gap between the rear of the cladding panel and the cavity barrier	2	4	8	Low
Cavity barrier material substitution	2.8	4.2	11.8	Moderate

DISCUSSION

The findings highlight that in terms of risk level, missing cavity barriers and gaps between cavity barriers have the highest ranking. Perhaps more importantly, in terms of probability of occurrence, gaps between cavity barriers and joints not being taped were ranked the highest. The requirement for taping of the joints is something highlighted by certain manufacturers of cavity barriers in their installation guidance documents (Siderise, 2019). The findings from this study are in broad alignment with a study by Comiskey *et al.* (2019) which also highlighted potential inadequacies in relation to gaps between cavity barriers in ventilated façade makeups. Note that whilst Comiskey *et al.* (2019) use the term ‘fire barriers’, its scope and the vignette clearly illustrated this was in relation to an enclosed cavity in a wall envelope makeup. The findings would suggest that there is a genuine potential for breaks in the continuity of cavity barriers when installed on-site.

Impact of Cavity Barrier Gap

It is reasonable to assume that a break in the continuity of a cavity barrier caused by a gap could provide a passage for the movement of smoke from one compartment to an

adjoining compartment and would therefore be in contravention of the building regulations. A gap could potentially occur where two cavity barriers abut, perhaps most critically at external or internal corner junctions with mitred edges or around doors and windows. Additionally, where vertical penetrations sometimes occur through horizontal cavity barriers, such as with rainscreen support rails.

Consideration of the movement of smoke is important due to suggestions that a major cause of fatalities in a fire is due to spread of smoke and its inhalation (Cheung *et al.*, 2006), with smoke gases being ranked as more dangerous than heat or particulate matter by respondents in a paper by Littlewood *et al.* (2017). Whilst acknowledging their scope and focus is not the same as what has been identified for this paper, several authors have highlighted the possibility of unwanted spread of smoke if there are potential issues with construction. Cheung *et al.* (2016) discussed the impact of gap size around fire-rated doors on smoke spread. Littlewood and Smallwood (2017), in a study which included both a dwelling and flats, demonstrated the effect of potential failings in the building fabric in relation to the spread of smoke. They concluded by suggesting that compartmentation between dwellings within the UK context is potentially not working in relation to smoke and fire spread, with a high likelihood of injury or death in the event of a real fire.

There is a need to discuss and highlight the potential consequences in higher rise projects which have different, and could be argued more complex, wall envelope makeups and detail assemblies. With added complexity comes the greater risk of workmanship or product installation issues. It is therefore important to have an awareness and understanding of what these are and their potential significance. The FMEA has begun to address the former, but the impact of such failings also needs to be investigated. Should gaps exist between compartments in a ventilated rainscreen makeup, what is the likelihood of smoke not only spreading between compartments but making its way into a building and the potentially serious consequences this presents in relation to life safety. A speculative analysis would suggest that such a likelihood is minimal as the smoke would need to find a pathway through various layers of the wall envelope makeup. However, analysis of as-constructed detail assemblies identified in this paper would suggest that it is a possibility and thus needs to be considered further, along with the impact of the dimensional tolerances of any gaps.

Methods of Analysis

The only way of understanding the true impact of gaps between cavity barriers is via the results of experimental testing or simulation. Full scale fire tests which align with the area under investigation as described in BS 8414-2:2015+A1:2017 (BSI, 2017) and supporting document BR135 (Colwell and Baker, 2013), and intermediate scale fire tests as per ISO 13785-1 (ISO, 2002), are all undertaken in a laboratory and therefore assume "perfect and controlled conditions" (Colic and Pecur, 2020). This is echoed by Littlewood *et al.* (2017) who caution that testing of products does not account for in-built performance, with the potential for components and products not being installed as specified. Colic and Pecur (2020) acknowledge "detailing is difficult to evaluate." These tests are unlikely to provide the data required, not to mention the considerable cost associated with them.

Computational Fluid Dynamics (CFD) simulation is also often used to predict the likely consequence of a fire (Drean *et al.*, 2019), but for this to be accurately modelled a detailed understanding of the materials and their performance under simulated real-

world conditions is required. In the case of ventilated rainscreen makeups, an understanding of the impact the intumescent strip has on the gap between cavity barriers would be beneficial before such analysis takes place. For instance, what impact does the intumescent strip have in the event of a fire, does it potentially close any gap between the cavity barriers and thus negate the impact of the gap. There are other related questions such as what impact the size of the gap has on the performance of the intumescent strip. With this in mind, this paper is proposing that a logical first step could be to adapt the fire test identified in the Association for Specialist Fire Protection (ASFP) (ASFP, 2014) which is designed to evaluate the fire resistance of open state cavity barriers in ventilated rainscreen systems, specifically focusing on the upward spread of fire. Whilst this test is focused on the intumescent strip and the time from ignition until the cavity barrier is sealed, this test could be adapted, with a gap left between cavity barriers to evaluate the impact of the intumescent strip under test conditions. This would provide an insight into the potential effect of the gaps.

CONCLUSION

This paper has highlighted the potential for deficiencies in the installation of cavity barriers during on-site operations, with gaps or breaks in the continuity of cavity barriers posing a high risk and having a high probability of occurrence, along with joints not being taped. Such occurrences, certainly gaps between cavity barriers, could be considered as being in contravention of the building regulations. To evaluate the impact of this occurrence this paper is suggesting that the fire test identified in ASFP (2014) could be adapted to evaluate the effect the intumescent strip has on gaps between cavity barriers under differing dimensional tolerances. This would provide a better understanding of the likely gaps being present in the event of a fire, after the intumescent strip has been activated, and allow for CFD analysis to predict the severity of consequence in terms of smoke movement between compartments. Once a fuller understanding is developed, medium and large-scale testing could be undertaken to evaluate the likelihood of smoke not only moving between compartments but finding a path into the inside of a building.

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FACTORS CAUSING FATIGUE AND SAFETY-RELATED ERRORS ON CONSTRUCTION SITES IN BLOEMFONTEIN

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Fatigue is experienced as mental and muscular (physical) exhaustion that obstructs actual work performance. The factors that contribute to fatigue which, in turn, leads to errors on construction sites, were explored in the reported study. Using a case study approach, semi-structured, face-to-face interviews were conducted to obtain responses to "What factors cause fatigue that leads to human errors in construction?" Data were collected from construction sites in Bloemfontein to examine the phenomenon through the lived experiences of people in construction. The interviews were conducted with site management, professionals and craft workers in the frontline of physical site construction work. The interviews were audio-recorded and transcribed before being analysed. The results affirmed the notion that fatigue could lead to human errors through muscular and mental exhaustion that reduces alertness and, then, impede the ability to complete tasks correctly. A fatigued worker would have reduced mental alertness that increases the likelihood of unintentional errors (slips and lapses) which, in turn, could lead to accidents. The origins of fatigue cited by the interviewees included: long hours of work, lack of comfort or rest breaks in between shifts, dehydration while working, excessive heat or cold, and lack of food. The various on-site activities during which incidents occurred, where fatigue was implicated, included: loading and offloading materials, digging trenches, brickwork and plastering. Therefore, there is a need to rethink work procedures on sites where fatigue plays a leading role in the manifestation of errors with safety implications. The results from this case study provide the impetus for further research into the mental and physical factors that cause fatigue and the practices that perpetuate it on construction sites. Reducing fatigue supports fairness and social justice in promoting the Common Good agenda on sites.

Keywords: errors, fatigue, safety, site work

INTRODUCTION

Fatigue is a feeling of mental and physical exhaustion that leads to the inability to perform work effectively. A fatigued person will be less alert, less able to process information, and slow to react to events when compared with a person who is not fatigued (Zhang *et al.*, 2015a). Fatigue can lead to errors in task performance (Techera *et al.*, 2016). Human error leads to injuries and fatalities, including a

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reduction in the quality of work and productivity of workers (Hagan, Montgomery and O'Reilly, 2015).

The most significant outcomes of fatigue include short-term, cognitive and physical degradation and, to a lesser extent, error, injury, and illness (Techera *et al.*, 2016). Performance and productivity also suffer in construction when people are fatigued (Aryal, Ghahramani and Becerik-Gerber, 2017). The drivers of fatigue include sleep deprivation and work environment factors such as noise, vibration, and temperature.

In this paper, a descriptive study is presented to respond to the question "What factors cause fatigue that leads to human errors in construction?" The purpose of the research was to determine factors that contribute to fatigue that leads to errors committed by people in construction. The study is critical because an association between reported fatigue and difficulties with physical and cognitive functions experienced by workers in construction has been established elsewhere (Zhang *et al.*, 2015a) with limited awareness of the phenomenon in South Africa.

Strategies such as job rotation, stabilising shifts, controlled overtime, exercise, and maintaining healthy eating habits that enhance scheduled performance are deployed in a work environment to prevent the eventuality of fatigue (Hagan *et al.*, 2015).

However, the successful use of the above interventions relies on the identification of the type of fatigue to be addressed. There are two types of fatigue: mental fatigue and localised, muscular fatigue (which is physical fatigue). Mental fatigue is associated with the weariness of thought and decision processes, while localised muscular fatigue is the reduction in a specific muscle's ability caused by prolonged, excessive use (Phillips, 2014). Mental fatigue is likely to contribute significantly to slips or lapses (unintentional errors), which are problems of task execution (Reason, 2008) caused by cognitive processes during specific instances in time. The execution problems can be the result of recognition failures, memory failures and attention failures (Reason, 2008).

To understand the connection between fatigue and adherence to a safe working procedure (SWP) better, it is essential to observe the effects of mental fatigue and muscular fatigue on human error (Fang *et al.*, 2015). According to the literature, human errors are caused by deficiencies in mental functions that are accelerated as mental and physical fatigue increase. Studies of the causes of accidents show how organisational factors, local workplace conditions, and unsafe acts of people can compromise precautions in a system to produce adverse outcomes (Reason, 2016). Hallowell (2010) observed that the frequency and severity of injury increased during overtime work in construction because of a surge in human error caused by weariness in cognitive processes (mental fatigue). Typically, errors are detected through self-monitoring of formal processes in the human body. As mental fatigue increases, the workers' ability to perform mental checks decreases and the speed at which decision processes are executed is reduced. This behaviour is notable among workers (such as general workers in construction) who perform repetitive tasks for an extended time (Zhang *et al.*, 2015b). In summary, the effects of mental and muscular fatigue on people in construction are the immediate reduction in safe work behaviour, productivity, teamwork and morale (Fang *et al.*, 2015; Zhang *et al.*, 2015a). Additional effects include physical weakness, reduced production, mistakes, slips, lapses, weariness, memory loss, sleepiness, discomfort, and illnesses (Hallowell, 2010).

METHOD

The reported study was conducted on construction sites in Bloemfontein, South Africa, as the location for primary data collection. The interpretive perspective of the study helped the researchers to collect data that were closely related to the social and contextual beliefs of the participants. The study conformed to the notion that qualitative research is a situated activity that locates the researcher in the field (construction sites served as the field in this case study) (Denzin and Lincoln, 2008). The data collection exercise provided a view of the world through interviews and field notes (Denzin and Lincoln, 2008). The data collection tools used in the study were semi-structured interviews and field notes. The interviews were conducted with a semi-structured protocol that elicited information from site management. The face-to-face interviews were used to obtain responses to "What factors cause fatigue that leads to human errors in construction?"

Multiple researchers were used in the study to collect the primary data from several construction sites in Bloemfontein, South Africa, to allow for the possible convergence of observations to improve confidence in the results and to promote a more reliable substantiation of constructs (Huberman and Miles, 2002). A purposive sampling strategy was used to select construction sites and, ultimately, interviewees. The main criteria for selection were involvement in physical work on-site and prior experience of the interplay between fatigue and safety errors in construction. Three field workers were used to collect the primary data, which was textual. The field workers were registered, construction management students who were knowledgeable about fatigue concerning safety. They were trained in interviewing techniques before data collection commenced in 2018. All the interviews were audio-recorded and transcribed before being analysed thematically in line with the open-ended questions. Before the start of the fieldwork, informed consent was obtained from participants. Other ethical considerations that were applied in the study included confidentiality, the anonymity of data and voluntary participation. A covering letter and the field workers informed the participants of the purpose and benefits of the study. An option to sign a confidentiality agreement was also available to the participants, although none of them exercised the right.

The data analysed thematically, gave insight into the phenomenon of fatigue and errors as a lived experience of the interviewees. The strategy used to analyse the data relied on theoretical propositions informed by the central research question. The question, in turn, influenced the literature that was reviewed, and which guided the compilation of the questions used in the interviews. The analysis was organised by using the central research question to identify relevant, contextual statements that were collated to form specific themes.

Although 30 potential interviewees were approached on different construction sites, only 20 of them took part in the study. The interviewees have cognate on-site working experience in construction. Their education levels ranged from a Secondary School Certificate to a Postgraduate Diploma, and their construction work experience ranged from two to more than 18 years. The interviewees had various job titles, which included: engineer, foreman, site supervisor, and construction manager. Detailed demographic information of the interviewees is not provided here due to page number limitations.

FINDINGS

The 20 interviewees were requested to use yes, no, or unsure options to respond to fatigue-related questions, to gauge their perceptions of the phenomenon. Table 1 shows that 18 of the interviewees concurred with the definition of fatigue extracted from the literature, while two were not sure of the definition. This observation implies that most of the interviewees agreed with the description of fatigue in the context of the study. Most of the interviewees were also in agreement with the notion that fatigue is linked to incidents that influence productivity negatively despite the belief that it can be prevented. More importantly, all the interviewees agreed that fatigue influences productivity on sites.

Table 1: Perceptions of interviewees on fatigue in construction

Perception	No	Yes	Unsure
Fatigue is described as a state of physical and mental exhaustion, which reduces a person’s ability to perform work safely and effectively by reducing alertness that leads to errors, which increases workplace incidents.	-	18	2
Fatigue can be prevented.	4	14	2
Fatigue affects productivity on a construction site.	-	20	-
Fatigue has been linked to accidents on construction sites.	-	14	2

The causes of fatigue among construction workers

In responding to the opening set of questions, the interviewees identified factors that were influencing fatigue and errors on their construction sites. The factors mentioned included: long hours of work, excessive heat, lack of breaks between tasks, sleeping problems, dehydration (not getting enough water while working), hunger, and lifting of heavy materials and equipment (Figure 1). In Figure 1, the size of the words reflects their representation within the data. In the literature reviewed, these factors were deemed to be leading indicators of cognitive and localised muscular fatigue. Some factors are unique to either cognitive or muscular fatigue, while others, such as extended work periods and heat, are linked to both cognitive and muscular fatigue.

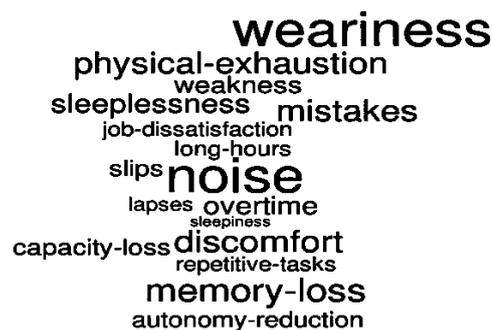


Figure 1: Factors contributing to fatigue on construction sites

To follow-up the question that checked whether the interviewees concurred with the definition of fatigue, the researchers asked them to describe fatigue on the worksite from their experience. The feedback indicated that the interviewees regard fatigue to be the feeling of physical tiredness, loss of concentration while working, and evidence of mental exhaustion. The interviewees also mentioned that workers work slowly when fatigued. In particular, explanations based on physical and mental tiredness were mentioned by 12 interviewees, loss of concentration while working was mentioned by four of them and working slowly with less productivity was mentioned

by four interviewees. Given the recognition of the manifestation of fatigue in their worksites, the interviewees were requested to indicate whether their firms informed workers to be aware of fatigue. It was notable that 12 interviewees indicated that there was no awareness of fatigue on their sites because their firms were not aware of the risk associated with fatigue, while eight of them indicated that there was an awareness of fatigue on their worksites because of the mindfulness of the risk associated with fatigue. The feedback implies that the employers of the 12 interviewees did not pay attention to the signs and effects of fatigue in their workplaces.

The participants were asked, next, to mention site activities that lead to fatigue. Brickwork and plastering were mentioned by three interviewees, working with shovels and spades were mentioned twice, digging trenches was mentioned by four of them, erecting and working around scaffolding was mentioned by two interviewees, loading and offloading of heavy materials was mentioned by four, while using vibrating equipment and working in the office the whole day were mentioned once. Some of these activities are highlighted in Figure 2, where they have been categorised under equipment, process, people, materials, environment, and management causes. In summary, the interviewees cited the lack of quality work produced on-site, workers sleeping on-site during working hours, workers having low morale, lack of productivity on site, increased risk of injuries and accidents on site, increased absenteeism, and poor housekeeping as the effects of fatigue observed in construction. Figure 2 shows that, where the outlined causes predominate in construction, fatigue-induced errors are a possible event on a site.

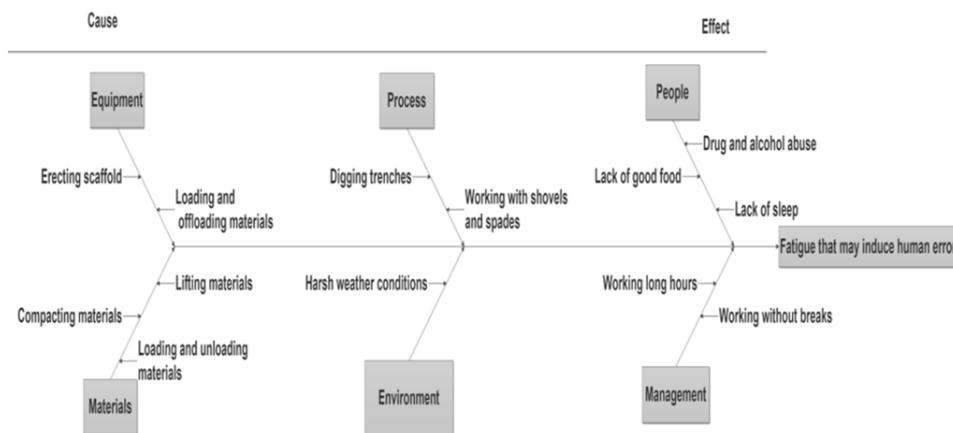


Figure 2: Illustrated cause and effect factors contributing to fatigue on construction sites

The data also revealed the factors contributing to fatigue shown in Table 2.

Table 2: Factors contributing to fatigue

Factor	Frequency
Long hours	5
Harsh environmental conditions	5
Working without breaks	2
Lack of sleep	2
Alcohol abuse	2
Lack of proper nutrition	2
Lifting heavy materials and equipment	2

In addition, 12 interviewees contended that scorching temperatures were a principal cause of fatigue on their sites, while four of them also noted extreme cold weather as a

contributing environmental condition. Two interviewees commented that it was difficult for them to work in dusty areas and wet conditions without significant errors. Another interviewee responded that it was also challenging to work in steep and mountainous environments. Another interviewee observed that exposure to rapid changes in environmental conditions could make workers uncomfortable to the extent that their biological rhythms and physiological functioning might be altered.

When the interviewees were asked whether they could link human error on their projects sites to fatigue based on their lived experiences, 18 of them responded with a strong affirmative, while only two said 'no'. An interview cited one accident as a case in point. The interviewee said that a truck driver hit electric poles, which caused an explosion due to lack of concentration. Although other work-related factors may cause a lack of concentration, fatigue was flagged as a primary reason in this cited example. In this study, the assumption is made that the factors that were identified as causing fatigue are the same that lead indirectly to human error, given the complexity of fatigue aetiology. The following are some of the interviewees' verbatim remarks:

Yes, because most workers get injured when they are tired.

Yes, I would link it. When project deadlines are near, employees are overworked... failures.

If people are overworked on a project, they are bound to make a human failure.

A worker is highly adaptable but not without end. There should be limits for any activity. Fatigue can lead to poor decision-making and poor performance on a project that requires attention or high levels of skills. Fatigue disrupt physiological functioning.

The effectiveness of mitigation strategies

The comments of the interviewees, quoted verbatim below, suggest an over-reliance on breaks and availability of water as interventions. The breaks include 15-minute tea break twice a day with 30 minutes for lunch. Exchange in working shifts and awareness helps to limit fatigue among the workers. The provision of clean drinkable water and a place to rest also serve as a mitigation strategy. A paid weekend reportedly gives the workers enough time to relax and rest. Managing fatigue with rest is one of the most effective fatigue management strategies. However, when it is used within-shift and between-shift breaks, it might not be useful in all situations. Beyond breaks, workers are advised on how to take care of their health through text and visual while the use of equipment is deployed to reduce manual labour that could lead to physical fatigue.

However, six interviewees said that their firms did not have mitigation strategies for fatigue. Among this group of interviewees, three of them perceived that contractors do not address fatigue because they did not see anything happening on-site to mitigate fatigue. However, seven other interviewees said that contractors allowed workers enough time to rest during lunchtimes, encouraged workers to eat healthy food and drink lots of water. These interventions were combined with the provision of machines to undertake heavy tasks. For example, excavators were used in place of people to dig trenches. One interviewee cited a common practice on a site where job rotation was implemented so that workers who required a break could rest.

Contractors who are mindful of the need to reduce the manual labour required by specific tasks, even when there is time pressure to end the project, promote such a practice. Ways to mitigate fatigue were mentioned by 14 interviewees who confirmed that their firms gave workers enough time for breaks and did not allow workers to

carry heavy materials on-site; a machine would be used instead to transport the load for workers.

When the interviewees were asked to indicate whether mitigation strategies led to practical changes to ease fatigue on their sites, only one interviewee responded with confidence. In contrast, most interviewees were not convinced of the impact of mitigation strategies. Some of the interviewees were sceptical because of the view that workloads often make workers miss rest opportunities available through either tea or lunch break. One interviewee opined that when the workers carry on working without eating and breaks, the likelihood of fatigue increases. Mitigation strategies are also not practical due to the improper attitude of workers and poor reporting of fatigue risks. The views of the interviewees imply that the implementation of mitigation strategies to prevent fatigue had to be intentional and monitored on sites. If the implementation is left to chance, the desired results might not be forthcoming.

DISCUSSION

The results corroborate the notion that measurable factors can predict construction worker fatigue (Techera *et al.*, 2018). The findings and interpretations, in the section above, indicate that a range of factors, some of which are latent, contribute to the manifestations of fatigue which, in turn, increase the likelihood of errors that could be blamed on people in the frontline of construction. This line of thought is the basis of the person model of unsafe acts (Reason, 2008). Reason (2008) explains that, in the person model, unsafe acts are viewed as the result of disorderly mental processes observed as forgetfulness, inattention, distraction, carelessness, culpable negligence and recklessness. The focus of this paper was on the person model of unsafe acts because of its relation to mental and physical (muscular) fatigue.

In addition, the causes and effects of fatigue mentioned by the interviewees in the previous section make it mandatory for a contractor to find ways to prevent it. The factors that contribute to the cause and outcomes of fatigue could have a profound impact on the well-being, work performance and safety of workers (Powell and Copping, 2010). The primary outcomes of fatigue include a reduction in short-term, cognitive and physical alertness, and errors to some extent, not to mention accidents, injuries, and illnesses (Techera *et al.*, 2016). When lax attention is paid to workload, Fang *et al.* (2015) observed that there is a linear relationship between fatigue levels and human errors. Fatigue is a significant driver of human error (Techera *et al.*, 2018).

In terms of accidents, fatigue either might reduce the ability to process information concerning a hazard (error linked to fatigue) or might limit the ability to respond to the hazard and its manifestations adequately (error linked to fatigue) (Fang *et al.*, 2015). The error is the outcome of the impact of cognitive fatigue on humans. In literature about social psychology, deficiencies in mental function that increase in tandem with mental and physical fatigue, lead to errors (Reason, 2008). Human errors and the likelihood of their occurrence as a result of fatigue should encourage site management personnel to implement effective programmes. Low productivity, injuries and fatalities, and rework result from errors in judgment, decisions, and physical actions (Hallowell, 2010). Physical actions, such as digging trenches for extended periods, mentioned by an interviewee, could lead to low productivity and human errors with implications for safety. For example, Fang *et al.* (2015) noted that, when the fatigue level is low, human errors are caused by failure to perceive hazards because of cognitive challenges (low information-processing abilities) and, when the

fatigue level is high, the level of motor control failure increases (low response abilities). Motor control failure often happens during prolonged physical actions.

Mental fatigue increases the possibility of human errors, so it must be mitigated in workplaces (Hallowell, 2010). In the central region of South Africa, two interviewees, mentioned by Emuze (2017), said long working hours are a risk because people make mistakes when they are fatigued. The interviewees in the previous section of this paper also identified long working hours, as illustrated in Figure 1. In effect, long working hours, work pressures and the poor working conditions of workers on some project sites in South Africa provide a platform for the proliferation of the causes of fatigue (Emuze and Mollo, 2019). Emuze and Mollo (2019) also observed how poor working conditions and evident [dis]respect for people severely limit the promotion of HSW on construction sites, citing a requirement to work in severe weather conditions without adequate protection as an example.

There is a need to address the gaps in the work environment where general workers and artisans struggle to have enough rest on site. Based on their experiment, Fang *et al.* (2015) affirmed that the effects of fatigue could be mitigated and one of the practical ways is to ensure that it does not accumulate. However, the insights from fatigue-related experiments must be accepted with caution because of the inability of laboratory-based research to be directly applied to field conditions in construction (Techera *et al.*, 2018). Beyond organisational approaches to fatigue management, such as rest between breaks, mentioned by the interviewees, contractors must embrace technology-based countermeasures to ensure successful detection, prevention and mitigation of fatigue (Horrey *et al.*, 2011). For example, a recent approach to monitoring physical fatigue in real-time among construction workers using wearable sensors has been reported by Arya *et al.* (2017). The high accuracy level of wearable sensors makes using technology for fatigue management an approach that contractors should explore.

Apart from the multiple causal factors that should not be treated in isolation, it notable that the type of worker or trade is a predictor of fatigue manifestation (Techera *et al.*, 2018). The above narrative shows that construction workers are exposed to fatigue, which has multiple causal pathways. The textual data presented in this paper require analytic generalisation as opposed to statistical generalisation. In terms of analytic generalisation, the results which shed empirical light on the central question of this case study can be generalised beyond construction sites in Bloemfontein to similar work settings. It can be argued that the results presented in this paper corroborate the underlying ideas about the causes of fatigue (Techera *et al.*, 2016; 2018). For example, while several authors, such as Hallowell (2010), have confirmed that fatigue remains a problem in developed countries, this paper has reinforced analytically the notion that fatigue confronts construction in developing countries as well, especially among general workers.

CONCLUSION

This paper presents factors that cause construction worker fatigue. The paper further demonstrates how fatigue could lead to human errors in construction. The interview technique provided perceptions of the phenomenon based on the lived experiences of people who have encountered fatigue in the frontline of construction. An attempt to answer the question, “What are the causes of fatigue that lead to human errors in construction?”, shows that the causes of fatigue can be categorised under equipment, process, people, materials, environment, and management-related causes, as illustrated

in Figure 2. However, it is noted that the causality illustrated in Figure 2 is not linear because the factors relate to each other and can lead to pervasive manifestations of fatigue if left unchecked. The inter-connected factors that predict fatigue could be conceived as a “recipe”. An example of a causal recipe would be the combined influence of working long hours, harsh environmental conditions, and alcohol and drug abuse. While the factors mentioned in this example contribute to fatigue (mental and physical), their effects vary.

One significant insight from this study was the realisation that not all contractors give due attention to fatigue and its consequences on the sites visited. This inadequate attention to the causes of fatigue and their links to human errors require further inquiry. The findings showed that contractors who promote awareness of fatigue tend to implement preventive measures, while contractors who do not promote awareness fail to implement preventive measures.

Some preventive measures include the intentional monitoring of continuous work hours and the periods for breaks on a site and the inclusion of fatigue-related topics in inductions and toolbox talks on site. However, the research results presented in this paper are not exhaustive. There is a need to conduct further research that would establish the strength of the causal factors and the magnitude of their influence on errors committed by construction workers. The robustness of the fatigue management model by Hallowell (2010) in the context of a developing country needs to be tested in a future study. The limitations of the primary data sources presented, in the form of small sample size and the work type (a higher number of managers than general workers in the sample) do not permit statistical generalisation of the results. The insights provided in this paper, as a case study, are framed as a call for more research involving larger projects, higher sample sizes and varied worker types that serve as predictors of fatigue. Such a study will be able to test predictive fatigue models with well-known factors and emergent factors from the field. Comparative studies to further interrogate the predictive power of the factors across multiple trades should also be considered.

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GOVERNING THE COMMON GOOD: COLLECTIVE ACTION IN INSTITUTIONAL MAINTENANCE

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This paper deals with the governance of a particular common good in the Danish construction industry popularly referred to as 'the technical knowledge commons.' The technical knowledge commons encompass the sum of practical experiences, professional literature, techniques and tested routines in different technical areas that professionals are expected to be familiar with. Due to its role in institutionalizing conceptions of proper conduct and professional practice, the technical knowledge commons have been met by industry criticism, being seen as 'backdoor' regulation that stifles innovation and constitutes a barrier to the globalization of labour and building materials. We illustrate how the technical knowledge commons is singled out as a battleground for struggles to redefine the governance of the industry. Using the concepts of institutional interlocks and meta-routines, it is analysed how actors are connected to the knowledge commons and contribute to a distributed maintenance of contested institutionalized practices. On this basis, we discuss how existing interlocks have been challenged and lost legitimacy in the face of the industry's deregulation and globalization, and how a new form of collective agency has arisen as professional associations have rallied in an attempt to establish new and legitimate governance structures to maintain the common good.

Keywords: collective action, deregulation, interlocks, knowledge commons, routines

INTRODUCTION

In the Tragedy of the Commons, Hardin (1968) tells the story of a pasture open to all where local herdsman let their cattle graze. Each herdsman will keep as many cattle as possible to maximize their personal gain. For centuries, a fine balance is maintained, but eventually the number of cattle exceeds the carrying capacity of the land, and the resource is depleted to the detriment of the common good. The tragedy lies in the eventual overexploitation of the commons that the collective action of individuals acting independently in own self-interest leads to (Feeny *et al.*, 1990). The story of the tragedy of the common is an example of a collective action problem. Collective action problems are situations in which individuals would benefit from

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collaborating but fail to do so as conflicting interests discourage joint action (Ostrom, 2000) leading to depletion of a resource. The problem of sustaining a public resource, which everybody is free to overuse, emerges in many contemporary social dilemmas where misalignments between individual interests and common concerns may exist (Milinski *et al.*, 2002). One of two solutions usually is typically offered to avoid this problem: privatization or government regulation (Ostrom, 1990). Ample empirical evidence, however, exists that common-pool resources may be self-governed. Feeny *et al.*, (1990) e.g., demonstrate that users have been able to establish rules and social norms among themselves for the sustainable use of the resource. Still, Ostrom (2000) argues for more research to investigate which conditions enhance or discourage collective action, and how to make structural changes to support collective action.

In this paper, we analyse forms of collective action in the governance of a particular knowledge commons in the Danish construction industry, referred to as ‘the technical knowledge commons’, which encompasses the techniques, routines, literature and practical experiences that professionals within different areas are expected to be familiar with. The technical knowledge commons has historically played a prominent role in the industry's regulation. In a neoliberal perspective, however, it is seen as 'backdoor' regulation, which constitutes a barrier to the globalization of labour and building materials as it institutionalizes professional norms and preserves tried and tested methods. This is, on the other hand, the very reason why opponents of the neoliberal economic model endorse the technical knowledge commons, highlighting its role in reducing defects and increasing the quality of the built environment. In the wake of the increasing deregulation and spread of neoliberal policies in the Danish construction industry (cf. Gottlieb and Frederiksen, 2020), the technical knowledge commons has consequently become centre of attention for discussions on which (and whose) values should be reflected in the governance and political institutions of the industry, and more importantly how to maintain the common good. On this basis, the purpose of the paper is to analyse how alternative forms of governance to the state-centric and neoliberal models emerge to sustain a contested knowledge commons.

First, the technical knowledge commons is introduced, followed by the theoretical framework with focus on institutional infrastructure interlocks and meta-routines. These are relevant for studying collective action, as they can shed light on different types of agency. Next, we analyse two interlocks and meta-routines. These are seen as expressions of a distributed form of collective action, which connects actors to the technical knowledge commons. It is then discussed how these interlocks and meta-routines are challenged by globalization and deregulation, leading actors to engage in a new form of deliberative collective action in maintenance of the common good.

The Technical knowledge commons

The technical knowledge commons inscribe a relationship between legal-regulatory requirements and professional practices in the industry, as illustrated in Figure 1. On the one hand, the technical knowledge commons is a concretization of the often abstract and vaguely defined requirements in the building regulation that prescribes methods and technical solutions to help practitioners meet the legal requirements in the building code. The technical knowledge commons consist of technical standards and norms that specify detailed requirements for the design and construction of solutions within various technical areas. This include international as well as specific national standards. Their use can be mandated explicitly in the building code or rest on the assumption that they are part of proper professional customs.

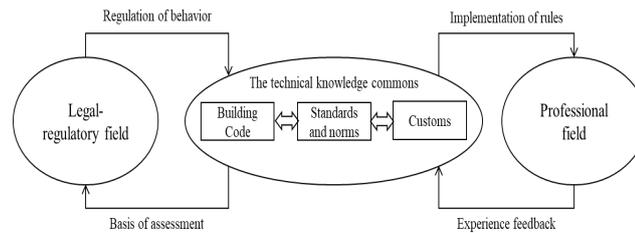


Figure 1: The dual role of the technical knowledge commons (own elaboration)

Customs are thus a third element of the technical knowledge commons. Customs are part of professions' esoteric knowledge base (Muzio *et al.*, 2013) and may over time become codified and find their way into norms standards and the building code. On the other hand, the technical knowledge commons is a codification of the often-tacit knowledge that professionals in the industry possess, which over time has been tried and tested and proven its worth in the sense that it is regarded as an expression of proper practice. In the legal-regulatory field, the technical knowledge commons is the basis for the standard of the 'bonus pater familias.' The culpa rule thus states that a tortfeasor commits the tort of negligence if he/she fails to show the degree of consideration that a reasonable person, the bonus pater familias, would show in similar circumstances. This is an extra-legal standard that rests on often vaguely expressed standards defined within a given profession - the technical knowledge commons.

THEORY

We see the technical knowledge commons as a particular type of common good, i.e., a good that serves members of a given community and its institutions (Etzioni, 2015). Our interest is in understanding what role it plays in the industry, and how it is shaped by a group of heterogeneous users (Hess and Ostrom, 2007) in a collective effort to organise institutional arrangements at the field level. To this end, we draw on the concepts of institutional interlocks and meta-routines.

Infrastructure Interlocks

Collective action takes several forms. In this paper, we deal with two modes, which result in institutional maintenance due to the creation of infrastructure interlocks. In business studies, interlocks have been studied in context of so-called interlocking directorates (e.g. Dooley, 1969), where they are seen as mechanisms employed by organizations or dominant social actors to regulate their environments. Interlocks are indicators of inter-firm ties, and there are many reasons why interlocks are formed. Palmer (1983) argues that interlocks form to facilitate formal coordination whereas Mizruchi (1996) propose collusion, co-optation, legitimacy, and social cohesion among the reasons. While this literature focusses on inter-firm ties, interlocks are also relevant in a context of distributed agency at the field level. In this context, Raynard *et al.*, (2019) define interlocks as the connections that influence the behaviour of actors and suggest that interlocking is the result of co-dependency processes between organizations, that does not necessarily take the form of direct inter-firm ties but can be more distributed. In their study of the persistence of the recruitment model of elite French business schools, Raynard *et al.*, (2019) identified three types of interlocks that mobilize actors in and across fields to maintain certain practices. These are: (i) sequencing interlocks where different actors produces outputs on which other actors depend, (ii) competitive interlocks that pull actors together, as they compete for the same pool of resources; and (iii) credibility interlocks that connects actors whose

independent activities reinforce the symbolic value of a given practice. Multiple interlocks can exist in an organizational field. These form a complex institutional infrastructure of interlocks (Raynard *et al.*, 2019), which gives rise to meta-routines.

Meta-routines

Meta-routines are routines for changing other routines (Adler *et al.*, 1999). They are loosely connected activities that coalesce into repetitive, interdependent actions that animate a distributed maintenance process, and as such, reinforce interlocks by promoting engagement, participation, and information-sharing (Raynard *et al.*, 2019). Meta-routines can take different forms. Van Driel and Dolfsma (2009) understand meta-routines as a propensity to select particular solutions for certain types of problems and suggest that they need not to be formalized. They also suggest that meta-routines may develop over time, and even prevail in the industry or in the economy as a whole. Adler *et al.*, (1999) see meta-routines as formal procedures for standardized problem-solving, which organizations develop to change existing routines and invent new. Meta-routines can thus both be formal or informal and serve an instrumental purpose or emerge as a shared logic of action. Institutional change is thus not necessarily a purposive act, but also can result from distributed agency based on the multiple actions and interests among actors within a collective (Semper, 2019).

METHODOLOGY AND DATA

The analysis is based on interviews with key persons from government, research and professional associations as well as archival data. In order to understand the context for the current debates over the technical knowledge commons, historical accounts were analysed, including policy documents, legislation, and industry reports that shed light on the origins and function of the technical knowledge commons. In order to analyse recent developments, multiple data sources were used, including industry and government publications, trade press news articles, interviews and presentations. Twenty-four interviews were conducted with professional associations, government agencies, non-profit information councils and universities. Observations from a public seminar in 2017 entitled “What is in the future for the technical knowledge commons?” is also used. This seminar gathered 100 participants from government and industry to debate recent developments and plot a course for future initiatives.

The empirical data was analysed in an abductive manner (Alvesson and Kärreman, 2007). We analysed data in three steps. First, we coded data qualitatively focusing on identifying the institutional underpinnings of the technical knowledge commons by identifying the rationales mobilized by the different actors in their elaboration of the role and functioning of the technical knowledge commons. The second step was identification of different interlocks and meta-routines in the maintenance of the technical knowledge commons. Here we identified several varieties of mechanisms that eventually was combined in the two interlocks and meta-routines presented in the paper. Finally, in the third step, we combined insights from step one and two to examine challenges to the interlocks, and the responses and practices the industry has engaged in to sustain the technical knowledge commons. As a limitation it should be noted that much of the source material were written in Danish making referencing difficult. It has been chosen not to include the numerous Danish language references.

FINDINGS

Interlocks and Meta-Routines

We identified two infrastructure interlocks (sequencing and expertise interlocks) and associated meta-routines (standardized problem solving and distributed enabling and policing). Sequencing interlocks are co-dependency relationships between actors, whose individual activities produce a collective whole (Raynard *et al.*, 2019). The building code contains the requirements that all building projects must comply to in order to ensure satisfactory performance. Specific guidance on how to fulfil the requirements are published by non-profit knowledge providers in the form of directions that professionals may apply to conform to the requirements. Some of these are local implementations of international standards and others are codifications of existing customs and best practices. The different knowledge providers are closely linked to each their professional area of expertise and exert a strong and relatively direct influence on professional practices in the industry. Where actors within the state and the knowledge provision sectors produce input to the building code and technical standards, the remaining actors play a role in relation to customs and practices. The insurance sector contributes to the technical knowledge commons by legitimizing and delegitimizing solutions and products through insurance policies. This is an indirect way of preserving certain customs and practices, as some new and untested solutions are attributed high risk and can be difficult or costly to ensure thus preventing use. In the case of the Building Defects Fund, they monitor existing buildings one and five years after completion and publicize statistics of recurring defects to contribute to the promotion of quality and efficiency in the construction industry. Companies in the sector reproduce and contribute to the gradual codification of customs and practices and rely heavily on the aids that are part of the technical knowledge commons. The judiciary, most notably the Danish Building and Construction Arbitration Board, monitor customs in the industry through rulings in cases of disputes and misconduct. In this way, legal practice plays a role in determining proper practice and contributes to stability in the industry. All these actors are connected to each other by their distributed contributions to the maintenance technical knowledge commons rather than through hierarchical relations.

Sequencing interlocks have developed hand-in-hand with a meta-routine we refer to as standardized problem solving. Standardized problem solving is an approach that is particularly suited in situations characterized by high degrees of uncertainty, as it is an efficient way of coordinating interdependent tasks whether through standardized work processes, outputs or knowledge and skills (Kadefors, 1995). Standardized problem solving is at the core of the technical knowledge commons, as it prescribes specific guidance and standard solutions that professionals follow. When the technical knowledge commons was legislatively formalized in the 1980s, the building regulation was characterized by its prescriptive nature. This meant that the building code contained specific solutions that were considered acceptable in the legal-regulatory field. Standard solutions were actively promoted in unison by state and industrial actors as they could help achieve the political aspirations of providing sufficient housing while contributing to efficient production and economies of scale.

The second type of interlock, we have identified, involves a set of actors that relate to the technical knowledge commons due to their technical expertise, and reproduce norms and customs by playing different roles in various parts of the system. We refer to this as an expertise interlock. As the technical knowledge commons to some extent is constituted through a formalization of existing best practice in different technical

areas, it is common practice among the knowledge providers to draw on the technical expertise of selected experts working in the industry (or at other knowledge providers) in the process of developing new aids and guidance. This is a meritocratic model in the sense that individual experts are appointed directly by the knowledge providers, either permanently or on a project-to-project basis, to serve on boards, expert forums or workgroups based on personal technical merits rather than company interests. There is thus a dialectical relationship between these experts and other professionals in the industry that act as consumers of the guidance. The guidance to which the experts contribute has a prescriptive effect in the industry as other professionals use it as sources of reference in their daily practice. In addition to their role in contributing to the technical knowledge commons, experts moreover often work as appointed building experts. In this role, they are a part of the judiciary when they testify as expert witnesses in disputes and tort liability cases. The judiciary, in turn, defines both professional standards in the industry and what is to be considered technical knowledge commons through their specific verdicts and rulings. This is done by attributing different types of guidance more or less importance as sources of law, hence curating the formal bases of the technical knowledge commons.

Expertise interlocks relies on mechanisms of distributed enabling and policing. This meta-routine can be seen as a system of checks and balances that ensures compliance to the technical knowledge commons, and contributes to the formation, dissemination and reproduction of shared meanings (Lawrence and Suddaby, 2006) among actors in the field. Judiciary, state and professional actors alike conduct enabling and policing through formal and informal means. Formal means include verdicts from the arbitration board or other authorities. These are instrumental in legitimizing or delegitimizing certain construction products or technical norms. Aids and guidance are moreover produced that are based on de jure standardization work. This is e.g., the case in some technical areas, where expertise is controlled through accreditation and where international standards exist. As a part of the quality assurance and liability reform, publicly subsidized housing schemes are given two building inspections. The first, a so-called deficiency inspection, takes place one year after completion. The second is an inspection with the purpose of monitoring whether deficiencies registered at the year-one inspection have been eliminated. Appointed building experts conduct inspections, registering all deficiencies, which fail to comply with public rules, good ethics and practice or agreements. This work has led to a reduction of major deficiencies in public housing schemes, which has not been matched in other sectors, e.g., private housing, that have voluntary market-based insurance schemes. Informal means of enabling and policing include decisions taken by knowledge providers on which technical solutions to include in aids and guidance. Such decisions are not formally authorized or endorsed but are often made within self-selected groups or forums of experts that have been assembled to produce, or provide input to, new or revised guidelines within a specific technical area.

DISCUSSION: CHANGING FORMS OF COLLECTIVE ACTION

On the back of the preceding findings, we now turn to a discussion of how pressures stemming from globalization and deregulation challenge existing interlocks and meta-routines, and how a new form of collective, deliberate agency has arisen in response.

Deregulation and Globalization: A Challenge to the Technical Knowledge Commons

The technical knowledge commons was initially established under a strong influence of concerns for the intrinsic quality and durability of the built environment. In an

open-market perspective, the technical knowledge commons, and the standardized problem-solving it promotes, however constitutes a barrier for trade and innovation due to its prescriptive character and local embeddedness. In this context, prescriptive regulation is a barrier towards the aspirations of improving the industry's productivity through increased competition and uptake of new innovative products and solutions. Prescriptive regulations and a technical knowledge commons promoting standardized problem solving are thus not congruent with market values. Moreover, as the technical knowledge commons is a codification of existing local norms, a regulation predicated on these is argued to constitute a technical barrier to trade, which is problematic in a competition perspective. As argued by a respondent from a major business and employers' organization: "The way experiences are used is the problem. If it the technical knowledge commons was less prescriptive and more generic, it would be better [...] it should be technologically neutral".

In order to improve the productivity of the industry and transpose EU legislation into a national context, efforts have been made to decrease the state's involvement in the building regulations. This development is linked to the increasing deregulation and spread of market values in the public sector in general. This is a development that has been problematized by actors opposing the potential harmful consequences of an unrestrained market focus, where even ethics, as one respondent remarked it, have been commodified. Several actors see a conflict between societal values and market interests, arguing that the free circulation of construction products, underpinned by European standards, constitutes a race to the bottom in terms of quality.

We suggest that this development is driven in part by the reconfiguration of interlocks, where the state's role in maintaining a strong common technical good has decreased concurrent with the gradual abolishment of the prescriptive building regulations. This has resulted in increased reliance on international norms and standards and a spread of building methods and practices that have yet to be tested and codified. The distributed enabling and policing that is associated with this interlock, has also been considered problematic in context of the deregulation and globalization of the industry. In particular, the informal foundations of this meta-routine are a cause of concern in a market perspective. The lack of transparency in the production of technical knowledge commons is thus associated with illegitimate 'backdoor' regulation enforced by self-proclaimed experts. In order to avoid distortion of competition, increased reliance on international standards and certifications has been proposed. This, is, however, problematized as such measures support market interests, and are seen as a benefit for producers and not consumers and clients. A respondent from a knowledge provider thus stated: "Only the market remains [...] It will end up as the wild west if they get what they want. They just want to throw one product after another onto the market."

From Distributed to Collective Action

The above discussion highlights how two different change processes are at play. One is motivated by industry interests in dismantling the technical knowledge commons. This is a process driven by efforts to undermine the moral foundations of the technical knowledge commons, by questioning its efficacy and legitimacy with reference to a market logic. The technical knowledge commons, as a form of quasi-regulation, originally played an important role in extending the state's legislative reach and concretizing the intentions of the law into practice. It is the legitimacy of this type of regulation that has been called into question due to the spread of market-based forms of organizing. This development has been supported by more indirect mechanisms of

transformative change in the form of defection and differential growth (Streeck and Thelen, 2005). Defection is the slowly rising salience of subordinate relative to dominant institutions, which e.g., is based on the cultivation of a new logic inside an existing field. Differential growth designates a situation where new rules or systems are introduced onto an existing system and over time crowd out the old system. These mechanisms are seen in the way that functions that hitherto have been public affairs have become subject to demands for regulatory simplifications to improve efficiency.

From the perspective of proponents of a strong technical knowledge commons, the problematic consequences of the deregulation became apparent in the wake of the recent rapid and uncontrolled spread of an innovative magnesium oxide board used as wind barriers that were found to be unfit for this particular use. This led to costly damages in many newly built and refurbished housing schemes. In order to anticipate similar future issues, various professional associations established a joint working committee to prevent the spread of untested products and new ways of using otherwise known products. Acknowledging the state's limited capacity to impose legislation to prevent the uptake of certified, yet in a local context unproven products, we suggest that the committee's efforts constituted a shift in the mode of governance. This was accomplished through conscious efforts directed towards orchestrating collective interests and redefining the contested meta-routines.

In response to the criticism of the distributed enabling and policing that had created an expertise interlock, all sectors of the industry were invited to sit on the committee; architecture, engineering and construction associations, professional bodies, clients, insurance companies, regulatory bodies, manufacturers, universities and knowledge providers. The idea was to gain a wide representation of actors to avoid allegations of cartel formation and illicit decision-making. Despite announcing that the committee would not hinder innovation and the development of new products, the construction manufacturers and suppliers' association declined participation in the committee.

The committee and its members worked to legitimize their collective action and dismantle the criticism that the technical knowledge commons constitutes a 'backdoor' regulation enforced by self-proclaimed experts. As argued by a respondent from the major Business and employers' organization: "Certain bodies have more or less gained the status of being producers of the technical knowledge commons [...] certain requirements must be set for them". The collective response was to increase procedural transparency to comply with external demands. The committee framed itself as a forum for knowledge sharing to working to mitigate the potentially problematic consequences of different products. The working foundation of the committee was arguably apolitical with potential decisions to issue warnings against specific products or methods being taken not with the mandate of the committee but by the individual membership organizations. Moreover, several knowledge providers developed procedures for developing their aids and guidance that were informed by the EU guidelines on horizontal co-operation in relation to standardization agreements that stipulate unrestricted participation in the standard setting and voluntary adoption.

In both cases, we argue that the committee, by driving the development of shared expectations across the entire value chain, acted as a 'filter' (Geary *et al.*, 2019) to mitigate pressures associated with the deregulation and globalization of the industry. Lee and Lounsbury (2015) suggest that community logics can dampen (or amplify) the influence of broader field-level logics. In our case, it was done by reattributing the meaning of the infrastructure interlocks and meta-routines.

We do thus not observe structural changes as such but more a change in the mode of maintenance, driven by an institutional arrangement shaping social norms in a heterogeneous community. Unlike commons, where overuse leads to depletion of the resource, the tragedy of a knowledge commons lies in its potential underuse (Hess and Ostrom, 2007), which result from restriction of access whether through privatization, commodification or regulatory fencing. Knowledge commons play an important role in many sectors of society from educating and engaging the public to building inclusive, resilient, and safe societies and ensuring values that not necessarily can be monetized or be paid for by the potential beneficiaries. Levine (2007) argues that knowledge commons need protection by groups interested in their maintenance. He suggests that 'associational' commons, where groups are in control of a good, will be an important part of the democratic use of public goods in the future, as they can promote values and protect the common good while being held accountable through democratic deliberations and collective decision-making. This is also the case in our analysis, where we have seen how the proliferation of neoliberalism and market-based values and the retraction of state have strained existing institutions and prompted alternative forms of governance to emerge based on the collective action of heterogeneous actors.

CONCLUSION

The paper has focused on the governance of a particular knowledge commons in the Danish construction industry. We have shown how existing infrastructure interlocks and meta-routines that had contributed to a distributed maintenance of the commons have been challenged by pressures arising from the globalization and deregulation. In response, a new form of governance has arisen, which is based on the collective action of heterogeneous actors in the field. A particular finding is that the establishment of a community to defend the commons acts as a filter to mitigate the pressure from wider field-level developments. On this basis, it can be concluded that collective action in a heterogeneous community assumes a function in governing common goods in the absence of firmer state regulation. Time will tell whether self-interests will prevail, or the collective action will be for the common good of the industry.

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THE MANAGEMENT OF DISPUTES AS AN ELEMENT OF CONSTRUCTION TRANSACTION COSTS: AN EMPIRICAL STUDY

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The process of delivering construction projects is characterised by a multiplicity of transactions between individual organisations whose integration is vital yet problematic. The premise of this paper is that the management and resolution of contractual disputes between these organisations represent a substantial element of their transaction costs. The argument is set in the context of Transaction Cost Economics (TCE) theory, according to which the concepts of bounded rationality, uncertainty, information asymmetry, and opportunistic behaviour together present serious problems for transaction efficiency. The work presented here is part of a wider study examining the impact of advances in information technology (specifically, the availability of information-rich building models) on the more efficient resolution (or even avoidance) of contractual disputes. We argue that there is a *prima facie* case for this, and therefore for the reduction of transaction costs, by exploiting the potential of digital building models. However, the operationalisation and measurement of transaction costs, especially in the construction context, has proved an intractable barrier to the empirical testing of the applicability of TCE theory. To address this, the initial stage of the work, reported here, is concerned with defining and measuring the resources currently required for the management of certain types of contractual dispute. Data were collected from three selected project case studies and the time spent by delay analysts was categorised. Up to 70% of the time spent on delay analysis was concerned with searching for and establishing supposedly factually based information that could ideally have been automatically captured. The implications of these inefficiencies are considered, and a case is made for the exploitation of information technology, thereby reducing costs.

Keywords: case studies, contractual disputes, IT, Transaction Cost Economics

INTRODUCTION

Delays to construction projects are persistent, perhaps even endemic (Adam, *et al.*, 2017; Ansah, *et al.*, 2018; Durdyev and Hosseini, 2019; Larsen, *et al.*, 2016) and result in claims and disputes that are time consuming and costly (Arcadis, 2019). The work presented in this paper focuses on time-related disputes as a facet of the transaction costs of construction. The theory of Transaction Cost Economics (TCE),

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initiated in 1937 by Coase and refined by Williamson (1979) has long appealed to commentators seeking to explain construction industry inefficiencies. However, the operationalisation of the elements of TCE theory has proved controversial. Here our three propositions are: (1) that contractual disputes offer a striking example of unnecessary transaction costs; (2) that, following TCE theory, they are fuelled by information deficiency or asymmetry; and (3) that this effect can be mitigated by advances in the use of information technology within the industry. The empirical work reported here comes from three project case studies and addresses the first of these propositions by defining and measuring the effort currently required for the management of contractual disputes. First, the contextual background is presented, and this brings together two aspects of the relevant literature: (i) construction delay disputes and how they are managed; and(ii) a resumé of TCE theory. The methodology describes a case study approach to data collection, the results of which are analysed for insights into what certain components of transaction costs can amount to. Finally, and with a view to the larger body of work that this study forms part of, we consider how advances in information technology can be exploited to mitigate or eliminate these costs and enable the more efficient resolution (or even avoidance) of contractual disputes.

Project Disputes as Transaction Costs

A 2019 Global Construction Disputes report (Arcadis, 2019:8) calculates the average dispute to be US\$33 million- and 17-months' duration. The proportion relating to delay claims is not identified but it is reasonable to suggest it represents a significant proportion of the total.

Time-related construction disputes

As noted by Pickavance (2010) the word 'delay' itself is open to differing interpretations. It is not defined in most standard form contracts but is generally understood to relate "to the works being affected by events that have a critical effect on the progress of the works" (Lexis Library, 2020). Project delays can result in losses for all parties involved and contract drafting bodies apportion the risks through mechanisms such as liquidated and ascertained damages and extensions of time. However, such contractual provisions are, of necessity, general and can prove ineffective in preventing disputes. Despite attempts to establish more detailed agreed procedures such as those by the Society of Construction Law (S.C.L., 2002; 2017) the complexity of these disputes combined with a lack of supporting information (Love, *et al.*, 2008) and inherent tendencies towards escalation (see Loosemore, 1999) drive the parties towards disputes that require resolution (Clay and Dennys, 2018).

Forensic delay analysis

As noted by Kumaraswamy (1997: 95) the intricacy and value of construction disputes has created opportunities for claims management and dispute resolution consultants who specialise in 'Forensic Delay Analysis' (FDA). The relative merits of different FDA techniques has been discussed in the literature (e.g. Kraiem and Diekmann, 1987; Braimah, 2013; Society of Construction Law, 2002, 2017; Scott *et al.*, 2004; American Association of Cost Engineering, 2011) but underlying them all is a comparison of 'as-planned' and 'as-built' versions of the project programme/schedule. Quantification of project delays is usually supported by critical path analysis (CPA) and is reliant upon the availability of validated programmes. If the project records required to validate construction programmes are unavailable (as they often are) the CPA can be highly speculative and subjective. The role of the FD analyst may be to

assist a party or its legal team in building a case or to act as an independent expert in dispute resolution proceedings (adjudication, expert determination, arbitration or litigation). Before this a “vast number of documents to be reviewed and people to be interviewed” (Carmichael and Murray, 2006:1008) and Alkass *et al.*, (1995) estimated that information search and verification accounts for around 70% of the effort in building a case. Indeed, the 2017 SCL Delay and Disruption Protocol (Society of Construction Law, 2017: 13) recognises that any FDA method adopted must depend on “the nature extent and quality” of both the programme information and records available. We will argue that the management and resolution of construction disputes exemplified by FDA are palpable examples of transaction costs and so contribute to operationalising TCE theory and understanding how greater efficiencies can be achieved. The next section briefly summarises the key literature on TCE theory and attempts to apply it to Construction.

The theory of transaction costs

According to the theory’s originator the “costs of organizing transactions” arise from efforts “to conduct negotiations leading up to a bargain, to draw up the contract, to undertake the inspection needed to make sure that the terms are being observed, and so on” (Coase,1960: 22). Dahlman (1979:148) identified “search and information costs, bargaining and decision costs, policing and enforcement costs” and added that “fundamentally [these] reduce to... resource losses due to lack of information”. Williamson (1975: 8) recognises two factors that influence these costs as “the characteristics of the human decision makers ... on the one hand and the objective properties of the market on the other”. Eccles (1981:341) following Williamson, described two influential pairings of these factors as (1) bounded rationality and uncertainty/complexity and (2) opportunism and small numbers. TCE theory has its critics; the most cited being Simon (1991) who claimed they have “no empirical support” and Ghoshal and Moran (1996) who regarded TCE as “not only wrong but also dangerous ...”. These criticisms have themselves been refuted; by Masten (1996) in the former case, and by Williamson (1996), in the latter. David and Han (2004:52) describe a “significant variation in support for the theory’s predictions”. This debate has continued. Recent examples include Lacity and Khan (2016) who conclude that TCE theory only applies “to specific contexts”; Schermann, *et al.*, (2016) with evidence that both supports and negates TCE theory; and Haaskjold *et al.* (2019) who see a general association between collaboration and reduced transaction costs but support a more restricted context-specific view of TCE applicability.

Transaction costs and construction projects

Many authors have employed a ‘TCE-lens’ on construction organisations and projects. It is at this point that Williamson’s (1989) division of a TC approach into a “a governance branch and a measurement branch” should be invoked. Some authors (e.g. Reve and Levitt,1984; Winch, 1989, 2015; Walker and Wing, 1999; Lai, 2000; Bridge and Tisdell, 2004; and Bygballe, *et al.*, 2013) have studied the governance branch and followed Eccles’ approach of using TCE theory to account for the ‘boundaries’ of construction firms and how their businesses or projects are organised. Others have followed the latter and used TCE constructs to explain project performance and other outcomes, such as the behaviour of participants. Yates and Hardcastle (2003) examined how bounded rationality and opportunistic behaviour might relate to conflict and disputes in projects and Greenwood and Yates (2006) supported this approach with evidence from a partnering case study. Empirical studies by Li *et al.*, (2012; 2013; 2014; 2015) and You *et al.*, (2018) identified pre-

and post-contract transaction costs and their implications for choosing project delivery systems and type of contract.

METHODOLOGY AND DATA COLLECTION

Here we are concerned with (i) identifying the processes and resources currently required for analysing delay disputes; (ii) categorising them using TCE ‘language’ and aligning them with components of transaction costs (as discussed above); and (iii) operationalizing and measuring these costs by examining data collected from three project case studies. For ethical reasons cases have been anonymised and described by their function (i.e. 1: Infrastructure Design; 2: Panel Manufacturing Plant; and 3: Bridge Construction). The methodological approach is primarily archival and based upon analysis of the records of three case study projects chosen from an initial sample of 60. In common with many types of consultant, the FD analysts’ activity records are kept for payroll, project accounting and client billing purposes. These provided a rich source of data for identifying, categorising and quantifying the FDA process and the resources required to sustain it.

The selection of cases was based on four criteria. The first was that each involved a delay or delays upon which the parties were unable to reach agreement under the terms of the contract (hence escalated to a dispute). The second criterion was recency: the case studies were selected from the period between January 2016 and January 2019. Projects started before this timeframe or incomplete by the end of it were eliminated. The third criterion was representativeness: the case studies must as far as possible, be reasonably representative of the range of projects dealt with. Finally, the fourth criterion, in order to secure the accessibility and consistency of collected data, was that the entire delay analysis process had been undertaken ‘in-house’ by a single FDA consultant. This is a significant filter, as projects are often completed by a network of analysts in different international locations. Based on the above criteria three projects were identified for further analysis.

Case study 1: Infrastructure design

The scheme was to provide road-widening improvements to 40km of dual carriageway encountered complications that included work alongside live traffic and environmental sensitivities. Construction started in 2015 with a planned completion date of 2018, later adjusted to the autumn of 2019. Negotiation over delays was unsuccessful and escalated to adjudication. The FDA consultant was instructed to defend the designer (against the Contractor’s claim for LDs) and prepare a loss and expense counterclaim for the designer.

Case study 2: Panel manufacturing plant

A contractor had ordered cladding panels for three rail stations. The dispute related to delay in the supply of panels by the manufacturer who commissioned the FDA to support a claim for an extension of time (EOT).

Case study 3: Bridge construction

The project was for the engineering, procurement and construction of a new cable-stay bridge of total length 525m and a central span of 290m. The FIDIC contract contained provision for a Dispute Adjudication Board (DAB) as an alternative dispute resolution device (see Bunni, 2005). The main contractor instructed the FDA consultant to help establish entitlement to EOT for unforeseeable ground conditions encountered during piling works.

Daily record-keeping is a fundamental requirement for the FD analyst, as it is for most consultant organisations. The records from the three case-study projects were reviewed to identify: (a) the type of task conducted by each consultant for each working day; (b) the reason for conducting the tasks; (c) the product that was produced as a consequence of each task; and (d) the time spent on a particular task. Initial analysis revealed that the FDA process can be divided into the following four broad categories of activities (or tasks):

Category 1: Preliminary tasks

These include a review of available records, meetings or correspondence with clients to establish the aims, objectives of the FDA and a basis for further records requests.

Category 2: As-planned v as-built analysis

These involves a review of available programmes to establish the accepted ‘baseline’ (as-planned) and as-built programmes, their validation, and the creation of tables, schematics and other charts to illustrate high level, mid-level and detailed comparisons, and drafting the methodology and findings. It is a process where the start and completion dates of the programme activities are compared to the available as-built records which could be in the form of daily, weekly or monthly reports.

Category 3: Causation analysis

This includes a review of contemporaneous records to identify relevant issues, create chronologies to describe identified issues, creation of tables, schematics and other charts to illustrate findings and draft and edit relevant sections of report.

Category 4: Undifferentiated activities

Where in a record it was difficult to allocate time to a single category, e.g., where records related to time spent overall on all of them, it was assumed that the relative proportion of time could be allocated to Categories 1-3 pro-rata to the predominant patterns from data that could be differentiated.

DATA ANALYSIS

Analysis of the records from each of the three case studies produced the following results.

Case study 1

The tasks executed by the Consultant to prepare a delay analysis were allocated to the four categories discussed above. Table 1 shows a summary of hours spent by the Consultant.

Table 1: Summary of production hours for Case 1

Categories	Preliminary Tasks	As-planned v As-built	Causation	Others	Total	Total less Others
Hours Spent	27	1518	823	1588	3956	2368

The major part of identifiable time (64%) was spent in the preparation of the As-planned vs. As-built analysis. Although this activity accounted for around 38% of the total, it was not possible to identify the ‘other’ activities, due to the level of accuracy in the description provided in the time sheets. It may be that a significant part of the 1588 ‘Others’ hours was also spent on As-planned vs. As-built analysis. In contrast, the time spent on Causation Analysis, which is arguably the most contentious issue in FDA was 35% of identifiable time.

Case Study 2 (Panels manufacturing plant)

Table 2 shows a summary of hours spent by the Consultant on Case 2. Here, the records were more helpful (only 17 hours had to be classified as ‘Others’).

Table 2: Summary of production hours for Case 2

Categories	Preliminary Tasks	As-planned v As-built	Causation	Others	Total	Total less Others
Hours Spent	52	374	35	17	378	461

The 374 hrs spent on preparation of the As-planned vs. As-built analysis accounted for 81% of the classifiable hours (78% of the total). Again, a proportion of the ‘Others’ category may be similarly attributable. Less than 10% of time was spent on Causation Analysis.

Case Study 3 (Bridge construction)

Table 3 shows a summary of hours spent by the Consultant on Case 3

Table 3: Summary of production hours for Case 3

Categories	Preliminary Tasks	As-planned v As-built	Causation	Others	Total	Total Less Others
Hours Spent	58	374	175	381	988	607

As-planned vs. As-built analysis accounted for around 62% of the classifiable hours (38% of the total). As before, a proportion of the relatively large (381) ‘Others’ category may also be similarly attributable. The time spent on Causation Analysis (29%) was less than half that spent on establishing accepted as-planned and as-built programmes.

CONCLUSION

Following Haaskjold *et al.*, (2019), who found that “conflicts can lead to significant transaction costs”, we conclude that TCE theory can be invoked to relate those costs to information deficiency or asymmetry. Based on three cases, we measured the resources required for managing contractual disputes over project delays. The findings indicate that up to 70% of FDA costs are expended in retrieving, validating and processing project records for analysis. Where these records are incomplete, inferences are needed that themselves require further efforts to justify. Not only does this support the estimates of Alkass *et al.* (1980) but indicates that little has changed in the intervening 40 years.

This is information that could theoretically exist in accurate and verifiable formats. For example, there is a range of available software products to support the management of time on projects and versions of these were available to all the key participants in the cases in question. All such products have a facility for the capture and archiving of evolving versions of the schedules they are used to produce. A more recent technological advance is that of Building Information Modelling (BIM). Authors from Gibbs, *et al.*, (2013) to Sanchez *et al.*, (2019) have explored how BIM and related digital technologies could assist with FDA. Advances in technology such as the introduction of 3D scanners (El-Omari and Moselhi, 2008), drones (Li and Liu, 2019), sensors (Akinci and Anumba, 2008) and other developments in information technology for the construction sector present an opportunity for accurate contemporaneous collection and processing of construction project. Furthermore, the automation of progress records in a construction project is likely to remove the human

contribution and, as such, remove potential subjectivity. Hence, the exploitation of information technology is likely to improve the current efficiency of resolution (or avoidance) of contractual disputes by reducing (or even eliminating) the factual arguments, particularly arguments relating to the actual progress of the construction works.

Despite these opportunities, the proportion of time the FD analyst spends on As-planned vs. As-built analysis indicates serious current deficiencies in the capture, storage, retrieval, and processing of information by the representatives of the organisations in question. The findings indicate that this process is time-consuming and resource-intensive and, at nearly 70%, compares with less than 25% spent on the more contentious aspect, i.e., making an argument for causation. This lack of adequate and credible information is a clear example of the bounded rationality, which, as discussed earlier, is one of the main factors in the escalation of transaction costs. Bounded rationality provides scope for opportunistic behaviour and this is exploited by individual agents in their unwillingness to share such information that does exist. Together these factors contribute to the conflict and disputes in construction projects, and ultimately to their cost. Transaction efficiency could be improved by automating the capture and management of the required information by minimising arguments over the sufficiency or accuracy of the records and, as a consequence, potential disputes regarding the parties' liability for critical project delays. In the language of TCE, this amounts to relieving the impact of bounded rationality as well as that of information asymmetry, by making that information accessible and transparent: such a development could improve current issues of uncertainty and reduce opportunistic behaviour.

There are limitations to drawing conclusions from these findings. First, the sample is small and requires further cases. It should also be noted that although they are in themselves significant, FDA costs represent only a fraction of the avoidable transaction costs in the project delivery life-cycle. Here, they have been used as a lens through which to investigate how such costs can be measured and ultimately minimised. A more systematic, possibly automated or semi-automated, approach to the collection of project information that is both verifiable and accessible would go a long way to improving efficiency.

The automatic digital capture, storage and retrieval of project information is likely to increase efficiency and reduce transaction costs in terms of bounded rationality (through more accurate recording, collection and processing of information) and information asymmetry (by increasing its accessibility and transparency). The consequent reduction in uncertainty and prospects for opportunistic behaviour would lead to a reduction in disputes, the cost of managing them, and hence to construction costs in general.

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COLLABORATION AND RELATIONSHIPS IN NORDIC INFRASTRUCTURE PROJECT NETWORKS

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Since the turn of the millennium, project planners have tried reducing the adversity commonly seen in infrastructure construction projects by employing collaborative project management models, such as alliancing, early contractor involvement, or partnering. In the public sphere these models are utilised with the hope that public funds would be used efficiently to meet the needs of society through well-executed projects. One of the major drivers for these expectations is the practice inherent in the models of early-stage collaboration between all involved actors, e.g., client, design consultant, and contractor, which opens up the opportunity to focus more on intangible metrics, such as life-cycle perspectives, sustainability and societal good: factors that have recently become more significant through societal demands. In the Nordic countries, several different models are currently being applied in practice. Employing a project network perspective, we look at two infrastructure projects, employing collaborative project management models in the Nordic countries and study the expectations on collaboration models as well as the actual collaboration between the different actors in these project models. The empirical evidence, consisting of 41 semi-structured interviews, points to a discrepancy in the application of collaborative project management models as well as changing actor roles in the project network. There seem to be clear benefits realised through employing such models, such as time savings and resource use reduction, but as the benefits depend on the changing roles, it is uncertain if the projects will realise these. Results indicate a collective interest to produce a common good in all involved actors, i.e., a well-functioning, qualitative infrastructure project, while simultaneously highlighting the discrepancy between expectations and actions.

Keywords: Actors, collaboration, infrastructure, network, project management

INTRODUCTION

The impact of the Architecture, Engineering and Construction industry (AEC) industry is a relatively traditional, project-based field (Hastie *et al.*, 2017, Lundin *et al.*, 2015), which doesn't easily yield to outside influences (Lundin *et al.*, 2015) and has a slow adaptation rate of new ideas and processes. It is also characterised by adversity, disputes, and a lack of cooperation (Franz *et al.*, 2016, Hansen-Addy and Nunoo 2014). But increased focus on sustainability and resource efficiency in the AEC industry (Ryd 2014), the increasing inclusion of stakeholder views, as well as

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the growing size and scope of projects (Flyvbjerg 2014) are starting to change the way infrastructure projects are executed. There is therefore a pressing need to look closer at this changing industry.

Novel forms of interdependent and complex major, mega and tera projects (Flyvbjerg 2014) require novel ways of management (Volker *et al.*, 2018). New project governance models, focused on collaboration and relationship building, have been introduced in both project-supported organisations, such as manufacturing companies and public institutions (Lundin *et al.*, 2015), but also in construction and infrastructure projects (Bygballe *et al.*, 2010, Volker *et al.*, 2018), partly in order to be able to deal with the added complexity of developing large infrastructure. One of the major drivers for introducing collaborative project models, such as alliancing, early contractor involvement, and partnering, in infrastructure construction, has been to reduce adversity and improve project outcomes (Lundin *et al.*, 2015, Volker *et al.*, 2018).

The infrastructure development industry is, as is the AEC industry, project-based, where the project shapes a project network, formed around the project and consisting of organisations participating in the project with different roles and goals (Adami and Verschoore 2018). Large infrastructure projects require a temporary network of actors, in which value is created in large-scale inter-organisational cooperation that is temporally bound (van Fenema *et al.*, 2016). As collaborative project models have increased in popularity since the turn of the millennia (Volker *et al.*, 2018), there are implications for the roles of actors and the way they act in the project network and this changes the way infrastructure projects are delivered and governed. However, there is currently very little research on how these roles and relations change. While many studies primarily focus on the benefits of collaborative project models, few discuss the transition in ways of working and in the network relationships between the different involved actors. It is therefore interesting to see how the roles of the actors in a transitory project network can impact project delivery: how the actors utilise the network, manage resources available to them, and engage in activities (Håkansson *et al.*, 2010). Our aim is to describe changing actor roles in complex, large-scale, collaborative infrastructure development projects.

We first discuss the theoretical background and framework. In the methodology section, the data collection approach consisting of semi-structured interviews in two case studies is presented. The findings section discusses the qualitative data related to the different network actor roles and these findings are related to literature in the discussion section. The paper ends with a conclusion section, as well as recommendations for future research.

THEORY

A project network is here defined as the network created in and around a specific project. It can be viewed as a network of actors, in an infrastructure construction project constrained to the client of the project, the lead designer, and the contractor; connected by state and event ties, such as project meetings and the governing contract (Adami and Verschoore 2018, Borgatti and Halgin 2011, Hastie *et al.*, 2017). These actors are engaging in activities, determined according to their role in the project network, and strive to fulfil mutual goals, defined by the project (Adami and Verschoore 2018). The parties involved also have their own goals that dictate their participation in the project, funded on both project goals but also goals put forth by their parent company, such as profit (Adami and Verschoore 2018).

A project network view opens up for understanding the dynamics of systems, such as people, material, resources, and knowledge, connected to temporary organisations. Some project networks may be governed by distinctive roles, performed by project participants, and the functional interdependence between these roles (Steen *et al.*, 2018). Such networks and roles are often seen in the AEC industry, although there does not seem to be a commonly accepted allocation thereof, so changes may occur between and inside projects (Hastie *et al.*, 2017). While research has discussed distinct roles in AEC projects, there is little known about both the relationships and networks forming in the collaborative models of project management, as well as the changing roles these new relations define, that are increasingly used in the infrastructure construction industry (Chen *et al.*, 2018, Jelodar *et al.*, 2016, Pryke *et al.*, 2018). Thus, there is a need for further study in this field.

Attributes that make infrastructure construction projects especially challenging relate to their complexity (Pryke *et al.*, 2018) and the impact they have on their environment (Eriksson 2015). Collaborative project models consist of both contractual mechanisms and non-contractual mechanisms like leadership, collaboration, communication and integration (Chen *et al.*, 2018). Many of these collaborative project models share an aim of integrating different phases of the construction project (i.e. design and construction) and include an early involvement of all concerned actors, to foster collaboration and deliver increased value to the client compared to traditional models. Some of the collaborative models used in infrastructure construction include alliance, early contractor involvement (ECI), integrated project delivery (IPD), and partnering (Chen *et al.*, 2018, Lahdenperä 2012). These models are often divided into phase 1, design or planning, and phase 2, construction. The reported benefits of these models include lower costs and improved constructability, a lower risk of delays, improved teamwork, higher levels of trust within the project organisation, as well as reduced litigation and improved satisfaction (cf. Franz *et al.*, 2016, Hansen-Addy and Nunoo 2014, Volker *et al.*, 2018). It is therefore possible that a well-managed project, contributing to strong relationships within the project organisation, will both facilitate collaboration and lessen conflicts (Jelodar *et al.*, 2016).

The rising interest in collaborative project models, such as alliancing, early contractor involvement, and partnering, brings with it changing roles, activities and impacts on the project network, which relate to one of the main points of collaborative models: the relationships it promotes within the project network. These relationships can be seen as relationships in the project network itself, but also the relationships involving parent companies and subcontractors taking part in the project. The client is an organisation that initiates a project to fulfil an identified need. In a construction project, the client has to manage “requirements and conditions within building and construction projects” (Ryd 2014: 135). In infrastructure construction, the client is usually a public organisation or institution, as infrastructure projects generally are large-scale, society-impacting programs. The client does have a possibility to impact development of future fields, such as sustainability, through project requirements and involvement in the project (Lundin *et al.*, 2015, Ryd 2014). The role of the client depends much on the project context, as different models often require specific client input. A small-scale municipal construction project in a well-known field, such as building a school, doesn't need much client input as the goal is clear and construction process well-known. As the size of projects grow, so does the need for a more

involved client, as trust, commitment, and teamwork need involved actors to flourish (Jelodar *et al.*, 2016).

The lead designer is contracted to develop concepts and plans. The lead designer can be either a single firm with multiple specialties, or a combination of smaller companies, including architects, construction designers, and experts in different related fields. In the Nordic construction industry today, the role of the lead designer is focused in the planning phase of a construction project and many existing processes are based on plans being completed before the construction phase begins. The role changes with a deeper collaboration with the contractor in the planning phase, which impacts the design work. The contractor is engaged to realise the project. The contractor can subcontract parts or all of the construction work and thus create a separate network within the larger project network. A contractor is often viewed as a project-based organisation (Hastie *et al.*, 2017, Lundin *et al.*, 2015), where the network actors are focused on one project at a time and their home organisation is focused on managing a portfolio of projects. The contractor role has traditionally been focused in the execution phase of a construction project. As their involvement is demanded in the earlier stages of the project, the role changes from a purely executing one to include aspects of planning and facilitation.

In keeping with current international trends, public infrastructure project clients in the Nordics have started to apply collaborative models to their projects. This has raised interest in how the public actor's role is impacted in the project. As collaborative models become the norm, the roles of the different actors involved in the infrastructure project will change as well.

RESEARCH DESIGN

The study applies an inductive and interpretive approach in order to study the transitioning role of the main network actors in large-scale infrastructure projects that apply a collaborative project model. In order to fulfil the objectives of this study we studied two large and complex infrastructure projects in a Nordic setting, where document analysis and 41 semi-structured interviews (20 for case A and 21 for case B) with various project actors were carried out. All interviews were taped and transcribed. The projects were selected on the usage of a collaborative project model, and both projects are pilot projects. For the semi-structured interviews, a common interview guide was used that focused on questions concerning the role of the actors and their relationships, the project itself, and collaboration in the project. The interviews were conducted with respondents in both managerial positions, i.e., project manager or division head, as well as in positions like technical specialist and construction site manager. Interviews were conducted in the three actor segments of client, lead designer and contractor. In addition to the interviews, we carried out a number of observations of the collaborative spaces and collected secondary material in terms of project documents, e.g., organisational charts and contracts, for both cases. For the analysis, data was coded thematically in relation to the different actors in the project network, the relations between the actors, and activities for collaboration.

The case studies (see table 1) represent two Nordic infrastructure construction projects, implemented in an urban setting and employing a collaborative project model approach. The cases can be classified as major projects with respect to their projected cost and time span, as well as the number of stakeholders involved. Both projects employed a two-step process, where a design phase (phase 1) was followed by a client decision on whether to continue with construction (phase 2) or end the project. The

projects are applying different collaborative project management models and are performed in different countries which makes a direct comparison difficult. However, the differences in the cases help us highlight variances between the models, as the cases are comparable in both size and cultural framework.

Case A is a large-scale infrastructure construction project, constructing a new public transportation setting based on rail, where the public client and the contractor have a bilateral contract, with the contractor subcontracting planning, design and other aspects of project execution. Project planning started in 2014, phase 1 started in 2016, and phase 2 in 201. The project is still ongoing and is estimated to be completed in 2026. The project includes a reward system based on final price. The project is managed by a contractor who subcontracts planning and other aspects of the project. The contractor was chosen based on the contractor’s total estimated production cost, but also on so-called soft parameters, such as collaboration and teamwork.

Case B is a large-scale infrastructure construction project, constructing a new public transportation setting based on light rail, where the public client, the contractor, and the lead designer (planner) all are part of the same contract (multi-party contract). In case B, project planning started in 2016, phase 1 in 2018, and phase 2 in 2019. The project is still ongoing and is estimated to be completed in 2024. project includes a reward system based on final price, as well as key performance indicators tied to project performance and established parameters.

Table 1: Case descriptions

	Case A	Case B
Length	9,5 years (estimated)	6,5 years (estimated)
Monetary value	475 million €	390 million €
Contract type	Bilateral (client-contractor)	Multi-party
Research methods	Interviews, document analysis	Interviews, document analysis, observation
Interviews	20 interviews	21 interviews
Interview lengths	1-1,5 hours	1-3 hours
Roles interviewed	Main actors in the project: client (8), contractor (6), lead designer/subcontractor (6)	Main actors in the project: client (5), lead designer (7), contractor/subcontractor (9)
Observations	Observations of meetings and big room activities	Observations of meetings and big room activities

FINDINGS

The main findings relate to the transitioning roles necessitated by the new collaborative project models, as all actors’ roles are impacted by these changes. The largest difference was in the extent of transition achieved in the cases; in case A, the transition into a truly collaborative project model was only done to a limited extent and the actors had difficulty to transform their traditional roles, while case B showed that the different roles in the project transformed and all actors acknowledged this transition process. Below the three main actors and the changes in their roles and relationships are discussed.

In most infrastructure projects with more traditional project models, the public clients are not involved in the project team but have a role to define requirements and check if these requirements are met. However, for the collaborative project model the role of the client is changing. The two cases both perceived this changing role of the client but acted differently upon this. In case A, the relationship was fraught with tension and conflict related to how the actors’ perceived the project model. In case A, several

interviewees mentioned the lack of expected collaboration and how especially the client and contractor had diverse expectations on each other's role as well as the interpretation of the governing contract. The client in case A stated the following: "[the project delivery process] was not as we expected it to be. Either we [client] have been very bad at explaining that what it was we wanted out of this, or for some reason, the contractor interpreted it not as we expected them to". In case B, the client role was clearer, and they took on an active role in both phase 1 and 2. In both cases, both the contractor party as well as the client party discussed the changing role of the client in the collaborative project model employed. It became clear from the interviews that this role still needs improvement as it is still somewhat ambiguous. One respondent of case B states, "what's special about this is that this is a very complex and unusual situation, as this [project] model is new to [the clients] [...] and the model affects specifically the role of the client. And in my opinion, this is the biggest lesson in this collaborative model, the role of the client". Other respondents were of the opinion that it was a learning process for all. In both cases the transition in the client role was perceived as a major factor for the collaborative project model to work successfully. Interviewees mentioned that special care should be taken to ensure the client's active involvement in the early phases of the project, which was seen to potentially lead to less bureaucracy in the process. The biggest obstacle to active client involvement was insufficient human resources on the client organisations' part, such as specialists and people empowered to make decisions on their parent organisation's behalf.

Lead designers are, as opposed to the client, used to work collaboratively in projects and in a project network. However, many designers work in multiple projects and not always in one single project and they usually split their time between separate projects, which could be a problem in engaging full-time in a collaborative project model. One respondent in case B commented that it's easy for contractors, who are used to work with one project, but that "design firms have more of an '100 irons-in-the-fire' approach", which could lead to conflicts in the project network. The lead designers were, however, used to working in an iterative way with the client, when discussing and refining plans and were therefore quite comfortable with the collaborative models used.

In case A, the role of the lead designer was perceived as rather similar to traditional projects, as the project used a bilateral contract between the contractor and the client. In case A, the contractor hired the lead designers for phase 1 (design) and 2 (construction) and as the lead designer saw the contractor as their client and did not have a close relationship with the public client. For the design work, there had been some deeper collaboration with the client in the planning phase, but the majority of the lead designer's work was done at their home office. This was partly due to the resources available at the project office, such as peer knowledge and experience, well-functioning IT-connections, and support functions.

In case B, a multiparty contract was applied in which client, lead designer, and contractor had a joint contract. The biggest discussion point related to the lead designer's role in terms of the collaboration with the contractor and the need for more trust and communication with the contractor. As few designers had experience of such work settings, and the needs of the other party were unclear, as well as their own role, phase 1 (design) of the project had been characterised by smaller conflicts between designers and contractors. The conflicts had been exacerbated by a lack of resources from both sides, which was tied to project management and project resourcing in general. This continued into phase 2 (construction), where some of the

conflict persisted, mostly due to a lack of understanding of each other’s roles. The designers felt that the contractor mainly focused on construction aspects, related to time and costs, while they wanted more time to design the complex solutions of the project. The contractors felt, however, that the designers needed too much time and wanted the planners to finalise their designs so that construction activities could start. This was visible in the iterative way plans and construction proceeded; many respondents used the term “hand-to-mouth” about the process, as construction sometimes had to commence with quite fresh plans and the lead time for construction sites was short.

Table 2: Project phases and roles

Transitions in role	Client	Lead Designer	Contractor
Case A - phase 1	Mismatch of expectations on role client and contractor - Aware of a needed change, but struggling to change their role and maintain their traditional role	Lead designer works mainly with contractor - no changes in role	Mismatch of expectations on role client and contractor - Aware of a needed change, but expects this of the client and maintains traditional role
Case A - phase 2	Traditional contract and falling back in traditional client role	Lead designer works mainly with contractor - no changes in role	Traditional contract and falling back in traditional contractor role
Case B - phase 1	Active role of client in project, recognizing new role	Lead designer’s relation with contractors related to traditional role differences	New role of contractor in project not fully anticipated
Case B - phase 2	Active and engaged client interacting with designers and contractors	Iterative planning and short lead time create friction with contractor	Iterative planning and short lead time create friction with designer

The contractor saw no challenges related to project governance due to the collaborative model, although the contractors in both cases mentioned benefits related to using a collaborative model. The main mentioned benefit related to time savings, but also to improved constructability. The biggest difference between the cases could be seen in the perception of the contractor’s role in the project network. In case A, the contractor states that things have changed and that they are working in a collaborative manner, but the client perceives their actions as following established patterns of traditional, adversary, project management. In case B, the challenge in developing the contractor’s role was related to the inexperience of the actors with the project model and the inclusion of their input early on in the process. It was especially visible in the iterative nature of the early planning phase (phase 1), as the contractor was unfamiliar with this, and “just wanted to get to the real work”. This was also remarked upon by respondents from both the client and the lead designer in case B. The biggest challenges to the contractor’s role were found in the early phases of the project, where both lead designer and contractors commented on the need to increase communication and the lead designer’s trust in the contractor, and to share unfinished work between the two actors, in order to fully utilise the benefits of the collaborative model.

There were also differences between the public client and private contractor in terms of a focus outside of the project. Both infrastructure projects have high impact on society and the environment in terms of social, economic and financial sustainability. The role of the public client also includes to take care of the surrounding environment of the project. In case B there was extensive communication to the surrounding environment from a joint communication group consisting of client, consultants and contractor representatives. In case A, there seemed to be different expectations

between the two parties on their engagement with the surrounding environment. Here, the client expected that the contractor would take part in this communication role, which the contractor did not expect or acknowledge.

DISCUSSION

Large urban infrastructure projects have a major impact on society and could support the common good through improved collaboration between multiple actors (Flyvbjerg 2014, Volker *et al.*, 2018). In recent years collaborative project models have been introduced with the aim of improving project outcomes in the challenging and complex environment of urban infrastructure projects (Volker *et al.*, 2018). These large projects are the source of temporary networks of actors cooperating over organisational boundaries (van Fenema *et al.*, 2016). While there has been substantial research on different forms of collaborative project models, the main focus has been on procurement, governance, benefits and hindrances of working with these models (Bygballe *et al.*, 2010, Volker *et al.*, 2018). However, few studies focus on the different actor roles and changes in their relationships from a network perspective. From the two cases studied, it was found that the collaborative models impact the relationships in the project, partly through the changing roles of actors and relationships between the actors in the networks.

The biggest role and relationship changes in the project network appear in the role of the client and the contractor in both phases of a collaborative project model. A collaborative project model would seem to indicate a need for the client's role to develop into a more active and participatory one, especially in the early phases of the project, as seen in case B where the client, lead designer, and contractor all were part of the same project contract and developed a more joint perception of the project model as well as clearer roles. The contractor's role is also changing, as the collaborative model requires more input from them in early phases and a need for the contractor to collaborate with both client and consultants in iterative ways which they are unaccustomed to. This would impact the project network, as the collaborative aspects impact project delivery and goal consensus (Steen *et al.*, 2018).

While the collaborative project models aim for a collaboration between all actors, the change in behaviour, practice and perception was not clear for all actors especially in case A. In case A both client and contractor were aware of a need to change their roles, but their actions are not in line with the necessary transition. Although both stated an interest in collaboration, they maintained their traditional approaches to the project as evidenced by the inability to agree on contract interpretation. This might be in line with other research discussing the difficulties in changing institutionalized practices and behaviour in the AEC industry (Bygballe and Swärd 2019). In case B, the application of the new model was clearer, and interviewees stated that they perceived changes in their roles. Although conflicts appeared also in case B, they were mainly related to the unfamiliarity of the new roles.

Lastly, the organisations in the project network are working towards both mutual project goals and their own goals for participating in the project as well as goals from their parent organisation (Adami and Verschoore 2018). In the cases studied, the public client has goals related to urbanization and sustainability, as well as an efficient use of public funds for the common good. The contractor and consultant, usually private corporations, mainly work towards shareholder profits, but sustainability is also a major driver amongst private organisations active in the infrastructure sector. The goals of the private and public actors might not always go hand in hand and even

though the project has a joint goal, these differences in the actor's organizational goals and roles can come forward in the project as well. In case A for example there were different expectations on the way the project actors should communicate with the surrounding environment. These expectations were not clearly discussed but come forth from the different organizational goals of the different actors.

Even though the collaborative project models have been increasingly used in the Nordic Scandinavian countries and clear benefits are found in literature for their usage, the transition of behaviour of the different actors involved will need additional attention in future research. From our research it becomes clear that the different actor roles and relationships between the actors need a transition and this transition is not always easy in a rather institutionalized industry as the AEC, as evidenced by the difficulties the project actors in case A had in transitioning to a collaborative network relationship, while in case B the project network's evolving transition was reflected upon and interviewees noticed changes in the different roles within the project. This might be connected to the chosen collaborative project model, but this aspect is outside the scope for this study and requires further research.

CONCLUSION

In an urbanising world, the impact of infrastructure construction projects is immense. In recent years, collaborative project models have been implemented to help with problems endemic to the industry. These models bring with them new requirements for actors participating in the project network, as they impact the roles and relationships forming in the project. In this study the focus has been on the transition of the actor roles in the project network in major infrastructure projects.

From the two cases we found that all members perceive that a transition in the different roles is needed, but not all actors are transitioning to a new role and some maintain their traditional role. The major transitions are found in the client and contractors' roles. The lead designer's role has the least changes to it, as they are both used to a project-based process, as well as iterative work processes and close collaboration with the client.

This study presents an insight in the transition of roles in more collaborative project models, but future research would need to study the project network, the different actors, the relationship between the actors, and transition in actors' roles in more detail with multiple cases and additional qualitative and quantitative data. Another interesting aspect would be to look at how the chosen collaborative project model shapes the project network.

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ADVANCEMENT OF THE DESIGN OF AEC-RELATED BUSINESS MANAGEMENT CONCEPTS ALONG THE COMMON GOOD DIMENSION

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The background involves the reviewing of AEC-related business management (BM) concepts since 1999. The aim of this focused review is to advance the design of AEC-related BM concepts along the common good dimension. A BM concept is herein defined as an abstraction representing a firm managing its business with contexts embedded within AEC sectors. The high, medium, low or no degrees of the design of 73 AEC-related BM concepts (published between 1990 and 2019) along the common good dimension were assessed. It turned out that the seven areas of common good have been designed as part of 17 AEC-related BM concepts, i.e., environmental sustainability, networked communities, community engagement, social capital, social responsibility, fair trading and use value. In the future, many areas of common good can be incorporated into extended offerings (e.g. diversity in planned communities, beneficent owners and signature outlooks) as part of architecture (A)-related BM concepts, into core offerings (e.g. eco-efficient life cycles, energy resilience and circular materials) as part of engineering (E)-related BM concepts and into business processes (e.g. multi-year sub-city phasing, community roles of buildings and non-harmful uses) as part of construction (C)-related BM concepts. Indeed, ARCOM-related experts, business managers and other actors are invited to join the advancement of AEC-related BM knowledge, concepts and practices.

Keywords: AEC, business management, common good, environment, sustainability

INTRODUCTION

This author has been reviewing research on business management (BM) concepts with contexts related to architecture, engineering and construction (AEC) sectors since 1999. The eight review rounds have been carried out in 1999-2003, 2006, 2010-2012, 2014, 2017, 2018, 2019 and 2020. The coherent nature of managing firms and their businesses is maintained by focusing on research on firms that are based in the OECD countries. Exceptionally, references originating from Singapore and Hong Kong have been included due to these authors' British Commonwealth heritage and interests in AEC sectors across the globe. The planning and use of the method for the reviewing of conceptual research, i.e., ways of searching, browsing, in-/excluding, retrieving, coding, describing, analysing and interfering have been reported upon (Huovinen,

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2003 and 2008). Hart’s (1998) guidelines have been relied upon. The search for eligible BM concepts has been conducted comprehensively within the volumes of 28 AEC-related journals published between 1990 and 2019 and those of 47 journals on business administration published between 1990 and 2013. Concerning the other formal channels, the degrees of the comprehensiveness of the search have varied markedly. The original rules of relevance, elimination and inclusion (Huovinen, 2003a) have been re-adopted to maintain consistency and eliminate non-eligible concepts. Cooper’s (1998) approach and the original limitations have been re-adopted to protect the review validity during the rounds. This author submits the detailed report on the conduct of the reviewing process during 1999-2020 on request.

Aim and Units of this Focused Review

The aim is to advance the design of AEC-related BM concepts along the common good dimension. It is herein posited that the desired advancement be based on the revelation of the current degrees of such designs along the common good dimension via the focused review of AEC-related BM concepts published between 1990 and 2019.

An AEC-related BM concept is defined as an abstraction representing an object or a phenomenon, i.e., a firm is managing its business with contexts that are embedded within one, more, or all architecture, engineering and construction (AEC) sectors, i.e., the contracting, design, construction and project-based aspects of capital investments in natural resources usage, energy supply, telecommunications, transportation, infrastructure, manufacturing and general building concerns.

When an AEC-related BM concept is being designed, it is herein interpreted that a concept designer at the same time replies to the fundamental question “What is a principal way of managing a business entity that enables to set challenging goals and also to attain them?”

Along this line of conceptualisation, there are the four types of units of this focused review (Fig. 1). The 1st-tier management involves (1a) concepts for the creation and capture of value by a business entity, clients, and other stakeholders that are directly causally related to the setting and/or attainment of a business entity’s goals and (1b) concepts for supporting the same. The 2nd-tier management involves (2a) concepts for the development of competitiveness of a business entity that are necessarily enabling, but indirectly related to goals management and (2b) concepts for supporting the same (Huovinen, 2008).

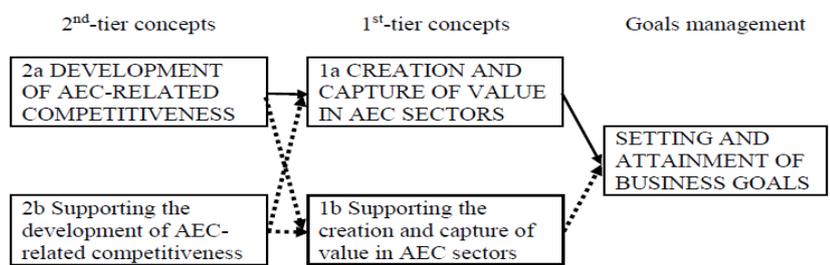


Figure 1: Four types of AEC-related BM concepts as the units of the review

The term "a business entity" accommodates (a) a single-business firm, (b) a business unit as part of multi-business corporation and (c) a business network consisting of two or more members and being managed by a leading member or all members on an equal basis.

Moreover, authors may design eligible BM concepts for contexts embedded within one, more, or all AEC sectors, or sub-sectors.

Conduct of this Focused Review

OED (2020) defines common as “belonging to more than one as a result or sign of co-operation, joint or united action, or agreement; to make common cause, to unite one's interests with those of another, to league together” and common good as "the public property of a community or corporation". For this focused review, the two generic definitions are adopted as the broad scope of AEC-related common good containing various areas, such as community engagement, environmental sustainability, fair interactions, stakeholder value as well as social capital, citizenship and responsibility. For the actual assessment, the four degrees were pre-specified for the linking of common good and BM conceptually. An authorship may have designed an AEC-related BM concept along the common good dimension to:

- a high degree: common good is explicitly and extensively assigned to both the demand side (e.g. to enable owners to deliver social good) and the supply side (e.g. to adopt environmentally sustainable operations) of BM of AEC firms
- a medium degree: common good is explicitly assigned to either the demand side or the supply side of BM of AEC firms
- a low degree: common good is only mentioned (e.g. to be socially aware)
- no degree: the authorship has written nothing about common good.

The results of the common good-focused, concept-specific assessments have been compiled in a set of tables. The corresponding sentences, phrases or single terms were quoted and coupled with the related page numbers within the references, respectively (see Tables 3 and 4). This author submits the common good-focused tables on request.

The focused review has been protected against the four biases as follows. Concept Inclusion Bias 1 involves this author perceiving that an author(ship) has designed an AEC-related BM concept along the common good dimension even if the authorship has not done so. This bias has been minimized by assessing each reference in the same way based on the quoted words that necessarily depict the focal area within each BM concept. Future reviewers can test the inter-concept consistency of inclusion by repeating the assessments, i.e., reading the references and confirming the quotations that this author has selected or rejecting some of them and, thus, excluding the same.

Concept Exclusion Bias 2 involves this author perceiving that an authorship has not designed a BM concept along the common good dimension even if the authorship has done so. A no-degree assessment indicates that this author did not identify any areas of common good. Future reviewers can test the inter-concept consistency of exclusion by repeating the assessments, i.e., reading the references and confirming the exclusions or identifying eligible elements in some concepts and including the same.

After the inclusion, Degree Assessment Bias 3 is related to this author's reliance on the pre-specified scale of the three analytical degrees instead of a quantitative scale. The 3-degree lens corresponds to the explorative nature of the focused review. This author could assign one of the three degrees to each of 13 BM concepts without hesitation. Future reviewers can request this author to submit the concept-specific quotations and assessments to them and test the inter-concept consistency of degree assignments by reading the references and confirming the same degrees or assessing

changes in some of the included BM concepts and justifying such changes with quotations. Or, they could adopt one of quantitative scales.

Concept Designer-Reviewer Bias 4 is related to a fact that this author has designed 12% or 9 out of 73 AEC-related BM concepts. Therein, I have designed 2 high-degree areas, 0 medium-degree area, 3 low-degree areas and 5 no-degree areas along the common good dimension. Future reviewers can carefully test the inter-concept consistency of my assessments versus each of the three other biases in the case of my 9 AEC-related BM concepts. Other reviewers may come up with some explanations for this reviewer being, so far, the only designer of 2 high-degree AEC-related BM concepts along the common good dimension.

Degrees of the Design of 73 AEC-Related BM Concepts Along the Common Good Dimension

Overall, this author has identified 73 AEC-related BM concepts that have been published between 1990 and 2019. This author submits a complete list of 71 references containing these 73 AEC-related BM concepts on request. In turn, this focused review reveals that the majority or 56 (77%) AEC-related BM concepts have not been designed along the common good dimension. So, 17 (23%) authorships have designed their AEC-related BM concepts along this dimension (Table 1).

Table 1: Results of the assessment of the designs of 73 AEC-related BM concepts (published between 1990 and 2019) without and along the common good dimension

BM concepts designed without the common good dimension No. (%)	BM concepts designed along the common good dimension No. (%)	All AEC-related BM concepts No. (%)
56 (77%)	17 (23%)	73 (100%)

Moreover, these 17 authorships have designed 20 areas within their BM concepts, i.e., 2 high-degree, 2 medium-degree and 16 low-degree areas (Table 2).

Table 2: Results of the three-degree assessment of the designs of 20 areas within 17 AEC-related BM concepts (published between 1990 and 2019) along the common good dimension

High-degree areas No. (%)	Medium-degree areas No. (%)	Low-degree areas No. (%)	All areas No. (%)
2 (20%)	2 (20%)	16 (80%)	20 (100%)

The converging authorships have designed 13 environmental sustainability areas within their AEC-related BM concepts along the common good dimension (Table 3). Huovinen (2011a) has implanted 23 high-degree sustainability drivers into life-cycle contracting and property development businesses (e.g. the coupling of object development ideas with sustainability advantages), design-build contracting business (e.g. the re-engineering of value chains with all tiers of stakeholders), design business (e.g. the transformation of design firms into long viewers, path dependency breakers, stock-specific programmers and object-specific planners) and building products supply business (e.g. cradle-to-cradle certifications and product formula renewals).

Huovinen (2011b) has designed a high-degree, 5-element BM concept by (i) customising sustainability into offerings and competitive strategies, (ii) leveraging sustainability into processes, (iii) crafting sustainability into the core of competitiveness, (iv) fusing sustainability into a business frame and governance, and (v) linking a focal firm with highly sustainable collaborators.

Chinowsky with Meredith (2000) have designed medium-degree competency spectrum and maps, including sensitive core designs based on support strengths, enabling solutions, engineering as a surface characteristic as well as environmental area and testing as a competency (150).

Table 3: Degrees of the designs of the environmental sustainability areas within 13 AEC-related BM concepts (published between 1990 and 2019) along the common good dimension

Author (year)	BM concept and its focal context	Assessed degree of the design of the environmental sustainability area (quoted page No.)
Huovinen (2011a)	4 environmentally sustainable businesses in 8 competitive arenas in construction markets	High: Implanting of 23 high-sustainability drivers into each of 4 businesses via 23 competitive arenas (6-12)
Huovinen (2011b)	BM concept as a 5-element system for managing businesses with contexts embedded within construction markets in highly environmentally sustainable ways	High: (1) customizing sustainability (S) into offerings and competitive strategies, (2) leveraging S into processes, (3) crafting S into the core of competitiveness, (4) fusing S into a frame and governance, and (5) extending the frame, linking with highly sustainable collaborators (11-13).
Chinowsky with Meredith (2000)	7 areas of strategic management, feedback with a competency spectrum and maps in US civil engineering organizations	Medium: Sensitive core designs, based on support strengths, enable solutions (130, 142), engineering as a surface characteristic (146), and environmental area and testing as a competency (150).
Hawk (1992,2006)	Continual learning system based on a learning capability in international building	Low: Growing environmental concerns are among 6 most promising ideas over the next 10 years (741).
Flanagan (1994)	Successful construction company in the year 2000 based in the UK	Low: Consciousness, sustainability among 11 forces driving strategies (312). Impacts of design on surroundings become important (316).
Veshosky (1994)	Framework for AE firms in the USA	Low: Systems (43), facilities (44) as projects, hazardous waste as core competencies (45).
Løwendahl (1997/2000)	Resource-based strategies for US professional service firms	Low: Environmental protection as a market (106).
Huovinen (2001)	Competitive strategy in technology-intensive contracting	Low: Solutions' environmental impacts as one of clients' 9 decision criteria (73)
Love <i>et al.</i> , (2002)	Model for alliances based on TQM and supply chains in Hong Kong	Low: To take ethical consideration of environmental responsibility in alliances (12).
Anderson, Merna (2005)	Business development process in PM services in the UK	Low: Environment management is one of 11 domains of development (175).
Mutka, Aaltonen (2013)	Business model for managing a (metallurgical) processing technology supplier based in Finland	Low: Mission involves life-cycle solutions for the best returns on clients' investments. Environment-friendly, safe, ergonomic technologies (170-171).
Brege <i>et al.</i> , (2014)	3-block and 5-element business model for industrialized building of N-storey dwellings in Sweden	Low: Frame system supplier with climate-proof structural frame offerings is one of 5 empirically identified business models (221).
Aliakbarlou <i>et al.</i> , (2018)	Contracting services+client values assessed by traditional, service and personnel attributes in NZ	Low: Low rate of environmental impact is specified among 8 client values of the category of service attributes (1019).

Among 10 low-degree environmental sustainability areas, Hawk's (1992, 2006) business ideas include growing environmental concerns. Flanagan's (1994) environmental consciousness is driving strategies. Veshosky's (1994) core competencies include hazardous waste. Løwendahl's (1997/2000) markets include protection. Huovinen's (2001) solutions with environmental impacts are among

clients' 9 decision criteria. Love *et al.*'s (2002) alliance involves environmental responsibility. Anderson and Merna's (2005) domains of development include management services. Mutka and Aaltonen (2013) case firm offers life-cycle solutions. Brege *et al.*'s (2014) business models include climate-proof structural frames. Aliakbarlou *et al.*'s (2018) client values include environmental impacts.

Besides environmental sustainability, the diverging authorships have designed many other areas within their 7 AEC-related BM concepts along the common good dimension, respectively (Table 4). Bennett (2000) has envisioned the medium-degree, 7-pillar paradigm of partnering with a goal to balance competition and cooperation.

Table 4: Degrees of the designs of the other areas within 7 AEC-related BM concepts (published between 1990 and 2019) along the common good dimension

Author (year)	BM concept and its focal context	Assessed degree of the design of the area (quoted page No.)
Bennett (2000)	A third way, a new paradigm's 7 partnering pillars balance competition and cooperation in the UK construction industry	Medium in memberships in networked communities: Industry is seen as richly interconnected networks. Lasting success can come only from the success of the extents of communities of which the industry is part (82-83). Organizations try to involve local communities in their decisions (83).
Flanagan (1994)	Successful construction company in the year 2000 based in the UK	Low in community engagement: Concerns about the community (318).
Love <i>et al.</i> , (2002)	Model for alliances based on TQM and supply chains in Hong Kong	Low in social responsibility: To take ethical consideration of social responsibility in alliances (12).
Huovinen (2003b)	Systemic concept for managing a 5-element, capital investments-based business in knowledge management (KM) -based ways	Low in social dimension: Among 5 elements, the governing framing takes place along social and other interrelated dimensions (378).
Huovinen (2011a)	4 environmentally sustainable businesses in 8 competitive arenas in construction markets	Low in fair trading, stakeholder (incl. human health and rights) impacts on communities: The implanting of 2 drivers into design businesses and 1 driver into supply businesses (8-11)
Bos-de Vos <i>et al.</i> , (2016)	Trade-off framework of use, professional, and exchange value creation and capture in Dutch architectural firms	Low in use value creation and delivery: To create the use value of buildings for clients, users and society, to offer unpaid services to highlight the use value from a user's and societal perspective, or to create sustainable buildings (27).
Goh, Loosemore (2017)	Adoption of off-site technologies based on 6 VRIN resource categories by subcontractors in the Australian residential construction market	Low in social capital: Networks do not translate automatically into intangible social capital located outside business in relations with others. Social capital is a critical resource for engagement in off-site prefabrication (292), but the social resources of local subcontractors were project-based (301).

Accordingly, the UK construction industry would become the tapestry of richly interconnected networks within societies. Lasting success can come only via a focal organisation's memberships to multiple communities.

Among 6 low-degree areas, Flanagan's (1994) concerns include also community engagement. Love *et al.*'s (2002) alliance involves social responsibility. Huovinen's (2003b) governing framing takes place along social and other interrelated dimensions. Huovinen's (2011a) drivers include also stakeholders' impacts on human health and rights in communities. Bos-de Vos *et al.*'s (2016) use value depicts architects who are

creating the value of buildings also for society. Goh and Loosemore's (2017) external relations-based social capital is a critical resource in the case of subcontractors that are engaging in prefabrication.

Designing AEC-Related BM Concepts Along the Common Good Dimension in the Future

It is herein posited that highly theoretically advanced and highly practically applicable AEC-related BM concepts be designed at the same time along the core business dimensions and the common good dimension. Ex ante, this dual effectiveness can be achieved when concept designers become aware as well as prefer and incorporate the specific areas of common good into BM concepts.

Readily, this focused review reveals that 13 authorships have designed the environmental sustainability areas as part of their AEC-related BM concepts, respectively. In addition, 7 authorships have designed the other key areas of common good, i.e., networked communities, community engagement, social responsibility, social capital, fair trading and use value, respectively.

Consequently, the design of common good-based, AEC-related BM concepts could be advanced segment by segment as follows.

When architecture (A)-related BM concepts are advanced, many areas of common good can be incorporated into extended offerings, such as (i) urban and regional plans with all-inclusive programmes for natural, built and social environments, diversity in communities, employment and entrepreneurship, well-being and safety, and the inspiring blending of public, private and third sectors and (ii) architectural solutions for various uses of buildings and spaces, both over life cycles and shorter periods, with the requirements of beneficent ownerships, signature outlooks, aesthetic values, easy orientation and smooth people flows, the affordability and flexibility of spaces.

When engineering (E)-related BM concepts are advanced, many areas of common good can be incorporated into core offerings, such as (i) infrastructures for transportation and logistics with options for eco-friendly use, upgrading and extension, (ii) frames and other structures in buildings with load bearing capacity and eco-efficient life cycles, (iii) technical building solutions and services with clean air and spaces, energy resilience, optimal water consumption, extensive waste management and real-time monitoring and (iv) the first uses and re-uses of construction materials with circular specifications.

When construction (C)-related BM concepts are advanced, many areas of common good can be incorporated into business processes, operations or functions, such as (i) city development processes with multiple balances between households, public organisations and private stakeholders, multi-year sub-city phasing, external and internal integration and green financing, (ii) building-specific development processes with the community role assigned to each building, early involvement of good preferred by owners and users, multiple common functional spaces, private and public services, (iii) infrastructure development processes with the blending of the life cycle perspective, user need fulfilment as well as environmental and social impacts, (iv) new and renovation construction processes with the high-productivity integration of off-site and on-site prefabrication and works, well-being of staff and workforce and (v) life-cycle management processes with the provision of joint full-time, smart, easy and non-harmful uses of buildings and infrastructures.

DISCUSSION

On the theoretical sphere, the design of AEC-related BM concepts along both the core business dimensions and the common good dimension serves as (i) the broader societal foundation of a communication, (ii) enhanced ways of looking at changing empirical AEC-related contexts, (iii) means of classifying and generalising BM situations, e.g., stating those common good-based, AEC-related conditions when the efforts of business managers are likely to be (un)successful and (iv) components of theories or models and thus of explanations, predictions [and prescriptions] vis-à-vis accommodating various areas of common good over time (applying Ghauri and Grønhaug, 2002).

On the practical sphere, common good may well become a key dimension of the management of AEC-related businesses. Contexts embedded within AEC sectors play significant roles in countries and societies across the globe. Thus, the design of AEC-related BM concepts with positive impacts on common good is one of the critical areas of advancement. However, all this requires that, *ex ante*, root clients (i.e. long-term owners and owner users, capital investors, developers) dedicate themselves in the spreading of common good around and include such key areas in investment and procurement strategies.

On the one hand, it is herein assumed that today the majority of owners and management in successful companies have adopted the hands-off approach to common good embedded within AEC sectors across the globe. Typically, such companies financially support common good initiatives as well as annually publish sub-reports on corporate governance, social usefulness, community engagement and alike.

On the other hand, many pioneering AEC companies have adopted the hands-on approaches to the environmental sustainability area along the common good dimension. These companies have based business ideas (e.g. Mott MacDonald 2020), offerings (e.g. Arup 2020) and processes (e.g. Skanska 2020) on the protection of natural environment. In addition, some AEC companies are also active in other areas of common good, such as United Nations Global Compact and good corporate citizenship (e.g. WSP 2019) and social enterprise and resilient communities (e.g. Bechtel 2020).

CONCLUSION

Overall, no research tradition or group has triggered a coherent flow of AEC-related BM concepts in any of the OECD countries. The temporal pattern is emerging. The content pattern is fragmented (Huovinen, 2019). Nevertheless, 73 AEC-related BM concepts published between 1990 and 2019 jointly address the issue-based dimensions, such as domestic business, international business, business ideation, competitive strategies, business processes, project phases and resourcing, competitiveness development, organising and framing, networking, digitalisation, financing, capital investing and risk taking.

The focus of this paper is on the advancement of designing AEC-related BM concepts along the common good dimension. In the future, the 73-concept platform readily offers a multitude of possibilities for concept designers to combine common good with the core business dimensions. Naturally, many other avenues will emerge and/or become dominant and call for the design of novel common good-based, AEC-related BM concepts. These avenues may include artificial intelligence, machine learning

and digitalisation as well as business networking (along the line of Bennett 2000) and the balancing of stakeholder's interests.

Indeed, ARCOM-related experts, business managers and other actors inside and outside the UK are hereby invited to join the advancement of common good-based BM knowledge, concepts and practices during the current COVID-19 era and beyond.

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THE PUBLIC CONSTRUCTION CLIENT OF THE FUTURE: NETWORK-BASED COLLABORATOR IN A TRADITIONAL PUBLIC ADMINISTRATIVE SYSTEM

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In the construction industry, public and semi-public clients increasingly depend on private parties to achieve project outcomes by adopting network type of governance approaches. However, social-political responsibilities remain at the public side. Hence, the general challenge for public commissioners is to find a new balance between dependency and responsibility when safeguarding competing traditional and network values. Based on three qualitative studies of a PhD project on safeguarding public values by public construction clients, applying concepts from public administration and public value theory, this paper presents three lessons learnt on future roles and responsibilities. We argue that future 'good' commissioning should be 1) more about embedding new value systems and less about changing existing values mechanisms, 2) more about paradox thinking in a convener role and less about trade-offs in a steering role and, 3) more about informal accountability in the value chain and less about formal accountability in the project chain. To ensure the 'right' kind of interference in the value process, public clients' way of coping with public-private conflicts, needs to correspond with the internal governance arrangements, and vice versa. Further research should focus on facilitating this alignment by providing a public value safeguarding strategy tool for public construction clients.

Keywords: public value management, public service, dependency, responsibility

INTRODUCTION

Similar to other industries, trends like globalisation, privatisation and servitization, change the relationship of public construction clients to society and market entities (Clifton and Duffield, 2006; Van der Steen, *et al.*, 2013). In addition, the complexity of today's construction challenges -such as growth of population, CO2 reduction and growth versus decline of urban areas -, asks for consideration of other (types) of values such as sustainability, circularity and 'smartness' by construction clients. To safeguard these values, clients need the expertise of market parties. As a response to the fragmentation of the construction industry and expanded levels of outsourcing

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therein, an increased focus on building a strong and unified sense of values, trust and value-based management between public and the private parties is ongoing (Bryson *et al.*, 2014). Together these tendencies call for more collaboration with both market and society in delivering and ensuring public values. This affects the task of public bodies in the public value process (Bao *et al.*, 2013; Bryson *et al.*, 2014; De Graaf and Paanakker, 2015). Traditional procedural public values such as integrity, lawfulness, reliability and equality are increasingly considered contextual, and public entities redirect their steering mechanisms towards other types of values such as serviceability and sustainability.

The shift of role and dominance of values can be recognized in the institutional change towards network governance. In the construction sector, the network type of governance can be recognized in collaborative practices such as Public Private Partnerships, co-creation and bottom-up initiatives. Public service delivery accordingly shifts from a direct to more indirect approach, becoming increasingly dependent on private market parties (Bao *et al.*, 2013; Tjosvold, 2008). In recent years we have especially seen a growing percentage of integrated contracts, where public parties outsource at least a part of their 'traditional' responsibilities regarding construction activity to private entities (Van der Steen *et al.*, 2013). Hence, the overriding challenge for public commissioners is to find a new balance between dependency and responsibility when safeguarding public values. This balancing implies dealing with often conflicting internal traditional administrative value systems and 'new' emerging value systems related to their external network oriented collaborative activities. This is referred to as a 'meta-governance' challenge; a (governance researchers') term to describe the way in which public authorities and other central, capable, and legitimate actors govern networks without reverting too much to traditional forms of command and control to ensure success (Koppenjan *et al.*, 2004; Sørensen and Torfing, 2017). Finding this balance is rather delicate, as a public party as a network collaborator, has to 'lean in' to the values of the network, but not 'tilt' and loose connection to the traditional public administrative system. Therefore, in this position paper we deduce three main lessons for the client of the future. Using theoretical insights from public administration and public value theory, we propose adjustments to be made to his role and responsibility when enhancing the possibilities for network governance.

Theoretical Background

Good governance is about the ability of public managers to optimize the balance between competing network and traditional values in public service delivery (Bruijn and Dicke, 2006; De Graaf and Paanakker, 2015), while engaging market and societal partners. The commissioning role is key in good public value management or governance, because the public construction client, is positioned at the intersection of their organisation and its social-political environment, while at the same time, the relationship between client and contractor is central in commissioning. Therefore, we focus on safeguarding values in the commissioning role. We define the activity of commissioning as 'the way a public organisation, in relation to its responsibilities in the built environment, shapes and implements its interaction with the supply market both externally and internally' (Hermans *et al.*, 2014). This dual - internal and external - focus corresponds with different ways to achieve public value; first from improving the government itself at organisational level, and second from public service delivery to specific groups or persons, using collaborative projects in a network environment (Cresswell *et al.*, 2006). Good network governance presupposes

alignment of internal and external commissioning activity within the public organisation, during the entire course of public service delivery (figure 1).

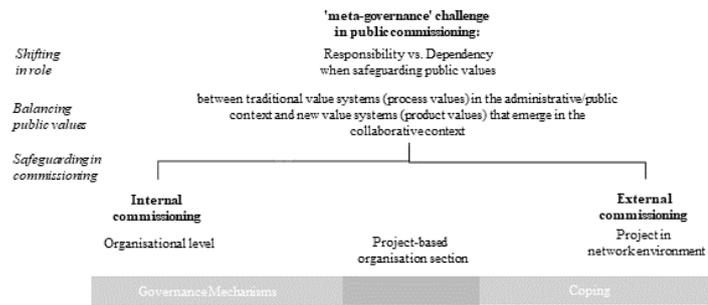


Figure 1: The meta-governance challenge in safeguarding public values

Discussing the external commissioning role, we look at the ability of metagovernors to find the right level of interference in the public-private network throughout public service delivery, as this affects whether or not this network becomes a successful policy tool (Sørensen and Torfing, 2017). Here, the concept of coping is relevant as it offers different ways to deal with the complexity of multiple values systems caused by the dominance of various - public-private- relationships occurring during the delivery process of public value. Coping literature provides a paradoxical perspective, allowing for engagement with complexity in network environments, in addition to the trade-off thinking focussed on reducing complexity used in more traditional conflict literature (Smith and Lewis, 2011). As the 'success' of network governance also depends on whether the chosen metagovernance strategy fits the objectives of the governance network, the alignment of what happens in the project network and in the parent, organisation is crucial (Sørensen and Torfing, 2017). In the project-based section of the organisation the vertical governance of the project chain, focussing on the relationship between the client and supplier/contractor (Winch, 2001), and the horizontal network governance of the value chain come together. When discussing the commissioning role, we therefore look at the implementation of the network type of governance, with its new value logics, within a traditionally oriented public construction client organizations, and the project-based urban planning section dominated by market mechanisms. The mixing of network, traditional and market governance modes results in internal hybridity, leading to internal governance conflict. This mixing also provides public actors with an ability to explore - innovating by crossing internal boundaries to work in an integrative way - using network management elements. While exploiting elements of traditional and market governance modes to sustain social political responsibility and ensure accountability (Eriksson, 2013; Keast *et al.*, 2006).

RESEARCH APPROACH

This position paper combines the findings of three qualitative studies belonging to the PhD project 'Safeguarding Public Values by Public Client Organisation in Construction'. This project aims to provide insight into the nature and impact of characteristics of public construction clients as professional 'safeguarders', and therefore metagovernors, of sector specific public values. The contents of each study is explained in table 1. As explained in the theoretical background section, safeguarding of public values exists of different actions at various levels. Each of the three studies focuses on specific actions at specific levels, but also partly overlap in their scope. The combination the three studies thus provides new insights in safeguarding public values in the commissioning role.

Table 1: Overview of studies

	Governance Mechanisms		Coping
	Study 3	Study 1	Study 2
Research Question	1. How do municipal organisations balance the multiple institutional logics that belong to different public value regimes in safeguarding public service delivery in the built environment?	1. Which public values play a role in public service delivery practices between public clients and contractors in construction? 2. What contextual factors influence construction client's value interests in these practices? 3. Which public value challenges do construction clients face in collaborative practices of public service delivery in construction?	1. How can multiple value systems coexist in the process of public service delivery? And; 2. How do public clients cope with value conflicts in public-private collaboration?
Methods and Data	Comparative case study between 2 municipal organisations - 15 semi-structured interviews with actors of various departments in the urban domain - 4 months of observations at one of the urban management department of one of the municipalities - Document analysis: value related documents, both internal and 4 projects	Semi-structured interviews - 44 qualitative semi-structured interviews, with 47 executives/public administrators of 17 different (semi)public organizations - Q-sort tables	In depth single case study of a participatory process of delivering a neighbourhood park - 19 case-based semi structured interviews with public, societal and market actors - 19 months of observations of gatherings of project team, local businesses and residents panel - 4 months of observations at public client organisation - Document studies
Output	- Internal governance conflicts: between layers and departments within the organization - Internal innovating and sustaining boundary practices	- Public value interests of public construction clients - Internal and external factors influencing the steering of public value interests - Dilemmas in balancing different types of values, and in being a construction client	- Value conflict arenas in hybrid projects - Coping patterns in hybrid project environments

A qualitative approach was chosen as this allows for theory building from practice and suits studies about processes of which little is known (Bryman, 2016); safeguarding in the commissioning role so far has not been studied in combination. Semi-structured interviews with open-ended questions were chosen as the primary method of data collection, to discuss the sensitive topics of conflicts and complex management in dealing with value plurality (Hennink and Hutter, 2011). Since in the project-based construction industry different (types of) public values need to be ensured in organisations differentiating in publicness, we included a wide range of public client organisations in the first study in order to increase generalizability. In studying project-based organisations, it is also important to account for the multi-level nature of governance of projects and administrative organisations, and we therefore interviewed multiple actors for each organisation. In the second study this multi-level element was taken into account. In our single case study of a participatory redevelopment of a municipal park, we interviewed both actors from the public-private project environment and from the public client organisation. Next to semi-structured interviews, we used participant observation both in the participatory process of public service delivery and at the urban management department of the municipal client organization. In addition, documents from both perspectives were conducted, also for triangulation purposes (Yin, 1994). In the third study we used a comparative case study - again based on interviews, observations and documents - of two municipal organisations, focussing on their urban planning section from an organizational governance perspective. Atlas.ti was used to analyse interview transcripts, documents and reports of observations in a systematic inductive approach applying thematic theoretical coding (Bryman, 2016).

FINDINGS

The research shows various practical difficulties in adapting and adjusting roles and responsibilities in the process of public service delivery when facilitating the shifting of value interests. This causes the overriding dilemma between dependency and responsibility. In combining the findings of the above three studies, we here create a deeper theoretical understanding of the practical meta-governance challenge, and present three lessons for the construction client of the future.

1. *More focus on embedding new value systems and less focus on changing existing value mechanisms*

The traditional approach of a strict distinction between the client and contractor responsibilities, or in other words, the idea that 'you pay and you will get the required product' is not sufficient anymore. Outcomes of study 1 show that joint competences are needed for adequate service delivery; there is a certain interdependency between client and contractor, a need to cooperate to come to the best solution. *"Sometimes, we do have the tendency to see the market as the other side of the spectrum. I think it is important that you actually search together for solutions in the middle. We have to draw upon our knowledge and skills, but we also have to trust that the others are not solely keen on the least effort for the largest part of the money."* To facilitate adequate use of competences, it is important to recognize and accept the interest of the potential contractors: *"By equality I mean that you have to recognize each other's qualities and each other's worlds and also that you have to accept that one has a different focus than the other."* Equality as a long-term process value of the public commissioning organisation, is also recognized in good governance public administration literature (De Graaf and Paanakker, 2015) and emphasises the importance of acknowledging the often-short term value systems of the contractor. This is also reflected internally. From organisational learning literature in project management (Eriksson, 2013; March 1991) we understand that especially in a project-based environment, construction clients are challenged with the constantly recurring value conflicts of the exploration-exploitation paradox. The short-term focus on efficiency, based on exploitation of existing knowledge and technologies, conflicts with the long-term focus on innovation and strategic development, based on exploration of new knowledge and technologies (Eriksson, 2013). This short term - long term tension is emphasized in the political environment of public construction clients, and relates to the implementation problem of public administration of how to make a long-term strategy attractive to politicians who need to score in the short term, as discussed in study 3 (Hupe, 2014; Jensen, Johansson, and Löfström, 2018; Keast *et al.*, 2006). The participatory policy implementation case from study 2, shows that political time pressure to deliver something visible, can endanger higher social goals like creating ownership and social return. Implementing longer term policy goals proves to be quite hard, not only because of political pressure, but also because of competition with other types of societal issues that are seen as more urgent by third parties, like unemployment. Discussing this implementation problem, the only way out seems to be to embed adaptation strategies in broader programs and to connect them to other issues and values (van Buuren, Driessen, Teisman, and van Rijswick, 2014). Embedding of 'new' value systems in 'old' value mechanisms has been discussed in the interviews of study 1 (Lizet Kuitert, Leentje Volker, and Marleen H Hermans, 2019). For example, through the basic project values of time, money and quality, who remain to significantly influence how public actors act in construction: *"Money is very much a driving force. That affects the functionality, which influences innovation, which affects quality."* Specifically, the alignment of the desired new approach towards the market with organisational structures, mechanisms and tools, proved to be a significant challenge in the often bureaucratic, traditional, slowly adapting public organisations (Kuitert *et al.*, 2019). Multiple examples in our studies, showed that existing contractual governance mechanisms do not necessarily support today's complex public construction service delivery, as they lack the flexibility to actually act upon anticipated changes. such as emerging technical opportunities: *"If you manage something contractually, than there are often many exclusions as well, but*

when you aim for improvements, you often want more flexibility, a new innovation or something happens in the city where I have to respond to.” Another issue with contractual arrangements is that the desired collaborative partnering relationship strived for, reveals to be hard to capture in contracts. Partnering is about encouraging clients and contractors to transgress the conflicting interests that lie at the heart of their exchange relationship, by appealing to common interests centred around specific project goals and/or more strategic long-term relationships. However, this presumes a level of mutual interest that is arguably unrealistic in many contracting situations, especially in short term (Bresnen and Marshall, 2000).

We can conclude that there is an increasing awareness of the fact that a public organisation in a public - private project has to deal with third party value systems that influence the considerations regarding values. And for now, it seems sensible to focus on embedding new value systems through existing value mechanisms.

2. More focus on paradox thinking in a convener role and less focus on trade-offs in a steering role

In our first study we showed that today’s external commissioning is still quite directive, however there is a desire to change this. *“The words here are a bit conservative, while I would like to be a bit progressive and I am also, but also believe that we need to be more reliable.”*. With the changing relationship between public client and contractor the public client aims to adopt a more facilitating and framework-setting role. There is more attention to the collaborative nature of the relationship and the resulting implications for both the approach towards the market and the interaction with contractors recognised in 'hands on' metagovernance. Where 'hands off' metagovernance can be exercised at a distance from the network and can include administrative or bureaucratic tools. Using 'hands on' metagovernance can bring the commissioner into closer contact with network participants and can include strategies to resolve conflicts, build trust or generate understanding (Ayres, 2019). The importance of 'soft' or more informal ways of working is recognized in the metagovernance and public value literature, however our understanding of how and why is limited (Bruijn and Dicke, 2006; Sørensen and Torfing, 2017). Our second study and third study show various examples of how public client organisations are often confronted with their double - internal versus external - role in delivering value and therefore are confronted with managing conflict situations between the more internal traditional and external network related roles. Public clients adopt facilitating network-related roles - understood as a convener role in public value governance literature (Bryson *et al.*, 2014) - in order to indirectly steer in their external relationships with contractors and private entities, on the dominance of value systems at certain moments of time. Where at the same time, they need to adopt more traditional roles in order to remain control regarding their public responsibilities. For example, in study 2, the public client was concerned with facilitating the interaction between the local businesses and the residents that ought to be involved in deciding on the actual design of a neighbourhood park. They did so by, for example, inviting neighbourhood welfare organizations to gatherings of the local businesses and provide them with the opportunity to discuss ways to collaborate on social return in their tender proposals. And next, we observed the discussion in project team meetings of acting as *“lubricating oil”* or *“boost in the back.”*. We also saw, that in dealing with occurring conflicts, this facilitating convener role in a network environment, asked for paradox thinking away from 'old fashioned' trade-off thinking in order to do justice to value co-creation (L Kuitert, *et al.*, 2019). This can be explained by different views

on creating and capturing value in complex environments in which value conflicts are likely to occur. Where previous institutional research focussed on the rational-technical view on complexity, based on either/or decisions, more current research acknowledges the importance of both/and decisions especially in solving today's multi-value societal issues (Fossestøl *et al.*, 2015; Kraatz and Block, 2008; Tjosvold, 2008). Acting as a convener and adopting paradox thinking in viewing complexity, however, also proved to be difficult in the public domain where accountability, for example including protecting the ambitions of the alderman, is highly important. The focus on administrative systems and performance of public services was, for example, observed in several sessions of the internal municipal Tenderboard. In this committee, upcoming assignments are discussed and judged before they are officially announced as tenders. It was shown that risks and prices remain important decision criteria, while public value related ambitions are also pursued. This does not lead to conflicts within these committees themselves, but they do cause friction in the operational units, such as the project teams that needed to execute the assignments. And in the interviews of study 1 it was discussed that with the pressure of projects in the public and political domain, one often reverts to old habits, again picking up the directive role. *'If it gets tense, we directly turn back to our old habits, we become the directive client again, which puts pressure on the collaboration.'*

We can conclude that particularly the way in which value conflicts are dealt with ('coping') by adopting one or multiple roles in a situation, also determines the value outcome. We state that public clients should give more attention to paradox thinking in a convener role, than trade-off thinking in a steering role, in any situation with multiple value systems, both internally as well as externally.

3. More focus on informal accountability in the value chain and less focus on formal accountability in the project chain

One of the key dilemmas facing public metagovernors concerns the question of how to ensure a high level of democratic legitimacy in a networked policy (Sørensen and Torfing, 2009). Increasingly, public administrators are being judged in terms of the ability of government to create authority that operates successfully in horizontally dispersed power settings in network type of approaches, such as PPP (Bao *et al.*, 2013). The traditional, vertical, hierarchical mechanism of accountability no longer adequately fits the current social and administrative developments (van Wart 2013) (Van Wart, 1996). In addition, more horizontal, informal, mechanisms of accountability should be deployed. The difficulty: Horizontal forms of accountability, just as vertical accountability, must meet the requirements of traditional value systems (Michels and Meijer, 2008). In public administration literature, it has been discussed that the mere identification of accountability relationships becomes problematic in PPPs, because clear principal and agent roles (and corresponding responsibilities) are disappearing (Willems and Van Dooren, 2011). In study 1 we showed that in the construction sector, integrated contract models ask for a dialogue about the division of responsibility between a client and contractor and understanding of the difference in accountability perspectives of the public and private entities. In addition, public actors already seem to have a strong sense of responsibility, implying that formalisation of accountability is often unnecessary for 'good' public action.

"Intrinsically, people working at governmental bodies feel that they are there to serve the general interest, not the interest of the organisation." Public construction clients seem to adopt combinations of governance modes. Findings from study 3 indicate that municipal managers differentiate in their governance approaches between

different layers and departments within the organization. Each governance mode has a central value system as a means of mediating between organizations and society, reflecting the interdependency of different public and private parties (Coule and Patmore, 2013; Smets *et al.*, 2015). Or in other words, they have various accountholders, both in the horizontal collaborative value chain, as the vertical traditional project chain (Willems and Van Dooren, 2011; Winch, 2001). In dealing with conflicting value systems in a construction process the combining of roles is facilitated by adopting the New Public Governance model within the public client organisation previously dominated by Traditional Public Management in combination with market mechanisms. Finding a new balance is a delicate matter in a public domain as shown in study 3. The ability to cross internal boundaries to work in an integral way is key for innovation in NPG. On the other hand, sustaining existing boundaries is needed to defend traditional public values. In order to bend over, but not tilt over in finding a new governance balance dominated by network elements, we found that many innovating boundary spanning 'actions' are counterbalanced by sustaining boundary 'actions'. This complicates the transition of public construction clients towards a network-based collaborator.

We can conclude that working with different governance models in a process of value creation - simultaneously or consecutively - leads to the crossing of conflicting accountability relations and internal conflict causes a reduction in value creation. To overcome this, it is important to focus more on informal accountability in the value chain and less focus on formal/hierarchic accountability in the project chain.

CONCLUSION

This position paper brings forward the meta-governance challenge for the construction client of the future in an increasingly collaborative environment in which they depend on private and societal partners to deliver the various competing public values they are ultimately responsible for. In order for public construction clients to facilitate the shift from traditional to network value interests, it is especially important to find the 'right' alignment of the shifted client roles and responsibilities with governance mechanisms at an organisational level. We argue that future 'good' commissioning should be 1) more about embedding new value systems and less about changing existing values mechanisms, 2) more about paradox thinking in a convener role and less about trade-offs in a steering role and, 3) more about informal accountability in the value chain and less about formal accountability in the project chain. To determine the 'right' kind of interference in the value process of collaborative projects as a public construction client, public clients should be able to sooner engage in a conversation or have an idea of potential value conflicts to prepare for coping throughout the whole value process. Their way of coping with conflicts in cooperation with third parties, needs to correspond with the internal governance arrangements, and vice versa. Further research will use the three lessons to work towards a preliminary public value safeguarding strategy tool for client organisations in construction.

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INFRASTRUCTURE DEVELOPMENT IN THE WEST AFRICAN EXTRACTIVE INDUSTRY: A SYSTEM THINKING APPROACH

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The extractive industry in the West African region contributes significantly to the socio-economic development of the host communities and the wider economies of resource-rich countries. However, the spill-over effects to the domestic suppliers and the wider economy are hampered by several factors key among is infrastructure development (ID). This study employs multi-strategy approach comprising system thinking tool of causal loop diagram (CLD) to identify key variables and high leverage points underpinning and affecting ID to enhance insight and understanding and interrelationships in the phenomenon under consideration. The literature on the case countries, Ghana and Nigeria, is used to map CLD for infrastructure validated via semi-structured interviews. The CLD demonstrates that strategic investment in infrastructure will boost economic growth, mitigate the negative secondary impacts of the extractive industry and quell social upheaval in host communities. Policy options are recommended for improving infrastructure development.

Keywords: causal loop diagram, extractive industry, infrastructure, system thinking

INTRODUCTION

The West Africa region is endowed with enormous natural resources ranging from hydrocarbons to minerals that significantly contribute to the socio-economic development of the region. In Nigeria, for instance, the oil and gas sector accounts for about 10 per cent of gross domestic product, and petroleum exports revenue accounts about 86 per cent of total exports revenue (OPEC, 2019). It has 40 billion barrels of proven oil reserve and regarded as the 13th largest oil-producing country in the world (ibid). Similarly, Ghana's extractive sector comprises oil, gas, mining including quarrying contributed 13.6 per cent of the country's GDP. In terms of employment, the Ghana Labour Force Survey 2015 estimated that about 74,663 people were employed in the mining and the oil and gas sector (EITI, 2020). Despite the region's immense wealth, the socio-economic impact of the extractive industry on local communities and the national economy has been less transformational due to myriad of factors. To stimulate economic diversification and avoid resource curse in these countries, studies have recommended creating enabling environment for

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transformation, proper utilisation of resource revenue, improving weak institutions and governance system (Sigma and Garcia 2012, Gary *et al.*, 2009; Kuzu and Nantoggmah, 2010; Robinson, 2006; Ross, 2001; Hodler, 2006; Collier and Hoeffler, 2005; Jensen and Wantchekon, 2004). In more recent times, studies have focussed on developing and passing local content policy (LPC) and regulations ostensibly to compelled extractive companies to increase the usage of local goods and services in their activities (Heum, 2008; Korienk and Ramdoo, 2017; Heum *et al.*, 2011; Tordo and Anouti, 2013; Acheampong *et al.*, 2015; Amoako-Tuffour *et al.*, 2015; Obiri *et al.*, 2019; Obiri and Bassam, 2019).

On-going academic studies and discussion on engineering resource-based development in resource-rich countries exclude one critical area; the role of infrastructure development in the extractive industry. Broadly, infrastructure can be grouped into physical and institutional infrastructure. Public utilities such as electricity, transport infrastructure, and telecommunications etc. are critical business development infrastructure that creates a conducive environment for business development and productivity. Africa's largest infrastructure deficit exists in terms of electricity generation capacity and security of supply (ADB, 2015). In terms of transport infrastructure, it is estimated that African transport cost is four times higher than developed countries thereby complicating imports of equipment and materials (McKinsey and Company, 2010). The quality of the above plays a significant role in influencing profitability considerations for investors (INTSOK, 2003). Apart from the above, public institutions play a key role in churning industrial policies to support local industry via establishing company registries, enforcing contracts, laws and strategies (Kazzazi and Nouri, 2012). These policies and laws will increase the reliability of institutions and the legal system, create the enabling infrastructure for business development, and also provide the incentive to enhance sound business practices (INTSOK, 2003). For this study, infrastructure development is deemed as a system defined as a group of interrelated elements forming a complex whole (Alasad *et al.*, 2013).

Sterman (1992) postulated, that a system must be complex with multiple interdependent components, highly dynamic involving multiple feedback process and have non-linear relationships. Infrastructure development, therefore, can be said to be a complex system with multiple feedback process, multiple stakeholders and relationships, involves a large number of resources, public entities and public spending (Capka, 2004; Frick, 2008; Williams *et al.*, 2009; Sewell, 1987). Consequently, system thinking will be adopted in investigating the subject as the method is premised on investigating interrelationships in a system. The paper contributes to the literature on resource-based development by emphasising the central role infrastructure can play in propelling socio-economic development in resource-rich countries. As highlighted above, previous studies on the subject focussed on revenue management, transparency and accountability, and legislation framework etc. neglecting the subject of infrastructure development which this study intends to fill the gap by using system thinking to demonstrate the importance of it. Accordingly, the study will identify high leverage points for infrastructure development and recommends policy options to that effect. To that end, causal loop diagram (CLD - system thinking tool) will assist in analysing the repercussion of infrastructure development in the extractive industry, and therefore, brings to the fore the importance of infrastructure development. The paper is structured into five sections: section one introduces the topic; section two explains system thinking and CLD;

section three covers research methods, section four, results and discussion of the study; and the last section covers conclusion.

SYSTEM THINKING

The theory underpinning system thinking (ST) sees the world as a complex system and consequently supports the understanding of its interconnectedness and interrelationship (Sterman, 2010). System thinking aids holistically in understanding the potential factors influencing an issue and its interrelationships. Furthermore, ST view "problems" as fragments of a complete system thereby addressing the root causes of the problem (Banson, 2015). Today's challenges can be overcome by shifting from a "traditional" way of thinking to a "systems" viewpoint that sees inter-connectedness relationships and patterns rather than events (Banson, 2015). Hence, the adoption of ST allows both the researcher and respondents to understand the phenomenon from multiple and diverse points of view that ultimately aids in better policymaking. Causal loop diagram (CLD) as one of the tools of ST is defined as the "diagrammatical representation of the interrelationships in a system based on a cause and effect scenario" (Obiri *et al.*, 2020). ST and CLD are based on the concept of feedback that sees the world as an interconnected set of circular relationship, i.e., 'A' causes 'B' causes 'C' causes 'A' and 'D' causes 'B' as illustrated in figure 1. This concept is markedly different from the linear cause-and-effect ('A' causes 'B' causes 'C') way of viewing the world.

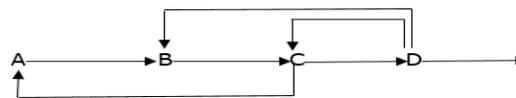


Figure 1: Feedback loop perspective

The above circular relationships give a clearer explanation of all the factors likely to affect an issue, and therefore you are in a better position to address the problem compared to the linear cause-and-effect perspective (Kim, 2014). Also, the feedback loop provides a better perspective into how and why things happened thereby helping the research participants to gain a better understanding and thereby proffer better solutions. The above definitions of system thinking and CLD bring two critical themes: the notions of interrelationships and interdependencies which form the basis for the adoption of this methodology to explain the relationships and the interdependencies. Additionally, this methodology allows the researcher and the research participants to understand the factors, relationships and feedback in the infrastructure model. The model, in turn, provides deeper insights and challenge research participants to holistically consider the cause and effect of any policy recommendations thereof. As argued by Boateng *et al.* (2016) the use of feedback diagrams (CLD) provide a basis for policy discussion, need to persuade stakeholders of new insights and challenge policymakers to be wary of overconfidence in taking decisions, and lastly, helps policymakers appreciate the essence of endogenous view to policymaking. Accordingly, the above underpinning theories formed the basis for employing system thinking and CLD to assist in formulating infrastructure policy for the extractive industry and in the process breakdown the various factors that will influence the policy thereof.

Two fundamental building blocks are considered in the construction of CLD: reinforcing loop with a function of increasing or decreasing indefinitely and balancing loop which stabilizes over time. In building the CLD, an arrow is used to depict a

causal relationship between two variables, i.e., “a” and “b”. The relationship between the said variables can be termed positive if an increase in “a” causes an increase in “b”, and negative if an increase in “a” causes a decrease in “b”. The other critical step in mapping the CLD is the extent of CLD boundary. The following guidelines were employed in identifying the variables:

1. Factors identification - model building begins with listing those factors that have a major influence on the output (Alasad *et al.*, 2013). Observation, discussion, interviews and existing data are some of the approaches recognized in identifying the influences (Forrester, 1992). Stakeholder databases and written database are significant sources of data for identifying a problem (Serman, 2000; Forrester, 1992).
2. This question can be addressed by ignoring variables which are not critical to the problem under consideration (Kim, 2002). The researcher should be asking questions like “If I were to double or halve this variable, would it have a significant effect on the issue I am mapping?” and “how detailed should the diagram be?” (Kim, 2002).

Accordingly, for the model in question, the above guidelines were used in analyzing data extracted from academic publications, government policies and regulations on the case countries (Tordo *et al.*, 2013; Tordo and Anouti, 2013; Kalyuzhnova, *et al.*, 2016; Ovadia, 2014; Ovadia, 2016; Klueh *et al.*, 2009; Kazzazi and Nouri, 2012; Neum *et al.*, 2011; Sigma and Garcia 2012; Obiri *et al.*, 2020; Acheampong *et al.*, 2015; Obiri and Bassam, 2019; Obiri *et al.*, 2019; Kuzu and Nantogmah, 2010). The system boundary constitutes the variables used in the modelling as indicated in table 1.

Table 1: System boundary for the infrastructure development model

Challenge Code	Challenge Type
Infrastructure (I)	Type 1: Endogenous Variables
I ₁	Infrastructure capacity
I ₂	Social Environment
I ₃	Employment
I ₄	Disputes
I ₅	Theft
I ₆	Business Environment
I ₇	Reputation
I ₈	Legal action
I ₉	Delay
I ₁₀	Economic growth
I ₁₁	Legal cost
I ₁₂	Local Content Development
	Types 2: Exogenous Variables
I ₁₃	Institutional infrastructure
I ₁₄	Social infrastructure
I ₁₅	Educational infrastructure
I ₁₆	Business development infrastructure

RESEARCH METHODS

The study employs a multi-strategy approach comprising system thinking (ST) methodology and qualitative data. The ST was adopted as its underpinning feedback loop perspective aids in conceptualising the various factors influencing the phenomenon under consideration, and thereby, provides research respondents with wholistic perspective to the issue before respondents' proffer solutions. Likewise, focus group allowed the researcher to receive a wide range of responses in one

meeting making it less expensive, and the participants had the opportunity to engage other participants and ask questions making the method appropriate for generating ideas. Dawson (2015) argued that focus group has the advantage of helping participants to remember issues they might otherwise have forgotten, and even group effect and participant interaction serve as a useful resource in data analysis (Dawson, 2015). In nutshell, the method was adopted to stimulate detailed discussion on the subject and offer the opportunity to seek clarification or counterproposals. The study is divided into two stages: stage one involves identification of the variables from literature, and the second stage involves the validation of the CLD which serves as a basis for policy recommendation. Identification of the variable is predicated on having a small and manageable model size, only variables with direct impact or major influence on the output are considered in the addition the guidelines outlined in section two (Obiri *et al.*, 2020; Alasad *et al.*, 2013). This facilitates easy appreciation and understanding of the model. After the identification (shown in table 1) VENSIM software is used to map CLD for infrastructure development as described in section 2. VENSIM software is primarily used for modelling, analysing and simulating for improved performance of real systems. At stage two, the focus group and interview are used to validate the model. The explicit purpose of the model was to disaggregate the central theme of the study and provide deeper insights and challenge research participants to holistically consider the cause and effect of any policy recommendations thereof. Purposive and snowball samplings were used to select industry players based on their knowledge and understanding of the research area and the ability to answer the research questions. After a brief introduction on the research topic, participants were asked to discuss the model and validate its causal linkages. Based on the validated model, participants discussed and recommended policy for enhancing infrastructure development. The on-line interview was used as a back-up method for researchers unable to attend the group discussion.

RESULTS

Validated Causal Loop Diagram (CLD) and Analysis

The proposed CLD was validated by industry experts who were asked to review the diagram to (1) add or drop variables (cause, effect), (2) verify the existence of relationships or otherwise in the model, (3) identify any missing relationship (Alasad *et al.*, 2013). During the validation of the CLD, participants agreed that there is an “interplay between these key factors whichever way you look at it...for instance the factors infrastructure capacity and economic growth”. However, they postulated that “the rate of impact of some factors on others vary considerably”. Research participants suggested the addition of technology infrastructure and financial incentive to the model which are captured under the variable of business development infrastructure. The validated infrastructure model contains the reinforcing loop from R1 to R8 as depicted in figure 2. From figure 2 as infrastructure capacity increases (as a result of investment in business, educational, social and educational infrastructure) in the extractive industry it will impact economic growth, and economic growth, in turn, impacts infrastructure capacity positively forming a reinforcing loop, R2. Likewise, as local content development (LCD - the building of local capacity and capability in the extractive industry) increases in the extractive, it impacts economic growth positively and economic growth, in turn, impacts LCD positively forming reinforcing loop R1. Again, increased LCD will impact economic growth, and economic growth will in turn impact infrastructure capacity positively forming loop R3. Reinforcing Loop, R4 suggests an increase in the business environment will

institutional level, wastage of scarce resources on non-essential projects to fulfil political party's manifesto depriving government's agencies of the requisite money for infrastructure projects and maintenance".

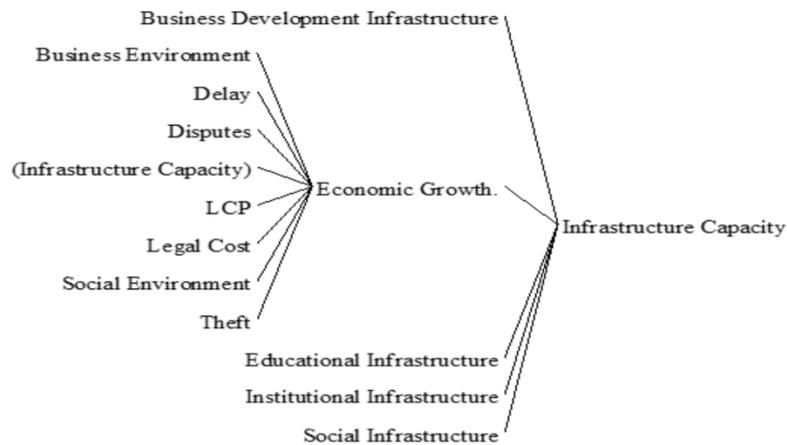


Figure 3: Causes tree for Infrastructure Development model

This, therefore, will require optimal utilisation of scarce resources in the identified high leverage areas, a broad consensus on national development policy, and special attention to the host communities to reduce negative secondary impacts of the extractive industry. Others postulated that overpricing of projects happens because “most public institutions employ procurement processes and selection matrices which are not transparent”. By abusing the use of a procurement process such as “sole-sourcing” which is not value for money-oriented, the state tends to lose huge sums for money. In certain instances, “projects are awarded to contractors who are not well-resourced; this often results in projects suffering delays and cost overruns”. It is worthy to note that state institutions supposedly have performance monitoring and evaluation outfits who are tasked to audit ongoing infrastructural projects. Conversely, however, such “auditors are easily influenced by contractors, and they eventually compromise on expected standards”.

Accordingly, this demand strengthening of institutional infrastructure to curtail political interference. Furthermore, there is an urgent need for strong political will to stamp out corruption and redefine the conditions for sole sourcing and procurement process. State institutions must be empowered to conduct a value for money analysis to curtailed mostly inflated government projects. Since there are limited financial resources of the state, there should be a government strategy to encourage private finance and public-private partnership (PPP) to bridge the infrastructure gap in resource-rich countries. This requires standardisation or clarification of laws concerning P Besides, a special purpose vehicle should be established with voluntary contribution from oil and mining companies (in exchange for reduced taxes), international development partners, a percentage of government extractive revenue and an infrastructure levy to support infrastructure development in the high leverage areas. Key to the success of the above-mentioned policies will be stakeholder consultation in the extractive industry. The above-suggested policies should be used in improving the high leverage points of business development, educational, social and institutional infrastructure.

CONCLUSION

The paper underscores the critical role infrastructure development plays in engineering resource-based development in resource-rich countries which previous studies have neglected. To that end, system thinking and causal loop diagram (CLD) were employed to identify the key variables influencing infrastructure development and its relationships and in turn, identify the high leverage points for improvement in ID. The CLD demonstrated strategic investments in infrastructure in the high leverage points can propel economic growth and on the other hand, lack thereof could increase negative secondary impact in host communities. Availability of this infrastructure will accelerate more volumes of in-country manufacturing and supply to the extractive industry. The study recommends strengthening of state institutions to clamp down on abuse of procurement practices, standardisation of PPP laws to attract foreign investment, channelling more state investment into the high leverage points and stakeholder engagement in the industry.

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PROMOTING EMPLOYEE SAFETY PERFORMANCE IN THE CHINESE CONSTRUCTION INDUSTRY

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In the construction industry, safety leadership has been widely recognised as an indispensable factor that affects organisational safety performance. However, in China specifically, research on safety leadership in the construction domain is not adequately developed. This paper examines the role of organisational leadership in promoting safety performance, as moderated by safety climate. The study adopts quantitative research method through questionnaire survey with 106 construction professionals leading or participating in safety management work in the Chinese construction sectors. The results show that exerting certain leadership strategies that encourage construction stakeholders to comply with safety practices will improve safety performance. At a moment when the whole industry is suffering from momentous safety challenges, transformation is required; these findings are intended to guide construction managers in their commitment to programme safety management. The study reinforces the interaction between upper layer and lower layer employees thereby improving the safety performance via improvements in the safety climate. In addition to being rooted in the full-range leadership model, this paper considered the important (and often ignored) characteristics of Chinese culture. The study recommends the early involvement of contractors in the design process and considers site hazards when making design decisions.

Keywords: safety leadership, safety performance, safety climate, China

INTRODUCTION

Construction is considered a high-risk industry, as workers engage in many activities that expose them to serious hazards: working at height, operating lifting equipment, controlling vehicles and other activities (HSC, 2001). Because of these inherent risks and complexity, accidents occur frequently in the construction industry, leading to undesirable consequences such as project delays, budget excess, and even loss of life (Soltanzadeh *et al.*, 2017). Poor safety performance in the construction sector has attracted widespread concerns, but despite this attention, the frequency of incidents in developing countries still remains high (Haslam *et al.*, 2005). Since 2008, the total number of accidents in the construction industry in China has exceeded that of the coal mining industry, ranking it as the sector with the highest accident rate for nine

consecutive years; further, the total number of construction accidents in China increased by 4.3% in 2018 (COSHA, 2018). Previous studies on the factors affecting poor safety performance identified various layers as illustrated in Figure 1 (Howell *et al.*, 2002; Haslam *et al.*, 2005; Khosravi *et al.*, 2014).

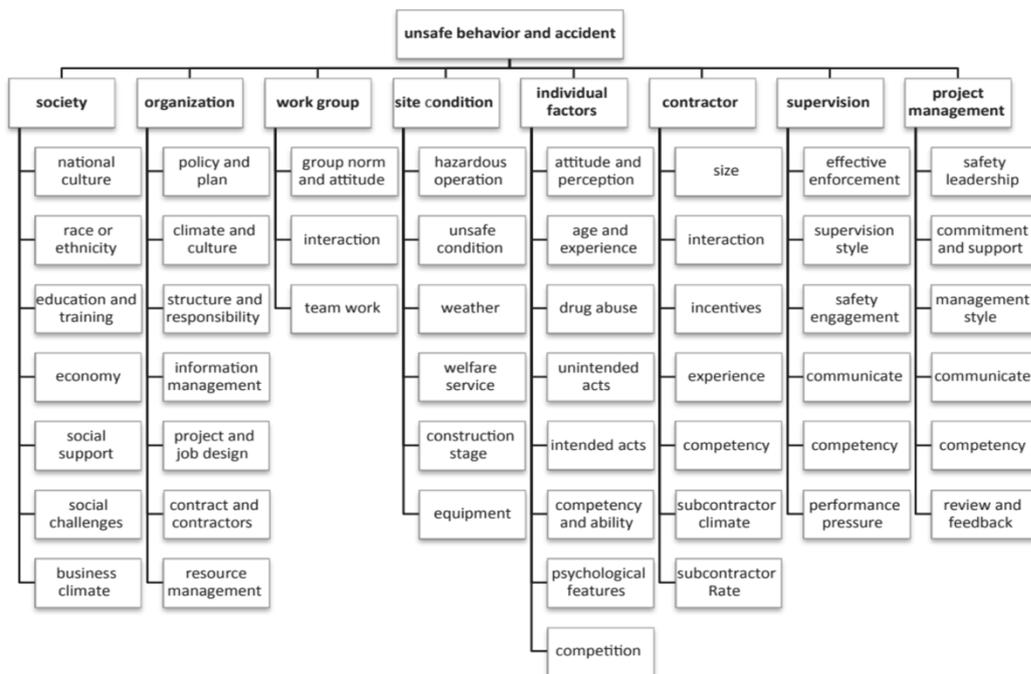


Figure 1: Primary elements leading to unsafety behaviour and accidents

Safety management is a practice that is meant to ensure the on-site safety of a construction project to reduce accidents (Wilson and Koehn, 2000). Safety climate is a representation of the attitudes, perceptions, and values that employees convey on the subject of safety (Wu *et al.*, 2017; Umar and Wamuziri, 2017). Effective leadership actions are intended to strengthen the interaction between managers and employees to ensure the smooth implementation of policies and practices. On the other hand, by establishing sound safety policies, visions, incentives, reward systems, and exerting an altruistic spirit, safety leaders can do much more than promoting a favourable safety climate; they can also improve safety performance (Wu *et al.*, 2015). An altruistic attitude as a form of ethical leadership encourages employees to behave in a mutually beneficial manner (Gao, 2016).

Employees who display altruistic attitudes will consider the interests of their leaders. The most effective way for employees to meet the interests of their leaders is to adhere to various rules and regulations and implement the orders issued by the leaders to improve their own safety compliance behaviour. Again, an altruistic attitude will enable employees account for the interests of their colleagues and maintain the safety of the entire group by complying with safety rules (Mayer *et al.*, 2010). Previous studies have demonstrated the impact of safety leadership on safety performance (Barling *et al.*, 2002; Clarke, 2013; Wu *et al.*, 2017; Umar, 2017). In China, the safety management of the construction industry is mainly dominated by clients, as the program leader of clients serves the role of safety policymaker and decision-makers (Gao, 2016). Therefore, the top manager of clients is considered to have the greatest impact on the safety of the enterprise. Considering the influence of Chinese traditional culture on program management, this study aims to provide empirical

evidence on how different Chinese leadership behaviours affect the safety climate and safety performance of construction projects.

LITERATURE REVIEW

Concomitantly, research into safety leadership in the OHS literature has also become a significant portion of construction safety management. Initially, leadership research evolved from the trait-perspective to a behavioural-perspective, after which it turned to the contingency-perspective over the last century. Leadership is “an interaction between two or more members of a group. That often involves different perceptions and expectations of the members. Leadership occurs when one group member modifies the motivation and competencies of others in the group” (Bass, 1990: 24). In other words, leadership is a process of exerting influence, which means a person possesses the capability to seek the backup of others for the accomplishment of a joint mission (Chemers, 2002). Accordingly, the concept of safety leadership is like that of leadership in that safety leadership is an interactive process in which leaders exert their influences on others to accomplish safety objectives in the context of environmental, organisational, and personal factors (Wu, 2005).

Safety Leadership, Safety Climate and Performance

Safe leadership can be regarded as a multi-dimensional variable, conceptualising its various dimensions can provide insight into some of the distinctive personal behaviours of safety leaders, and then explore which leadership behaviour conducive to better organisational performance (Wu, 2005). For example, Blair (2003) posited four key points to identifying aspects of safety leadership and establishing organisational safety excellence. The practices of safety leadership are as follows: setting up a clear target, confirming exemplary behaviours, creating cultures of excellence, and steering the right employees towards the right courses of action. The standpoint of Blair (2003) is to remind managers to focus more on leading by building a platform for communication, establish and change organisational safety climate, instead of strict monitoring.

Safety climate is a significant indicator that can reflect the effect safety leadership, generally, to the culture and perception of safety in a working environment (Du and Sun, 2012). In the field of OHS, Zohar first proposed the specific concept of safety climate, which has been approved by most professionals and widely used by numerous researchers. As noted by Zohar (1980), safety climate reflects common perceptions of subordinates about the organisational safety value and safety status. As for the dimension of safety climate, Zohar (1980) divides safety climate into seven sub-dimensions through a many practical investigations. For example, management attitudes towards safety, the risk level of the working environment, and the status of safety officers. Subsequently, Brown and Holmes (1986) argued that managers’ emphasis on safety and employees’ risk perception are the most important factors influencing corporate safety climate. In addition to safety commitments of the top management, safety commitments and actions at all levels, such as “employees’ safety commitments, perceived risk, and emergency response” are significant aspects of the safety climate scale (Wu *et al.*, 2007, 99).

Safety performance refers to the actual outcomes of safety systems in the workplace (Hinze *et al.*, 2013). The conventional method of evaluating safety performance is through measurement and statistical analysis of accident-related data (including the incident frequency of injuries and ill-health, accident costs). These data-points are

often referred to as traceability or lag indicators (Sgourou *et al.*, 2010). It is easier for managers and employees to understand these indicators. However, these are often insufficient at measuring the failure reasons of system and revealing cause-effect relationships that may provoke system melioration (Wu *et al.*, 2015).

Cooper and Phillips (2004) argue that safety performance should be assessed using indicators such as the number of safe and unsafe behaviours of employees, incident rates, and the frequency of employee-participation in safety training. An objective safety performance evaluation (SPE) framework was devised by Ng *et al.* (2005) at an organisational level and project level to evaluate the safety performance of construction contractors. SPE accounts for several critical factors, including administrative and management commitment, safety education and training, safety supervision and inspection, accident record, and hazard management.

DATA COLLECTION AND ANALYSIS

A quantitative research methodology with a questionnaire survey was adopted for this study; questionnaire adopted Wu's (2005) measurement scale of safety leadership practices. This model can determine the specific content of safety inspiration, safety policy, safety reward and punishment, and safety vision. The safety performance model explains the relationship between the crucial safety factors or variables such as safety leadership, safety climate and performance. The questionnaire adopts a five-point Likert scale (from 1=strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree). The study involves 106 professional construction practitioners (i.e. frontline workers, project managers, and safety managers) who either lead or participate in safety management work in the Chinese construction sectors. The questionnaire was distributed through online channels. The specific approach was to upload the questionnaire to a professional website (i.c.www.wjx.cn), which was sent to the respondents.

The questionnaire was sent to 120 respondents and 106 were received with response rate of approximately 88%. Cronbach's alpha (α) is statistical analysis was used to measure the reliability of questionnaire and the results is shown in Table 1.

Scale	Number of Items	Cronbach's Alpha	KMO
Safety Inspiration	4	0.893	0.702
Safety Vision	3	0.8052	0.653
Safety Policy	3	0.8317	0.715
Safety Reward and Punishment	4	0.8061	0.752
Altruism	3	0.8624	0.718
Safety Leadership	17	0.8735	0.755
Safety Climate	11	0.8304	0.702
Safety Compliance	4	0.6781	0.633
Safety Participation	5	0.7226	0.681
Safety Performance	9	0.7775	0.692
All	37	0.9282	0.732

Table 1 Reliability and validity analysis of questionnaire scales

In general, Cronbach's α beyond 0.6 is a standard that suggests that the result is acceptable, and the data are reliable. Cronbach's α exceeds 0.8, indicating that the data has a high degree of reliability data (Cronbach, 1951). The value of Cronbach's α for all items is 0.9282(N=37), which reflecting a significant reliability of final data.

For example, Cronbach's α of safety leadership, safety climate, as well as safety performance are 0.8735 (N=17), 0.8304 (N=11), and 0.7775 (N=9) respectively. The Kaiser-Meyer-Olkin (KMO) index was used to estimate the validity of the questionnaire data. Typically, 0.6 is a standard number that regarded to be the baseline for data validity. In this study, KMO values are as high as 0.732 which indicates the highly effective and accurate of data. High validity refers to the extent to which the method can accurately reflect the true characteristics of the research object (Klenke *et al.*, 2016).

RESULTS

Even though the number of respondents (N=106), each dimension contains a different number of variables and cannot be directly compared with the total or average score of each dimension. Therefore, the total score of dimensions was divided by the number of questions and finding the average score for each dimension. As shown in Table 2, the mean value of safety leadership is 4.13, with the highest mean value of safety reward and punishment (4.63) and the lowest mean value of safety vision (3.07). To sum up, the mean values of all safety leadership part are greater than the neutral value of 3, which indicates that project leader's well-implemented safety practices and respondents are highly satisfied with their safety leadership actions. The mean values of safety climate and safety performance are 4.10 and 4.19, respectively, demonstrating that the safety performance of employee and safety climate of organisations are generally satisfactory. Furthermore, the mean value of safety performance shows that employees are actively participated in safety activities (3.93) and consciously abide by the safety policies and regulations (4.53).

Scale	N	Mean	Std.	Median
Safety Leadership	106	4.13	0.48	4.24
Safety Inspiration	106	4.61	0.66	5
Safety Vision	106	3.07	0.76	3
Safety Policy	106	3.69	0.81	3.67
Safety Reward and Punishment	106	4.63	0.58	4.75
Altruism	106	4.35	0.77	4.67
Safety Climate	106	4.10	0.61	4.18
Safety Performance	106	4.19	0.57	4.33
Safety Compliance	106	4.53	0.53	4.75
Safety Participation	106	3.93	0.75	4

Table 2: Descriptive statistics of all scales

Correlation analysis is used to measure the strength of interrelationship between Safety leadership and performance. The results of Table 3 provide strong support for the significant and positive correlation between safety-specific leadership practices and safety manifestation as the correlation coefficient between those two variables is 0.809 ($p < 0.05$), reaching a significant level of 0.05. This result shows that program managers enable to enhance organisational safety performance by actively promoting leadership actions. Safety leadership is positively related to safety performance. As dimensions of safety leadership, safety inspiration ($R=0.660$, $p < 0.05$), vision ($R=0.372$, $p < 0.05$), policy ($R=0.587$, $p < 0.05$), reward and punishment ($R=0.728$, $p < 0.05$) and altruism ($R=0.378$, $p < 0.05$) are positively correlated with safety performance.

The results suggest that leadership behaviours have a positive impact on employees' perceptions, attitudes and behaviours of safety. As mentioned above, an organisation with high performance of safety is more likely to possess a leader who influences employees through his leadership measures, leadership styles, and commitment (Pilbeam *et al.*, 2016). Regarding the relationship between safety climate and safety performance ($R=0.646$, $p<0.05$), it presents a dominant positive correlation. Similarly, there is a positive correlation between safety participation ($R=0.398$, $p<0.05$), compliance ($R=0.664$, $p<0.05$) and safe climate (Table 3).

	Leadership	Inspiration	Vision	Policy	Reward	Altruism	Climate	Performance	Compliance	Participation
Leadership	1	0.837**	0.475*	0.645*	0.845**	0.568*	0.632*	0.809**	0.739**	0.694**
Inspiration	0.837**	1	0.211*	0.305*	0.799**	0.467*	0.453*	0.660**	0.592**	0.573**
Vision	0.475**	0.211*	1	0.360*	0.119526	-0.05148	0.508*	0.372**	0.09862	0.457**
Policy	0.645**	0.305**	0.360*	1	0.459**	0.05555	0.594*	0.587**	0.480**	0.535**
Reward	0.845**	0.799**	0.119526	0.459*	1	0.454*	0.461*	0.728**	0.802**	0.546**
Altruism	0.568**	0.467**	-0.05148	0.05555	0.454**	1	0.118663	0.378**	0.516**	0.227*
Climate	0.632**	0.453**	0.508*	0.594*	0.461**	0.118663	1	0.646**	0.398**	0.664**
Performance	0.809**	0.660**	0.372*	0.587*	0.728**	0.378*	0.646*	1	0.780**	0.934**
Compliance	0.739**	0.592**	0.098622	0.480*	0.802**	0.516*	0.398*	0.780**	1	0.506**
Participation	0.694**	0.573**	0.457*	0.535*	0.546**	0.227*	0.664*	0.934**	0.506**	1

Note: * $p<0.05$ ** $p<0.01$

Table 3: Correlation coefficients (Safety leadership, climate and performance)

This dataset is congruent with the results concluded by Kapp (2012), that is, safety climate is a leading indicator of safety outcomes. The safety performance of an organisation with a favourable safety climate is often ideal. Establishing a harmonious safety climate is inseparable from satisfactory safety performance and ripe safety management systems.

The effects of the harsh working environment in the Chinese construction industry are more likely to impact frontline workers who are often neglected by managers. Further, occupational injuries are responsible for many project delays, financial burdens, and human costs. Despite the generally accepted opinions determined that leadership is one of the important driving factors of good safety performance. The literature review identified five dimensions of leadership practice in line with the historical and cultural realities of the Chinese construction industry. These five leadership practices are the independent variables: safety inspiration, vision, reward and punishment, policy and altruism. Likewise, the safety behaviours of workers are further divided into two aspects: safety compliance and safety participation, both which serve as dependent variables. More importantly, understanding the relationship of safety leadership, safety performance as well as safety climate formed the basis of this study and the rationality of the relationship is proved by the results.

Again, a multiple linear regression analysis was performed to explore the contributory factors affecting safety compliance and participation. Multiple linear regression aims to evaluate the connection between two or more independent variables and a single continuous dependent variable by fitting a linear equation. When the p-value that corresponds to the F-value is less than 0.05, then at least one of the independent variables has an influence on the dependent variable. In the test where the dependent variable is safety compliance, the corresponding p-value is less than 0.05 when $F=34.91$ as shown in Table 4.

Variables	Unstandardized Coefficients		Standardized	t	p-value
	B	Std. Error	Coefficients Beta		
(Constant)	0.881	0.308		2.863	0.005
Inspiration	-0.150	0.078	-0.186	-1.928	0.057
Vision	0.002	0.043	0.003	0.051	0.959
Policy	0.111	0.044	0.168	2.509	0.014
Reward	0.711	0.097	0.767	7.348	0.000
Altruism	0.168	0.044	0.242	3.805	0.000

Note: $F=34.913$ $p=0.00$ $R^2=0.714$

Table 4: Influencing factors of safety compliance

The most critical analysis can be conducted to directly examine the relationship between the five independent variables and the dependent variables. An important criterion for estimating whether there is an influence relationship is to observe the p value if it's less than 0.05, this independent variable has an impact on the dependent variable.

After determining that there is an impact relationship, it is necessary to confirm the direction of influence; positive or negative influence relationship by the value B or Beta. It is positive when B or Beta is greater than 0, vice versa. As indicated in Table 4, policy ($p=0.014<0.05$, $Beta=0.168$), reward ($p=0.000<0.05$, $Beta=0.767$) and altruism ($p=0.000<0.05$, $Beta=0.242$), have the positive regression relationship with safety compliance. In other words, safety rules and procedures, rewards for efforts beyond standard requirements, as well as concerns for the collective interests and overall organisational safety, lead employees to comply with safety rules and policies. To be more specific, higher levels of transactional leadership can directly trigger employees to comply with existing organisational safety procedures. As Clark (2013) suggests that transactional leadership measures will facilitate workers to strictly comply with safety policies and regulations and timely prevent hazardous events. Likewise, Mayer (2010) deeply discussed that ethical leadership practices (i.e. altruism) can greatly promote safety compliance of employees and improve their misconduct. While, inspiration ($p=0.057>0.05$) and vision ($p=0.959>0.05$) have no significant regression correlation with compliance. This consequence indicates that no matter what supportive incentives the leader implements, employees are supposed to comply with the rules and regulations concerning safety procedures, which is an obligation and necessity of them to keep their contractual relationship. Punishment or even dismissal will be taken if their behaviours are in contravention of the regulations and rules. To the contrary, safety inspirations that encourage employees to work on

assignments not regulated in the contract could arouse their motivations (Fernández-Muñiz, 2017).

CONCLUSION

The paper explores the role of safety leadership actions in enhancing organisational safety performance with a specific focus on the Chinese construction sector. More importantly, understanding the relationship of safety leadership, safety performance as well as safety climate formed the basis of the research. From the micro perspective, this study showed how leadership actions exert influence on employee safety participation and compliance in a multifaceted way including incentives, punishment or other methods. The results further show that safety inspiration and safety vision have a positive effect on safety participation, but that they do not affect safety compliance in a significant way. Safety compliance, on the other hand, is conditioned by policies, reward, punishment, and altruistic spirit. Subsequently, it can be seen that perceived safety climate mediates the correlation between safety-specific leadership behaviour and occupational safety performance. Overall, this study expounds on the influential path of leaders' actions on employees' safety participation and compliance from both theoretical and empirical aspects. In terms of limitation to the study, this paper is concerned with the safety leadership of program managers (i.e. client leadership influence) and ignores the influences of other levels of safety leadership, including project managers or construction managers of tier 1 contractors and subcontractor supervisors. The study recommends that, project managers should require constructors to participate in the design process and consider site hazards when making design decisions. Early contractor involvement is important because of they have comprehensive understanding of the construction site than the designer.

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BARRIERS TO MENTORING OF GRADUATES IN QUANTITY SURVEYING FIRMS: FINDING A GOOD FIT

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The descriptive study seeks to determine barriers to mentoring practices for Quantity Surveying graduates employed by consulting firms based in Dar es Salaam. Data was collected from 53 questionnaires returned by graduates employed in firms involved in the study out of 65 administered. Analysis of data was done by IBM SPSS Statistics 20 using descriptive statistics-frequency and compared means one sample t test features. Findings revealed that there were several significant barriers to mentoring practices in consulting firms including poor delegation of work, mentor expertise, poor mentoring procedure and personal problems. Generally, there exist barriers to mentoring of graduates in quantity surveying firms in Tanzania which impede their learning process as well as work performance. The study recommends that Architects and Quantity Surveyors Registration Board (AQRB) and Tanzania Institute of Quantity Surveyors (TIQS) to advocate for informal mentoring, organize training programs to sharpen the skills of mentors in order to improve the performance of graduates, hence finding a good fit.

Keywords: graduates, mentoring, quantity surveying, Tanzania

INTRODUCTION

Although a person can learn and develop a career through many ways, being a mentor or mentee provides an interactive and customized experience. Mentoring offers invaluable benefits not only to individuals but also to the organization that employs them. Even some professionals agree that mentoring is an important leadership competency as well as professional responsibility (Oke and Otasowie, 2020; Hoffmeister *et al.*, 2011). Mentoring is a relationship between a mentor and a mentee that aims to guide personal and professional development over time (Inzer and Crawford, 2005; Mohtady *et al.*, 2019). The main aim of mentorship is to ensure that workers improve both psychologically and physically while performing work and come out with great work product. Some studies show that individuals who have been mentored will report greater career outcomes than individuals who have not been

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mentored (Nkomo and Thwala, 2013). Through mentorship individuals find it easy to transform knowledge taught at school into practice with minimum amount of errors. Mentoring is achieved through formal and informal setting to develop skills and knowledge within an organization. Formal mentoring involves structured system that include pre-set guidelines which assist both the mentor and mentee to fulfil the objectives of the program. Usually, in formal mentoring the organization develops a program and process for mentoring to take place (Inzer and Crawford, 2005; Oke *et al.*, 2016). Informal mentoring is a natural component of relationship that occurs throughout the society, in workplace, as well as in social, professional, and family activities (Inzer and Crawford, 2005).

Mentoring programs are important not only for business but also to serve as bridge between business and academia (Ilieiva, 2015). There is strong relation between competence and frequency that is the students with more years of experience tend to perceive themselves to be more competent (Lee and Hogg, 2008; Hoffmeister *et al.*, 2011). A particularly challenging task for someone who is starting out in their professional life is to assemble and integrate several kinds of knowledge gained from experience, education, and work (Lee and Hogg, 2008; Oke *et al.*, 2016). It is increasingly being acknowledged that mentoring practice can result in the much-needed innovation, growth, and sustainability for the construction industry demands (Oke *et al.*, 2016). However, mentoring mechanisms have been identified as a highly complex processes to further in an organization and as a result knowledge sharing or transfer hostility is perceived as a phenomenon that widely dominates organizational reality (Mohd Nor a and Egbu 2010). This is quite challenging because mentoring practices not only aid the professional development of a protegee but also the organization. The problem faced by most quantity surveying firms is the continuous loss of knowledge which is due to the retirement or resignation of key personnel (De Long and Liam 2000; Rahmah *et al.*, 2011). With the help of mentoring practice, knowledge and skills can be easily transferred in the workplace and thus minimizing risk of losing vital knowledge.

Researchers predict that the technical skills possessed by quantity surveying professionals will not advance without the mentoring process (Shafie *et al.*, 2014) as competencies in skills are becoming fast relevant and important for service providers (Rahmah *et al.*, 2011). Several studies have focused on the outcomes of mentoring as they relate to a particular style of mentoring such as the roles and functions of mentor-mentee (Swanepoel, 2012), challenges of mentoring in South African construction industry (Hoffmeister *et al.*, 2011), mentor-mentee relation (Nthombekaya, 2015), mentoring practices (Oke and Otasowie, 2020), benefits of mentoring to a Mentor, mentee and organization (Mohtady *et al.*, 2019). For example, it is believed that mentee in informal mentoring receive greater benefits than those in formal mentoring relationships (Washington, 2010) and that mentoring practices are essential for mentor-mentee aspirations as they expected to have thorough knowledge and understanding of client operating environment and dilemma (Oke and Otasowie, 2020). Most of these studies focus on formal and others on informal mentoring from the organization or firm perspective such as Melrose (2006) mentoring online graduate students and Schollosser and Kahn (2007) mentoring in an academic environment. However, the lack of study on barriers for mentoring quantity surveying graduates as identified from literature is a motivator to this study.

LITERATURE REVIEW

Mentoring in the Construction Industry

The process of construction projects is fragmented and complex, as it is made up of numerous projects of various sizes, of different nature, managed by several different players and stakeholders (Sospeter *et al.*, 2019). Mentoring is particularly useful within the context of the employment and skills development in the construction industry especially where most of its works are project oriented. The absence of mentoring in construction industry is an impediment to progress as the junior is constructed as in deficit of skills and appropriate socialization (Nkomo and Thwala, 2013). Nevertheless, evaluations of mentoring have pointed out the lack of knowledge held by middle class mentors about realities of growing up in different circumstances (Nkomo and Thwala, 2013; Hoffmeister *et al.*, 2011). In the construction industry, mentorship has been essential way to develop knowledge and skills of employees while performing the work in organizations. Due to its usefulness, there have been different career development programs that have been established by the Architects and Quantity Surveyors Registration Board (AQRB) such as seminars to mentor both employee and employers, and, Enhanced Articled Pupilage Program (EAPP) for graduates to undergo structured professional training for two years. These programs assist employers, employees, and graduates to cope with current construction techniques and technological changes.

Although Quantity surveying firms in Tanzania have different mentoring programs to ensure that their new employee become familiar with what must be done within the organization and produce high quality work with minimum mistakes, there have been barriers to mentoring of graduates in Quantity Surveying firms. It is also important to note that, mentorship within the organization has a big impact on the productivity of the individuals if well done. Thus, it is very essential to determine barriers to mentorship within the construction consulting firms in order to improve their learning process as well as work performance as a result of work taught at job by their mentors who are more experienced than mentees. There is extensive work on mentoring in both developed and developing countries. Several studies have focused on the outcomes of mentoring as they relate to a particular style of mentoring such as the roles and function of mentor-mentee (Swanepoel, 2012), challenges of mentoring in South African construction industry (Hoffmeister *et al.*, 2011), mentor-mentee relation (Nthombekaya, 2015), mentoring practices (Oke and Otasowie, 2020), benefits of mentoring to a Mentor, mentee and organization (Mohtady *et al.*, 2019). Most of these studies focus on mentoring online graduate students (Melrose, 2006), mentoring in an academic environment (Green and Bauer, 1995; Schollosser and Kahn, 2007). Moreover, some of the research studies are based on critical review of literature and others were done in the developed countries whereby the context, scope and structures are different from a developing context like Tanzania.

Mentoring Practices for Quantity Surveying Profession

A quantity surveyor is a professional who attempts to ensure the judicious use of construction industry resources to the best advantage by providing both financial management and consultancy service to the client during the construction process. According to Shafie *et al.*, 2014; Sospeter *et al.*, 2019), pre-contract stage services include: preliminary cost estimate for the purpose of advising the client on the probable cost of the project, preparation of cost plans, cost- checking to ensure that accepted tender is not more than the approved budget, preparation of tender

documents to be priced by different contractor, evaluating tender reports and recommending suitable contractors for the award of contract. Post contract stage services include preparation of interim valuation for interim certificate, periodic financial statements, valuation of variations, ascertaining of claims and final accounts. Mentoring plays a pivotal role in workplace-based learning (Mohtady *et al.*, 2019). Mentoring will provide the platform required for the transfer and sustainability of knowledge in providing the above services by quantity surveyors. Some researchers opined that a mentor and a mentee can greatly enhance their career and psycho-social development by the potential of mentoring relationship. Protégées can be assisted in developing a sense of confidence, effectiveness, and competence, through the career and psychosocial functions of mentoring (Shafie *et al.*, 2014; Oke and Otasowie, 2020).

Barriers to mentoring are acknowledged in the literature. For instance, Oke and Otasowie (2020) explain that many mentoring programs do not produce the main objectives that were set before they were implemented. The failure of mentoring programs is attributed to failure to follow the procedures of implementing mentoring programs and to formulate the appropriate objectives (Agumba and Fester, 2010; Nthombekaya, 2015). Sometimes mentoring programs are not successful because of the failure to match the correct mentor with correct mentee. Agumba and Fester (2010) reveal top ten problems in mentoring which are: dissimilar personality and habits, mismatch within the dyad value, self-absorption, poor work style, distancing behaviour and neglect, manipulative behaviour, inappropriate delegation of duty, intentional exclusion, credit taking and politicking. Nkomo and Thwala (2013) and Agumba and Fester (2010) report that dissimilar personality and habits (Oke and Otasowie, 2020) was seen as negative outcome whereas bad attitudes, personal problems and deception were never a problem to mentees. Plamondon (2007) groups dysfunctional mentoring into mentor-mentee mismatch, distancing behaviour, manipulative behaviour and lack of mentor expertise (Plamondon, 2007; Shafie *et al.*, 2014). Mohtady *et al.*, (2019) Seidel (2019) and Nkomo and Thwala (2013) reveal gender differences in mentoring those male mentors gave more advice on career development while female mentors were more on psychosocial support. Interestingly, (Mohtady *et al.*, 2019) male mentees received less psychological support than female counterparts. Akin to poor delegation (Trainer, 2017; Oke and Otasowie, 2020) and/or poor mentoring procedures, Suleiman (2013) found that improper job placement and poor motivation are main causes of poor attitude to work.

Furthermore, Insala (2019), Hoffmeister *et al.*, (2011), as well as Nkomo and Thwala (2013) suggested for more study to look on problems that are encountered during mentoring and propose a remedy so that the organization can enjoy the good fruits of mentorship. It is correct to say that certain barriers impede graduates learning process as well as work performance in consulting firms in Tanzania. The quality of the relationship between mentor and mentee can affect learning, particularly any disparity in their expectations (Hodges, 2009). Therefore, it is high time to unveil barriers to mentoring of graduate quantity surveyors in Tanzania to ensure that there is smooth transfer of experience from mentors to mentee in order to improve the productivity at individual level and in Quantity Surveying firms. Other studies found that; deception (O'Seanery, 2007; Nthombekaya, 2015), Personal problems (Nkomo and Thwala, 2013), bad altitude (Suleiman, 2013; Oke and Otasowie, 2020; Nkomo and Thwala, 2013) were some of the barriers. Steinberg (2007), Kovach (2017) and (Mohtady *et al.*, 2019) revealed religious difference, tribalism as among barriers to mentoring. A

study by Hoffmeister *et al.* (2011) identified nepotism as a barrier to mentoring practices.

METHODS

This is a cross-sectional study design which attempts to gather information from mentees on barriers to mentoring graduates in quantity surveying discipline. The survey research strategy was shaped by the need to generate robust findings on the mentoring practices that can contribute to and improve graduate's work performance. There are 112 quantity surveying firms located in Dar es Salaam which are registered by the Architects and Quantity Surveyors Registration Board (AQRB). Purposive sampling techniques was used to select 65 out of 112 firms to be included in the study, based on their knowledge of the phenomenon (Saunders *et al.*, 2016). The second reason for using the purposive sampling was deemed appropriate because the sample was hand-picked based upon the researchers' first-hand knowledge of the indigenous consulting firms (Rowley, 2014; Saunders *et al.*, 2016). This implies that 58% of all the firms were sampled for the study. These firms were found to engage in both formal and informal mentoring of graduates which implies they receive graduates from EAPP program organized by AQRB as well as those who are directly employed and volunteering to gain professional experience.

Data for the study was collected using review of literature and questionnaires. The information gathered from literature review related to the study guided the design of the research instrument used which was structured questionnaire (Saunders *et al.*, 2016). The questionnaire was divided into two distinct sections. Section 1 encompassed the general demographic information on participating QS graduates. Questionnaires had closed questions on barriers to mentoring and attribute variables of age, sex and experience. To enable cross comparative analysis as part of a robust data protocol, the responses were nominally coded questions so that they be entered one of various pre-prepared categories. Section 2 comprised of the rating and ranking of the 20 barriers impeding their learning process. Fifteen (15) barriers extracted from the literature formed a list of barriers in the questionnaire for respondents to rate using active variables. The barriers were assessed using 5= strongly agree, 4= agree; 3 = neutral, 2=disagree and 1=strongly disagree. Sixty-Five (65) questionnaires were sent out and 53 were returned fairly filled for use in the study equating to 81.5% success. The collected data was analysed using IBM SPSS Statistics 20 mainly descriptive statistics (frequencies) for attribute variables and compare means (One-Sample T Test) for barriers. One-sample t-tests was used to test the mean of a single sample to a predetermined value to determine if the sample mean is significantly greater or less than the test value of 3.5.

RESULTS

The respondents' attribute variables were experience, age and sex. The fact that the study was dealing with graduates; majority (83%) had experience ranging between 1 to 4 years, followed by 9.4% who had experience between 5 and 10 years and 7.6% of those with less than 1-year experience. All respondents had between 18 to 35 years of age. The participation of male and female graduates was fairly good with male attaining a higher proportion (58.5%) and female with 41.5%.

Table 1 presents results of One-Sample Statistics and T Test for barriers to mentoring graduates in quantity surveying firms. It reveals that poor work delegation, poor mentoring procedures, mentor expertise, distancing behaviour and neglecting, work

style and deception are generally agreed barriers ($MS \geq 3.5$) to mentoring graduates. Furthermore, results of One-Sample T Test in Table 1 indicate that most of barriers were significant except for distancing behaviour and neglecting, deception, work style and politicking with $Sig \geq 0.05$).

Further examination of the data shows that the poor work delegation was the highest ranked based on the overall sample (mean = 4.02). This barrier was also statistically significant different ($t(52) = 4.02, p = 0.000 < 0.05$). The second overall ranked barrier impacting the quantity surveyor graduates was that of poor mentoring procedures, (mean = 3.89). The barrier was statistically significant ($t(52) = 3.89, p = 0.001 < 0.05$). The third overall ranked barrier to mentoring QS graduates was mentor expertise (mean = 3.87). This factor was nevertheless statistically significant ($t(52) = 3.87, p = 0.002 < 0.05$).

Table 1: One Sample Statistics and t- Test

Barrier	Test value ($\mu = 3.5$)	df	Sig. (2-tailed)	Mean difference	Mean score	R
Poor work delegation	3.974	52	.000*	.519	4.02	1
Poor mentoring procedures	2.682	52	.010*	.387	3.89	2
Mentor expertise	3.309	52	.002*	.368	3.87	3
Distancing behavior and neglecting	.688	52	.494	.104	3.60	4
Work style	.622	52	.536	.066	3.57	5
deception	.361	52	.720	.047	3.55	6
Politicking (self-promotion)	-.485	52	.629	-.066	3.43	7
Dissimilar personality and habits	-2.467	52	.017*	-.292	3.21	8
Personal problems	-2.076	52	.043*	-.292	3.21	9
Intentional exclusion	-2.978	52	.004*	-.368	3.31	10
Bad attitude	-3.133	52	.003*	-.481	3.02	11
Gender difference	-7.997	52	.000*	-1.311	2.19	12
Religion differences	-9.455	52	.000*	-1.462	2.04	13
Nepotism	-9.389	52	.000*	-1.538	1.96	14
Tribalism	-11.442	52	.000*	-1.632	1.87	15

Notes: *Significant at the 95 per cent level ($p < 0.05$); R = Ranking

In the lower quartile, gender differences (mean= 2.19) religious differences (mean = 2.04), nepotism (mean = 1.96), tribalism (mean =1.87), ranked 12th, 13th, 14th and 15th respectively. All least ranked barriers were found statistically significant notably; gender difference ($p = 0.00 < 0.05$); religious difference ($p=0.000<0.05$, nepotism ($p = 0.200 < 0.05$); tribalism ($p = 0.000 < 0.05$).

RESULTS

This study looks at both formal and informal mentoring of graduates in quantity surveying career. As such it highlights on barriers to mentoring regardless of their settings. The barriers to mentoring of quantity surveyors’ graduates in terms of ranking are poor work delegation, poor mentoring procedures, mentor expertise, distancing behaviour and neglecting, work style and deception. The top 3 high ranked barriers are significant and the rest plus politicking are not significant. This explains that there are many barriers to mentoring graduates. The top 3 highly ranked barriers and the last 2 in the lower quartiles are discussed.

Poor work delegation was the highly ranked barrier and has been appreciated in various studies (Trainer, 2017; Oke and Otasowie, 2020). The barrier may affect the

learning process in that there could be continuous loss of knowledge which is due to unplanned activities of key personnel (Rahma *et al.*, 2011). This barrier also may culminate to a mentee being assigned repetitive work or assigned too much work that may impede his/her ability to learn (Trainer, 2017).

Poor mentoring procedures were the second ranked barrier. Mentoring procedure will provide the base required for the transfer and sustainability of knowledge in facilitating the learning process to quantity surveying graduates. Whilst absence of the mentoring procedure may hinder the knowledge transfer, the finding is consistent with several earlier studies that report that lack of proper mentoring procedure may hinder the mentoring learning process (Nthombekaya, 2015). In the absence of adequate mentoring procedures, a mentee lacks a systematic way of acquiring knowledge and as such the mentor and mentee will not reach their goals.

Mentor expertise was the third ranked barrier and supported by Plamondon (2007) and Shafie *et al.*, (2014). Mentorship is one of the important things in an organization that support learning and development and therefore the expertise of a mentor has a significant impact on the process (Hoffmeister *et al.*, 2011). The mentor is expected to be competent and possessing professional skills that will be imparted to the mentee. In the event the mentee realizes that mentor is incompetent the learning process will be jeopardized as a result of lack of trust as the mentee may hesitate to do some of the job assigned by the mentor (Plamondon, 2007).

Others such as gender differences (Seidel, 2019; Nkomo and Thwala, 2013) and religions differences (Steinberg, 2007; Mohtady *et al.*, 2019) appear to be significant barriers such that mentoring may not take place because the mentor or mentee is discriminating towards gender or religion. At times mentoring is not successful due to human related factors such as personal problems and nepotism (Nkomo and Thwala, 2013; Hoffmeister *et al.*, 2011); dissimilar personality and habits and intentional exclusion (Plamondon, 2007; Nkomo and Thwala, 2013), bad attitude (Suleiman, 2013; Oke and Otasowie, 2020) and tribalism (Kovach, 2017; Mohtady *et al.*, 2019). The human related factors are likely to dominate in formal mentoring as opposed to informal. In informal setting, a mentor and a mentee develop relationship over time which helps to overcome some of the obstacles and find a good fit. This is supported by the work of Inzer and Crawford (2005) that informal mentoring relationships develop because protégés and mentors readily identify with each other. The current system of mentoring of graduates in our country starts with identifying firms that are ready to assume such responsibility followed by placement which does not guarantee healthy relationship. This results into many challenges to both mentors and mentees. These challenges are contrary to the aspirations of both a mentor and mentee. The finding is consistent to the study by Oke and Otasowie (2020) that, future quantity surveyors are expected to have thorough knowledge and understanding of client operating environment, dilemma and aspirations and this knowledge can be transferred effectively through mentoring practices and therefore the opposite may sparkle to barriers for mentoring.

Collectively, barriers identified in this study deter learning process, work performance and organization outcome in many ways. Human related barriers such as gender and religious differences, personal problems, nepotism, dissimilar personality and habits, intentional exclusion, tribalism, and bad attitude may lead to abortive mentoring including quitting the program by either a mentor or mentee. This could be one of the reasons that many construction graduates participate in mentoring programs but do not

acquire the required skills (Oke *et al.*, 2018). The scantily or non-mentored individuals lack an important aspect to improve their performance which could have significantly contributed to professional development and sustainability of the profession. Individuals who have been mentored tend to report greater career outcome in terms of satisfaction with their job and career, commitment to their career and intentions to stay with current organization than non-mentored (Allen *et al.*, 2004). These qualities greatly contribute to individual performance, professional development, and organization outcome at large. Poor attitude to work elevates to non-cooperation of a mentor and mentee which has negative impact on morale and productivity level of the organizations (Suleiman, 2013). Dissimilar personality and habits bring about the mismatch in personalities that are likely to affect the mentor-mentee relation (Plamondon, 2007) such that mentor and mentee are not compatible due to their social or economic status and it becomes hard to work together. Religious differences pose a threat among the mentor and mentee relation which may emanate from working times and days when they have to catch up with deadline which in turn affects organizational goals. Gender differences, tribalism, nepotism, and intentional exclusion create a sense of exclusion or favouritism to mentor or mentee which will interfere with both the performance of individuals in the program and their organizations.

CONCLUSION

Generally, there exist barriers to mentoring of graduates in quantity surveying firms in Tanzania which impede their learning process as well as work performance. Graduates of quantity surveying career are experiencing both formal and informal mentoring and in the making they come across several barriers. These barriers are mostly out of human and social factors which include poor delegation of work, mentor expertise, personal problems, intentional exclusion, bad attitude and, religion and gender differences. It seems these barriers are exuberated by the formal system of mentoring that arbitrarily allocates graduates to firms. One of the main contributions of this study lies in the identification of an ordered grouped set of barriers for mentoring QS graduates in Tanzania. Another significant contribution of this paper is that it sheds light and provides insights on the understanding of the barriers impeding their learning process and work performance within a previously unexplored context. The study therefore recommends that AQRB and TIQS to advocate for informal mentoring among registered members and consulting firms; organize training programs for mentors so as to equip them with mentoring skills; and capitalize on sensitization programs to improve the morale of mentoring in quantity surveying firms. The findings can be used by the practitioners as a basis for providing the foundation to address the barriers and “find a good fit” during mentoring process in improving the performance of graduates in the future. Secondly, the findings provide insights into how the uniqueness of the formal/informal context and consulting firms affect the mentoring processes. The barriers to mentoring of QS graduates will affect the learning process, work performance and organisation outcome.

The study was limited to mentees in consulting firms of the construction sector in Tanzania and therefore, the findings may not be generalized to other sectors of the economy or public sector organisations operating in other countries. Secondly, the study only employed statistics analysis such as descriptive and inferential statistics which take into consideration the strength of association among the barriers. Future studies could use rigorous statistical analysis such as regression analyses, multivariate techniques such as factor analysis, and structural equation modelling (SEM).

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HIGHWAY SUSTAINABILITY CONSTRUCTION: REDUCING CARBON EMISSIONS USING PROCESS MANAGEMENT

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Carbon emission is a critical issue in infrastructure development, in which the highway construction industry is inclusive. Previous studies suggest that continuous carbon emission across the highway projects is due to the use of different types of construction equipment, and their inherent activities. Several research studies focused on arbitrary evaluation in order to reduce carbon emission using simulation, life-cycle analysis, and multi-criteria optimisation. The general lack of methodological rigours questions the effectiveness of those carbon reduction methods. In addition, some of those studies do not show subtle improvement in carbon reduction, and some of the findings are restricted for use. The study aims to develop an integrated technique and a better understanding of using process management in reducing carbon emissions in highway construction projects. A unique approach using the literature review as the mode of enquiry is used, which enables the use of secondary information as inputs to the analytical hierarchy process. The result shows that 'Strategy' has the highest weight score. The pattern of results indicates that a new paradigm shift is required in the use of strategic process management approach in highway carbon reduction. Two contributions are made: firstly, early decision-making, to include carbon reduction strategy during the highway feasibility study and tender phases. Secondly, to use the proposed strategic process management framework in determining realistic carbon reduction strategies across the highway construction sector.

Keywords: carbon-management, climate emergency, sustainability, infrastructure

INTRODUCTION

Carbon emission depletion has been an issue of great interest in a wide range of fields. The research constitutes relatively a new area, which emerged from a need to reduce carbon emissions during the highway construction projects. Kellogg (1978) revealed that in the past four decades, scientists and international communities had raised the alarm on the threat posed as a result of human-induced anthropogenic activities. Ripple *et al.*, (2017) warned that the risks associated with carbon emissions continue to rise dramatically. The identified perils due to carbon emissions are global warming, change in landscapes, sea-level rising and coastal flooding. The pre-industrial values of carbon emission were fewer than 300 parts per million (ppm), and

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the post-industrial values of carbon emission currently stands at 420 (ppm). The International Panel on Climate Change (IPCC) stressed that if anthropogenic human-induced activities continue to increase exponentially, that will result in continuous carbon emission, then by 2250, the atmosphere will get to a startling carbon saturation level of 2000 (ppm). As Huang *et al.*, (2018) noted that the construction industry is a contributory sector to carbon emissions, and the highway construction projects are encompassed (Wang *et al.*, 2015). There are several cross-sectional studies which suggest that carbon emissions continually emit as a result of construction equipment and attendant activities (Kim *et al.*, 2012; Cass and Mukherjee, 2011). The vast majority of the studies on carbon reduction focused on arbitrary evaluating emission using the life-cycle assessments, simulation, and multi-criteria optimisation.

Currently, there have been various arguments among the scholars on what methods and approaches that are appropriate in reducing carbon emissions in highway construction. The general lack of methodological rigours brings doubt in the various carbon emissions methods. However, most of the studies are short-term, which do not necessarily show subtle improvement in carbon reductions. Some research findings across this field are restricted to limited comparison, and some are descriptive. The vast majority of the studies have not considered the need to use process management as an approach to reduce carbon emissions in highway construction.

This, therefore, the paper aims to develop a better understanding of using a process management technique for reducing carbon emission in highway construction projects. The specific question which drives this study is focused on the significance of using process management to reduce carbon emission in the highway projects. The objective of the study is to investigate how decision-making helps in identifying the criteria needed in reducing carbon emissions. Information for this study was collected using a literature review as the mode of enquiry. The utilised technique is the analytical hierarchy process for decision-making, which is used in deciding on an appropriate protocol.

The present study fills a gap in the literature by providing insights into using process management approach in carbon reduction across the entire life cycle of a highway project. This study, therefore, provides an exciting opportunity to advance in knowledge using process management to reduce carbon emissions.

It is beyond the scope of this study to examine in detail the various rigorous processes, tools, techniques and outputs for each phase for the developed strategic framework. The reader should bear in mind that this study is based on literature review; thus, extensive primary data and development of the processes is an essential factor for future research. Another potential limitation is that the scope is too broad, and any future study should consider study boundary restrictions. The paper is structured in five sections; foremost is the summary literature, methods, results and discussion, and findings. We conclude with concise suggestions on the need to adopt process management in carbon reduction across phases of the highway construction.

LITERATURE REVIEW

Carbon Emission in Highway Construction:

Burgos *et al.*, (2015) claimed that anthropogenic greenhouse gases are emissions produced either through natural or human-induced activities. Approach and assertions in determining carbon emission have passionately been opposed in recent years by some scholars. Many experts argued that the use of life-cycle assessments (LCA) in

carbon reduction approach is consistent and wide-ranging, (Cass and Mukherjee, 2011; Duan *et al.*, 2015). Life-cycle assessments provides a practical framework in assessing potential environmental impacts due to human-induced anthropogenic activities. Cass and Mukherjee's study are of considerable significance, as it marks an attempt to examine carbon emissions associated with different pavement design and construction using LCA. The study method used construction data, which is a form of inputs of data across the life-cycle in determining carbon emissions. A significant concern with this method, is uncertainty in a change to the design and construction processes, which equally affect the data associated with the carbon reduction assessments. There are evident difficulties in accepting the reliability of the data collection as an input in carbon reduction. For instance, highway construction projects are overwhelmed with extensive data and paper trails, which may not be consistent considering deficient record modifications, lack of communications, design changes and materials substitutions which sometimes are not correctly archive.

Some study investigation focused on the empirical methods and multi-criteria optimisation to calculate and reduce carbon emission in highway construction (Wang *et al.*, 2015; Lidicker *et al.*, 2013). The empirical method estimates the carbon emitted in a project using budget sheets, and material records, which serve as an input to the construction materials, fuel and energy used across the phases of the projects. The multi-criteria optimisation is the concept of minimising life-cycle costing to reflect on the reduction of greenhouse gas emissions, which is vaguely comprehended.

The shortcoming of some of the carbon reduction methods is the arbitrary inputs and outputs of data, which sometimes are subjective. In most studies, the carbon life-cycle analysis omits and fails to follow the International Standard Organisation (ISO) guideline 14044:2006, and ISO 14040:2006 in calculating carbon emissions, and these undermine the usefulness of the study. Notwithstanding the subjective approach to some study, there are vastly available methods used in calculating the carbon emissions in highway construction projects. Cass and Mukherjee (2011) identified a method of using data inputs in determining carbon reductions. Though the authors suggested that, the carbon emissions results will continue to differ across research outcome, this is due to the use of non-prototype strategies. Ma *et al.*, (2016) shared the same sentiments that no universal criteria are acceptable for the evaluation of carbon emissions in asphalt pavement construction. The difference is the variable emission carbon data, which globally has different methods, inputs statistics, and assumptions. Apparently, in comparing some of the suggestions from past studies, most are considered short-term, which did not show a definite improvement in carbon reduction. Invariably, these studies indicate a restriction to limited comparisons, and some are illustrative, as a new paradigm is required in reducing carbon emission in highway construction.

METHODS AND MATERIALS

Many researchers have utilised life-cycle analysis (LCA) to measure carbon emissions in highway construction. The LCA method is particularly useful in studying carbon reduction and emissions if only a systematic approach is used following the guideline of ISO 14040 and 14044. However, there are certain drawbacks associated with the use of these carbon emission methods. The LCA methodology shortcomings are variation in different modelling approach and missing inventory inputs. The main disadvantage of carbon reduction simulation models is that it focuses more on uncertainties, no standardised approach is used, and it is challenging to validate the

results, so there are high scepticism and variations. Some studies evaluated the carbon reduction life-cycle analysis arbitrarily across phases of the highway projects.

The research questions, aims and objectives support the choice of research strategy. Figure-1 represents an overall methodology and pathway design for the study. The literature review is the mode of enquiry which enables the use of secondary data as inputs to the analytical hierarchy process (AHP). The reason for choosing literature method is that it forms a significant foundation for all type of research (Snyder, 2019).

In this study, primary data are absent, so the literature review using secondary data information serves as the basis of knowledge development. Creswell (2014) suggested that no particular method has an advantage over others, but several decisions need to be made, such as the identification of strategies of inquiry. The advantage of the analytical hierarchy process is in two folds for this study:

- (1) It is used to determine competing decision-making criteria, used in deciding on the appropriate protocol in developing a process management approach.
- (2) The AHP calculates the pairwise comparison to determine the consistency of the chosen sub-criteria in Figure-2 level-2.

The sub-criteria are contained in two subsets to enable the selection of appropriate decision protocol. Handfield *et al.* (2002) mentioned that AHP will not be clear substitute thinking for the decision-maker, but it organises thoughts and inputs for the development of process and procedures.

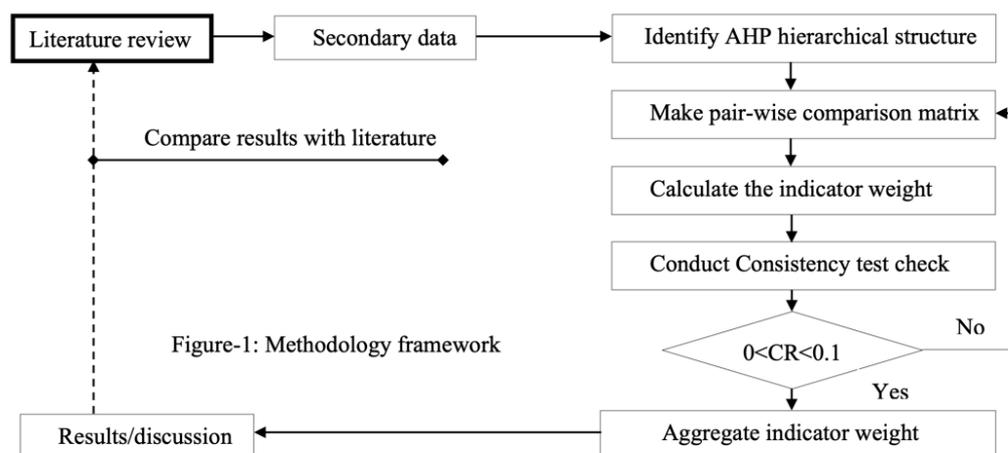


Figure-1: Methodology framework

Figure 1: Schematic of AHP development

The following section depicts the AHP systematic development for the study as summarised and presented in a schematic form in Figure-1.

Analytical Hierarchy Process (AHP)

The process evaluation is categorised in five distinct parts: Develop AHP hierarchical structure (Figure-2); develop pairwise comparison matrix (Table 3-5 and 12-13); calculate the pairwise comparison to determine weight-score (Table 5-7 and Table 13-15); conduct Saaty's (1980) Consistency test check (Table-11 and Table - 18); and aggregate criteria weights-score (Figure-2).

Develop an AHP Hierarchical Structure

The AHP structure (Figure 2) is categorised from level-0 to level-3. The overall 'Goal' is level-0, decomposed to level-1 having two subsets. The next level-2 is sub-criteria

from the literature review in Table 2. The aim is to determine most likely sub-criteria the AHP will select to develop a framework in carbon reduction. The level-3 is a result of highest weight-score from level-2.

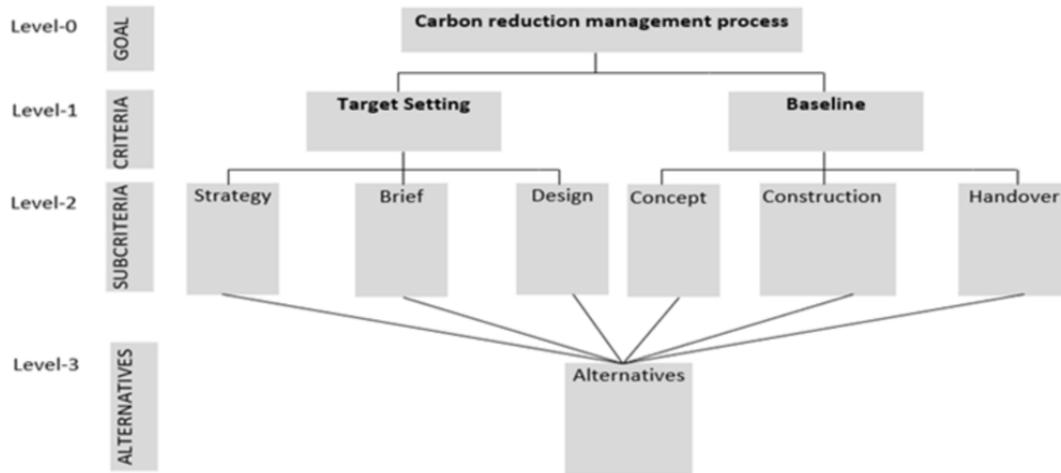


Figure 2: AHP Hierarchical Structure

Develop a Pairwise Comparison Matrix

In order to help decision-makers to develop the pairwise comparison matrix, Saaty (1980) created a nine-point "scale of relative importance" (Table-1). In past studies, the "scale of relative importance" is assigned based on subjective expert assessment (Handfield *et al.*, 2001).

That is a sensitive assertion, as the decision-maker may have a subjective bias in assigning appropriate scale of relative importance to the sub-criteria identified in level-2. In order to bridge the noted gap from past research. The current study conducted a literature review to identify frequencies and how many times carbon emission is measured across the highway project phases. The summary is displayed in Table-2, which aided in assigning of Saaty's scale of relative importance from the Table-1, to the respective pairwise comparison tables.

Table 1: Saaty's scale of relative importance

Numerical rating	1	2	3	4	5	6	7	8	9
Scale importance	Equal	Weak	Moderate	Moderate-plus	Strong	Strong-plus	Very strong	Very, very strong	Extreme
Reciprocal	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9

The objective assessment of Table-2 and Table-1 helped to assign unbiased scale of relative importance to the upper right corner of Table 3, which are {4: 8: 5}. 'Strategy' is given 'very-very-strong' than 'Design', which was assigned with value '8' from Table-1. Again, 'Strategy' is moderately-plus preferred than 'Brief' which is assigned '4' from Table 1, and "Brief" given '5' which is considered 'Strong' than the 'Design'. In completing the upper right-hand corner of Table-3, the next allocation is the lower left-hand corner of Table 3. Foremost, '1' is assigned to the entire diagonal in Table 3, as each sub-criterion against itself is 'equal' to 1 from Table-1. The lower-left corner of Table 3 is assigned 'Reciprocal', as stated in Table 1. Formerly from Table-3, 'Strategy' in the first row, and 'Design' in the third column is assigned '8'. Then, therefore, from the Table-1, the reciprocal is assigned in Table-4 as 1/8 in the third-row, first column. The same approach follows for other criteria in Table-4, and Table-12 for subset 'Baseline' respectively.

Calculate the Pairwise Comparison to Determine Weight Score

The pairwise comparison matrix is converted to decimals to make it easier to work with. The Table-4 is converted to decimals in Table 5, and the summation values of each three respective column yield: {1.38, 5.20, 14.00}. The values in Table-6 are attained by dividing each column criteria with its total summation in Table 5; say $(1/1.38 = 0.727, 0.250/1.38 = 0.182\dots\dots n)$. The concept in Table 6 is that each column summation must total equal to one: (1.00: 1.00: 1.00). The Table 7 is the average of each row in Table 6 to yield the weight score for each determined criterion in level 2: (Strategy = 0.689: Brief = 0.244: Design = 0.067). Similar pairwise comparison calculation applies to Table 12 - 15 for the subset 'Baseline.'

Table 2: Frequencies of carbon reduction in highway projects at different stages (Authors)

Phases of carbon estimation and reduction opinion in highway projects							
SNO		Strategy	Brief	Design	Concept	Construction	Handover
1	Cass & Mukherjee et al. (2010)	✓	✓	✓	✓	✓	-
2	Ma et al. (2016)	✓	-	✓	✓	✓	-
3	GschÖsser (2012)	✓	✓	✓	✓	✓	-
4	Ehn et al. (2010)	✓	✓	-	✓	-	-
5	Wang et al. (2015)	✓	-	-	-	✓	-
6	Huang et al. (2018)	-	-	-	✓	✓	-
7	Kim et al. (2012)	✓	✓	-	✓	✓	-
8	ADB India (2010)	✓	✓	-	✓	-	✓
9	Seo and Kim (2013)	✓	-	-	✓	-	-
Frequencies		8	5	3	8	6	1

Conduct Saaty's Consistency Test Check

The AHP decision tool is based on relative judgment. Unfortunately, the tool suffers from discrepancies. Saaty's Consistency Ratio (CR) is used to check the consistency of weight-score achieved in Table 7 and Table 15, respectively. The process of calculating Consistency Ratio (CR) is:

Determine Consistency Index (CI) = $(\lambda - N) / (N - 1)$ Equation (1).

Tables 3-11: Analytical Hierarchy Process analysis method (Target setting subset)

AHP	N=3	Table-3			Table-4			Table-5			
Target setting	Strategy	Brief	Design	Target setting	Strategy	Brief	Design	Target setting	Strategy	Brief	Design
Strategy	1	4	8	Strategy	1	4	8	Strategy	1	4	8
Brief		1	5	Brief	1/4*	1	5	Brief	0.250	1	5
Design			1	Design	1/8*	1/5*	1	Design	0.125	0.200	1
								Total	1.38	5.20	14.00
Target setting	Strategy	Brief	Design	Target setting	Strategy	Brief	Design	Table-8			
Strategy	0.727	0.769	0.571	Strategy	0.727	0.769	0.571	Saaty's RI			
Brief	0.182	0.192	0.357	Brief	0.182	0.192	0.357	N RI			
Design	0.091	0.038	0.071	Design	0.091	0.038	0.071	2 0.00			
Total	1.00	1.00	1.00					3 0.58			
								4 0.90			
Target setting	Table-9			Target setting	Table-10		Table-11				
Strategy	0.689	0.976	0.536	2.201	Strategy	3.19	Lambda 3.10				
Brief	0.172	0.244	0.335	0.751	Brief	3.08	CI 0.05				
Design	0.086	0.049	0.067	0.202	Design	3.02	CR 0.09				
					λ	3.10					

Tables 12-18: Analytical Hierarchy Process analysis method (Baseline subset).

AHP	N=3	Table-12			Table-13					
Baseline	Concept	Construction	Handover	Baseline	Concept	Construction	Handover			
Concept	1	8	5	Concept	1.00	8	5			
Construction	1/8*	1	6	Construction	0.125	1	6			
Handover	1/5*	1/6*	1	Handover	0.200	0.167	1			
				1.33			9.17		12.00	
Table-14				Table-15						
Baseline	Concept	Construction	Handover	Concept	Construction	Handover				
Concept	0.755	0.873	0.417	Concept	0.755	0.873	0.417	0.681		
Construction	0.094	0.109	0.500	Construction	0.094	0.109	0.500	0.631		
Handover	0.151	0.018	0.083	Handover	0.151	0.018	0.083	0.252		
1.000				1.000			1.000		1.565	
Baseline	Concept	Construction	Handover							
Concept	0.681	5.046	1.262	6.99	10.26	Lambda		15.75		
Construction	0.085	0.631	1.515	2.23	3.54	CI		7.38		
Handover	0.136	0.105	0.252	0.49	1.96	CR		12.72		
				λ			15.75			
Table-16				Table-17			Table-18			

Lambda (λ) from Table 10. Therefore, use Equation-1; $\lambda = (3.10 - 3) / (3-1) = 0.05$

Consistency Ratio (CR) = CI / RI: where (RI) is Saaty's Random Index from Table 8, and RI is 0.58; Thus; CR = 0.05 / 0.58 = 0.09

Therefore, CR = 0.09 in Table 11; ($0 < 0.09 < 0.10$)Satisfactory. A look at Table 18, the "CR" for the subset "Baseline is unsatisfactory" {12.72 > 0.10}.

RESULTS

The purpose of the analytical hierarchy process in this study is to determine competing decision-making across the sub-criteria, which is required in deciding on the appropriate protocol in developing a process management approach. A look at Figure-3, the aggregate weight of sub-criteria revealed a positive indication at level-1, with 'Baseline' subset weight score of 1.565. The reason for such a high score is that carbon emission reduction is most likely to occur during the concept design and construction phases, but less likely to occur during the handover phase. A look at level-1 in Figure 3, 'Target subset' weight scores 1.000, which is less than the other subset by 0.565. Although, the selection for the decision making is based on sub-criteria with the highest weight score, and the Saaty's Consistency Ratio is fulfilled. 'Strategy' scored 0.689, and Consistency Ratio for the subset is $0.09 \leq 0.10$, which is satisfactory.

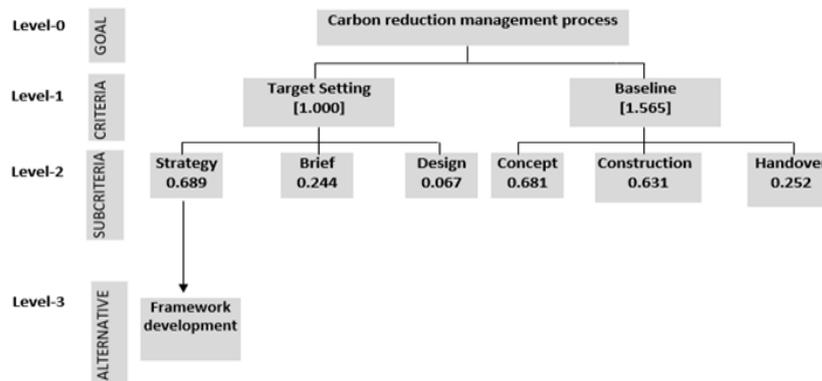


Figure 3: Aggregate weight of sub-criteria in decision-making

The level-1 subset 'Baseline' when compared with Saaty's Consistency Ratio, is unsatisfactory with $12.72 > 0.10$. The result is, therefore, rejected. Although, there

are noticeable differences from the results obtained from both subsets, the surprising and striking result to emerge from the analysis is "Strategy". It is a bit awkward, but expected, as that will play a vital role in establishing a strategic framework during the feasibility stage, and across various phases of highway construction in carbon reduction.

DISCUSSION AND FINDINGS

This study was designed to develop a better understanding of using a process management approach in reducing carbon emission in highway construction. Emphasis was to determine at what phase it is appropriate to implement carbon emission reductions, using process management framework.

The prominent finding that emerged from the study is the use of the analytical hierarchy process in using pairwise comparison calculation to select 'Strategy' from sets of sub-criteria. Maleka (2014, p.6) defined 'strategy' as a process of integrating activities and the allocation of scarce resources to meet objectives. Some scholars expressed their views in discussing strategy; (Mintzberg, 1994) considers strategy as a pattern in a stream of decisions. (McKeown, 2011) debates that, a strategy is about shaping the future to get desirable results. Subsequently, Maleka's model for the Strategic Management Process is adopted. The model resulted in the development of Figure 4, the Strategic Process Management Approach for Carbon reduction. The objectives of the developed framework are to enable systematic goal setting in the use of strategic process management in reducing carbon emissions, starting from the tender phase of a project. Every project is unique, and relevant project factors must be put into consideration in reducing carbon emissions.

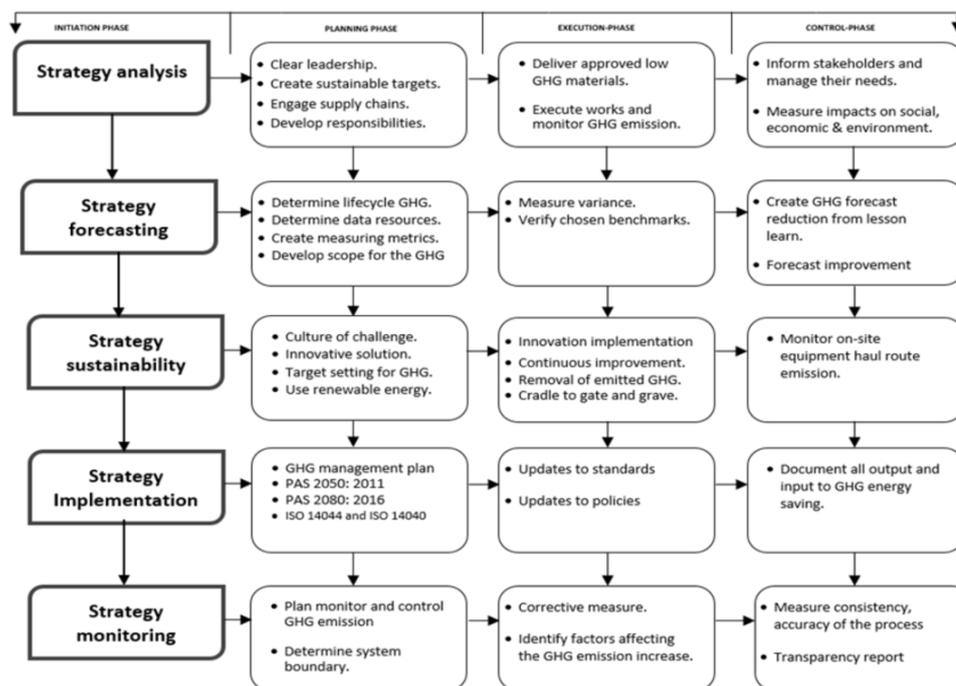


Figure 4: Strategic Process Management Approach for Carbon reduction

The research findings of this study is unique in that, "Strategy" scored higher when compared with the other sub-criterion, most notably the construction phase. Considering the fact that the construction stage is the most common period at which carbon reductions are implemented during highway construction. This pattern of

result indicates that a new paradigm shift is required. Although, this result has not previously been described. In comparing the result with other past studies, dissimilarities are revealed. Notably, past studies adopted a non-prototype strategy in determining carbon emission reduction. Generally, the life-cycle analysis methods are arbitrarily used to calculate the carbon emission reduction, and the result outputs undermine the usefulness. Moreover, no standard or universal criteria are globally established, hence different methods, inputs and outputs.

There are still several questions that remain unanswered. It is beyond the scope of this study to examine and develop in detail the various processes, tools and techniques and other outputs for each phase of the Strategic Management Process Framework. The present study used a literature-based data source. It is suggested that extensive primary data is required as an essential factor for future research. Another potential limitation is that, the scope is too broad, and any future study should consider a limited scope. It is also significant to consider the limitations of this study, in prioritising to assign the Saaty's relative scale of importance. Future research suggestions are made to utilise analytical brainstorming, using a knowledge base for assigning scale of importance to sub-criteria. Despite the promising results, the Strategic Process Management Approach in carbon reduction has its limitation; the process is dense and needs to develop robust processes, tools, techniques and outputs for each phase.

CONCLUSION

This study set out to gain a better understanding of carbon reduction across highway projects. These findings raised critical issues on how carbon emissions are arbitrarily determined across phases of highway construction projects. In most cases, the results from past studies have insufficient information to enable future decision-making in new projects. On the contrary, this study is an attempt to systematically examine and identify carbon reductions using a Process Management Approach. This paper presents two contributions. Firstly, is the early decision-making to include carbon reduction strategy during the highway feasibility phase. Secondly, to adopt the proposed Strategic Process Management Framework, in determining a realistic carbon reduction across the highway construction sector.

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WORK-RELATED STRAIN EFFECTS AND COPING STRATEGIES AMONG SOUTH AFRICAN CONSTRUCTION PROFESSIONALS

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The working environment in the construction industry is demanding and many construction professionals experience high levels of workplace stress, leading to physiological, psychological and sociological strain effects. The coping strategies that construction professionals adopt to manage work-related strain effects can be adaptive (e.g. physical and intellectual counter-measures) or maladaptive (e.g. unhealthy lifestyle counter-measures). A purposively selected sample of thirty-six construction professionals were surveyed regarding their experiences of strain effects and coping strategies for mitigating them. Between-gender and between-professional group differences in experiences were also investigated. The highest-ranked physiological strain effects in terms of frequency of occurrence were fatigue, inability to relax, disturbed sleep patterns, skeleton-muscular pain, and headaches. The psychological strain effects of frustration, anger / irritability, tenseness, anxiety, and feeling dissatisfied were most frequently experienced by construction professionals. Strain on professional relationships and strain on personal relationships were the highest ranked sociological strain effects in terms of frequency. Between-gender and between-professional group differences were identified for several strain effects across different categories. Regarding coping strategies, respondents reported non-competitive sporting activity, walking, competitive sporting activity, fitness classes, and shopping as the most effective physical counter-measures to stress. The intellectual counter-measures of travel, music appreciation, focussing on smaller tasks, reading and humour were ranked the highest in terms of effectiveness. With regard to maladaptive coping strategies, respondents ranked increased caffeine intake and confrontation as most effective counter-measures. Between-gender and between-professional group differences were identified in the rating of some physical and intellectual counter-measures, but not in the rating of lifestyle counter-measures. The research contributes to the understanding of strain effects of workplace stress on construction professionals and provides important implications for the development of targeted stress-management strategies within professional practices and construction organisations.

Keywords: workplace stress, strain effects, stress coping, professionals

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INTRODUCTION

Workplace stress is defined as an “adverse reaction people have to excessive pressures or other types of demand placed on them” (Health and Safety Executive (HSE), 2019a; p.3). Workplace stress has been recognised as a threat to the health and wellbeing of working people across the world. For example, in the Fourth Working Conditions Survey, stress was reported as one of the most frequently reported work-related health issues and experienced by 22.3% of working individuals across EU27 countries (European Foundation for the Improvement of Living and Working Conditions, 2007). Workplace stress is a major cause of occupational ill-health, which can lead to severe physical and psychological symptoms being experienced by employees (HSE, 2019a). Workplace stress is also associated with production lost and massive costs. According to HSE (2019b), 12.8 million working days were lost due to work stress, depression or anxiety, which was equivalent to 54% of all working days lost due to ill-health during 2018-2019 in the UK.

The construction industry is a high-risk sector in terms of work stress (Love *et al.*, 2010). Construction professionals work with restricted project budgets and tight schedules, and project delays can lead to considerable financial penalties (Lingard and Francis, 2004). Construction work is associated with high levels of dynamism and uncertainty, elevating its stressful nature (Mohr and Wolfram, 2010). A survey conducted by Campbell (2006) indicates that 61.9% of construction professionals who participated in the survey reported suffering from workplace stress.

Previous research found that the levels of stress experienced by construction professionals vary according to organisation type (i.e. contracting or consultancy companies) (Love *et al.*, 2010), gender (Sunindijo and Kamardeen, 2017) and professional groups (Bowen *et al.*, 2014b). These findings suggest that a more finely grained analysis is required to understand differences in the stress experiences of construction professionals and to develop targeted stress coping measures. Ongoing research is being conducted to examine workplace stress experiences among South African construction professionals. This paper reports research findings in relation to construction professionals' experiences of strain effects and stress coping strategies and associated between-gender and between-professional group differences.

THEORETICAL FRAMEWORK

Stress is used as an umbrella term that encompasses a range of environmental demands (i.e. stressors), the effects of stress (i.e. strains), and intervening variables that influence the relationship between stressors and strains (e.g. coping strategies and mechanisms, environmental support) (Jones and Bright, 2001). Hence, stress results from an imbalance between demands and personal or environmental resources (Houtman, 2005). Strain effects are therefore responses to the negative outcomes of stress (Jones and Bright, 2001). Strain effects are manifested differently. For example, Houtman (2005) identified four types of strain effects, including: physiological (e.g. headaches, cardiovascular disease), psychological/emotional (e.g. feeling nervous or irritated, depression, anxiety), cognitive (e.g. poorer quality decision-making, impaired memory), and behavioural (e.g. substance abuse, impulsive behaviours). Osipow and Davis (1988) added that stress stimuli (the pressures) can also lead to interpersonal strain effects which produce disruptions in interpersonal relationships, and vocational strains which negatively impact work performance. In addition, Bowen *et al.*, (2014b) described sociological strain effects as negative effects on individuals' family life, social activities, and social relationships. Coping

strategies might comprise a suite of individual coping mechanisms, each of which might have positive (adaptive) or negative (maladaptive) health outcomes.

In the construction industry, research has reported a variety of negative strain effects of workplace stress. For instance, Leung *et al.*, (2011) reported that construction project managers who experience job-related stress (e.g. stress relating to meeting project deadlines) are likely to show the psychological response of burnout, which further leads to physiological strain effect symptoms such as headaches, migraines, back pain, and loss of appetite. In addition, job-related stress is also shown to negatively impact on construction project managers' work performance and interpersonal relationships (Leung *et al.*, 2011). Bowen *et al.*, (2014a) examined psychological, physiological and sociological strain effects in the South African construction industry. They reported that these three types of strain effects are interrelated and either directly or indirectly predicted by personal factors (e.g. age, experience), workplace factors (e.g. job demand), and contextual factors (e.g. organisational climate).

Coping has been defined as “cognitive and behavioural efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person” (Lazarus, 1993; p 237). One way of classifying coping mechanisms is referring to a health promotion paradigm (Holton *et al.*, 2016). Following this paradigm, a coping mechanism can be evaluated based on its adaptive (protective) or maladaptive (detrimental) effect on an individual's health. Adaptive coping strategies are those used by individuals to deal with stressors in a positive and healthy way, such as exercise, meditation, and seeking social support. Maladaptive coping strategies, on the other hand, may temporarily reduce strain symptoms but potentially lead to greater health issues and contribute to the development of coping vulnerabilities, such as excessive consumption of alcohol, drug use, and habitual rumination (Holton *et al.*, 2016). Bowen *et al.*, (2014b) examined the coping mechanisms used by construction professionals and reported that although professionals adopt a range of adaptive coping mechanisms (e.g. physical, intellectual and cultural activities) to deal with stress, the use of maladaptive coping mechanisms (i.e. alcohol consumption, smoking, and the use of narcotics) is also common.

RESEARCH METHOD

This research was conducted using a questionnaire survey. The workplace strain effects section of the survey comprised scales for Physiological Strain Effects (15 items), Psychological Strain Effects (13 items), and Sociological Strain Effects (6 items) (see Table 1). The counter-measures section comprised scales for Physical Counter-measures (17 items), Intellectual Counter-measures (25 items), and Lifestyle Counter-measures (10 items) (see Table 2). The Physical and Intellectual Counter-measures are related to adaptive coping mechanisms while the Lifestyle Counter-measures are related to maladaptive coping mechanisms.

Purposive sampling was employed to identify suitable respondents, thus ensuring representation of professional disciplines and both genders (Patton, 2002). The target frame consisted of professionals working in the construction industry in the Western Cape, largely drawn from the metropolitan area of Cape Town. Respondents were selected on the basis that they were registered with a professional Council with at least 5 years post-registration work experience. Thirty-six respondents completed the survey. The demographic characteristics of the sample were: 11 architects (7 males, 4

females); 8 project/construction managers (PCM) (7 males, 1 female); 5 engineers (4 males, 1 female); and 12 quantity surveyors (QS) (7 males, 5 females).

For each of the three strain effects scales, respondents were asked to select five most frequently experienced items and rank the five items in terms of frequency based on their experience. A five-point frequency scale with interval definitions was given for the rating of each item (1=barely noticeable or least frequently experienced; 5=very intense or most frequently experienced). For each of the three counter-measure scales, respondents were asked to select five items that they would prefer to use and rank the five items in terms of effectiveness according to their experience. Again, a five-point frequency scale with interval definitions was given for the rating of each item (1=ineffective at relieving stress or not at all effective in providing relief to me; 5=very effective at relieving stress or the most effective in providing relief to me).

RESULTS

The reliability of the instrument was tested. For the strain effects scales, the Cronbach's alpha for the Physiological, Psychological, and Sociological strain effects scales was 0.86, 0.88, and 0.70, respectively. For the counter-measures scales, the alpha value for the Physical, Intellectual, and Lifestyle scales was 0.75, 0.87, and 0.81, respectively. These alpha values indicated good to very good internal consistency in each set. Means values were calculated to identify the most frequently experienced strain effects and most effective counter-measures. Given the small sample size, the use of non-parametric statistical analyses was considered appropriate (Corder and Foreman, 2014). Specifically, the Mann-Whitney U Test was used to test for differences on the basis of gender, and the Kruskal-Wallis H Test for differences on the basis of professional grouping (Corder and Foreman, 2014). The test results are not presented in detail here.

Frequency of occurrence of physical strain effects

The five most frequently experienced physiological strain effects were fatigue, an inability to relax, disturbed sleep patterns, musculoskeletal pain, and headaches (see Table 1). A Mann-Whitney U Test showed two significant differences between men and women regarding the frequency of occurrence of these five strain effects. Men reported fatigue as being significantly more frequently experienced than did women. Women experienced proneness to accidents significantly more than did men. The Kruskal-Wallis H Test did not reveal any significant difference between professional groups.

Frequency of occurrence of psychological strain effects

The five most frequently experienced psychological strain effects were frustration, anger / irritability, tension, anxiety, and feeling dissatisfied (see Table 1). The Mann-Whitney U Test for differences between men and women revealed three significant differences, namely, frustration; lack of self-confidence; and feeling useless. Men, significantly more than women, had frequently experienced frustration, but women, significantly more than men, had frequently experienced lack of self-confidence and feeling useless. The Kruskal-Wallis H Test found a significant difference between professional groups with respect to anxiety. Architects reported this effect more frequently than did the other groups.

Frequency of occurrence of sociological strain effects

The five most frequently experienced sociological strain effects were strained personal relationships, strained professional relationships, an unwillingness to meet people, an

unwillingness to discuss issues, and an intention to leave (see Table 1). The Mann-Whitney U Test for differences between men and women revealed one significant difference, namely, strain on professional relationships. Women experienced this effect more frequently than did men. The Kruskal-Wallis H Test did not find any significant differences between professional groups.

Table 1: Item catalogues for workplace strain effects and frequency of occurrence

Item	Physiological strain effects			Psychological strain effects			Sociological strain effects		
	Variables	Frequency		Variables	Frequency		Variables	Frequency	
		Mean (±SE)	Rank		Mean (±SE)	Rank		Mean (±SE)	Rank
1.	Disturbed sleep patterns	2.32 (±0.312)	3	Tenseness	2.17 (±0.327)	3	Strain on personal relationships	3.69 (±0.268)	1
2.	Nausea sensations	0.11 (±0.079)		Anger, irritability	2.45 (±0.343)	2	Strain on professional relationships	3.49 (±0.273)	2
3.	Stomach upset	0.61 (±0.264)		Frustration	2.86 (±0.304)	1	Unwillingness to meet people	2.24 (±0.292)	3
4.	Headaches	1.76 (±0.317)	5	Anxiety	1.79 (±0.312)	4	Unwillingness to discuss issues	2.15 (±0.235)	4
5.	Fatigue	3.15 (±0.317)	1	Feeling resentful	0.31 (±0.165)		Intention to leave	1.90 (±0.302)	5
6.	Daytime drowsiness	0.83 (±0.263)		Feeling unhappy	0.72 (±0.237)		Contemplating legal action	0.52 (±0.236)	
7.	Unable to concentrate	1.00 (±0.282)		Feeling depressed	0.24 (±0.137)				
8.	Unable to relax	2.53 (±0.317)	2	Lack of self-confidence	0.18 (±0.146)				
9.	Eyesight problems	1.16 (±0.291)		Feeling useless	0.25 (±0.190)				
10.	Musculoskeletal pain	2.16 (±0.341)	4	Feeling dissatisfied	1.26 (±0.266)	5			
11.	Hypertension	0.32 (±0.156)		Feeling unappreciated	0.66 (±0.229)				
12.	Decreased libido	0.25 (±0.151)		Assigning blame to others	0.18 (±0.179)				
13.	Hot / cold flushes	0.21 (±0.144)		Mood swings more frequent	0.90 (±0.277)				
14.	Increased absenteeism	0.11 (±0.079)							
15.	Proneness to accidents	0.21 (±0.157)							
	Chronbach's Alpha =	0.858		Chronbach's Alpha =	0.879		Chronbach's Alpha =	0.702	

Effectiveness of counter-measures

Effectiveness of adaptive physical counter-measures

The five most effective physical counter-measures used by participants were non-competitive sporting activity, walking, competitive sporting activity, fitness classes, and shopping (see Table 2). The Mann-Whitney U Test for differences between men and women revealed two significant differences, namely, walking and dancing. Women found both of these activities to be beneficial more frequently than did men. The Kruskal-Wallis H Test did not identify any significant difference between professional groups.

Effectiveness of adaptive intellectual counter-measures

The five most effective intellectual counter-measures experienced by participants were travel, music appreciation, focussing on smaller, more manageable tasks, reading and humour (see Table 2). The Mann-Whitney U Test for differences between men and women revealed one significant difference, namely, painting and sketching. Women found this activity to be beneficial more frequently than did men. The Kruskal-Wallis H Test identified significant differences between professional groups in respect of music appreciation, watching TV, and painting and sketching. In all three instances, architects experienced the therapeutic effects of these pastimes significantly more frequently than did the other groups.

Table 2: Item catalogues for stress counter-measures and effectiveness

Item	Physical counter-measures			Intellectual counter-measures			Lifestyle counter-measures		
	Variables	Effectiveness Mean (±SE)	Rank	Variables	Effectiveness Mean (±SE)	Rank	Variables	Effectiveness Mean (±SE)	Rank
1.	Competitive sporting activity	1.59 (±0.418)	3	Adopt formal problem-solving routine	1.33 (±0.369)		Increased caffeine intake	2.61 (±0.361)	1
2.	Non-competitive sporting activity	2.35 (±0.381)	1	Focus on smaller, manageable tasks	1.76 (±0.393)	3	Increased use of alcohol	1.48 (±0.314)	5
3.	Walking	2.24 (±0.348)	2	Reading & book clubs	1.61 (±0.367)	4	Increased use of tobacco	0.72 (±0.280)	
4.	Fitness classes	1.52 (±0.332)	4	Pastimes (cards, chess, etc.)	0.14 (±0.143)		Increased use of other stimulants	0.24 (±0.137)	
5.	Climbing	0.59 (±0.189)		Music (listening, attending performance)	1.88 (±0.294)	2	Increased gambling	0.14 (±0.108)	
6.	Orienteering	0.07 (±0.074)		Crosswords, Sudoku, word games	0.64 (±0.258)		Food addictions & over-eating	1.84 (±0.356)	4
7.	Dancing	0.86 (±0.303)		Travel	2.55 (±0.335)	1	Confrontation	2.58 (±0.340)	2
8.	Gardening	1.33 (±0.281)		Computer games	0.32 (±0.206)		"Distancing/Escape/Avoidance" actions	2.38 (±0.359)	3
9.	Woodworking	0.43 (±0.190)		TV	1.52 (±0.324)		Prescription medication	0.31 (±0.193)	
10.	Home Maintenance	0.64 (±0.199)		Radio	0.76 (±0.226)		Non-prescription medication	0.86 (±0.237)	
11.	Home Improvement	0.97 (±0.268)		Music performance (instrument, choir)	0.10 (±0.103)				
12.	Motoring	0.93 (±0.317)		Theatre/opera/ballet (attending)	0.76 (±0.256)				
13.	Cycling	0.63 (±0.268)		Theatre (performing arts)	0.24 (±0.107)				
14.	Motor-cycling	0.19 (±0.192)		Writing	0.20 (±0.147)				
15.	Inter-active computer sports (e.g., Wii)	0.57 (±0.244)		Painting, sketching	0.20 (±0.121)				
16.	Shopping	1.38 (±0.308)	5	Debating	0.17 (±0.141)				
17.	Window shopping	0.30 (±0.183)		Volunteering	0.11 (±0.107)				
18.				Photography & Visual media	0.52 (±0.236)				
19.				Sculpting	0.00 (±0.000)				
20.				Pottery	0.00 (±0.000)				
21.				Craftwork	0.29 (±0.155)				
22.				Antiques and collecting	0.37 (±0.200)				
23.				Humour	1.61 (±0.333)	4			
24.				Local politics	0.18 (±0.179)				
25.				National politics	0.00 (±0.000)				

Chronbach's Alpha = 0.750 Chronbach's Alpha = 0.874 Chronbach's Alpha = 0.808

Effectiveness of maladaptive lifestyle counter-measures

The five most effective maladaptive lifestyle counter-measures experienced by participants were increased caffeine intake, confrontation, distancing / avoidance actions, over-eating, and increased alcohol consumption. The Mann-Whitney U Test did not reveal any significant difference between men and women in maladaptive lifestyle counter-measures. The Kruskal-Wallis H Test also failed to identify any significant differences between professional groups.

DISCUSSION

Strain effects

Fatigue was the highest-ranked physiological strain effect in terms of frequency of occurrence. Previous research shows that fatigue is a common complaint from construction professionals (Brown *et al.*, 2010). This can possibly be explained by the demanding characteristics of the construction industry, i.e., long work hours, high workload, tight project deadlines, and competitive tendering systems (Brown *et al.*, 2010). Such a work environment prevents construction professionals from adequate recovery, which is a key factor in fatigue and exhaustion (Sonntag *et al.*, 2010).

The between-gender analysis showed that male professionals experienced fatigue more frequently than did female professionals, while female professionals experienced more proneness to accidents compared to male professionals. Sunindijo and

Kamardeen (2017) reported that male professionals experienced physical stressors (e.g. unpredictable work hours) more often than did female professionals, which may lead male professionals to experience higher levels of fatigue than do female professionals. The reason why female professionals appear to be more prone to accidents at work compared to their male counterparts is more equivocal. The literature is silent on this matter, pointing to the need for future research in this regard.

The results in relation to psychological strain effects frequently experienced by construction professionals (i.e. frustration, anger and irritability, anxiety, tenseness, and feeling dissatisfied) are generally consistent with previous research such as Chan *et al.*, (2012). The between-gender analysis indicated that male professionals experienced frustration more frequently than did female professionals, but female professionals were more likely to experience lack of self-confidence and feeling useless than were male professionals. According to Loosemore and Waters (2004), generally more male professionals hold senior positions than female professionals in the construction industry, and thus male professionals tend to experience higher levels of stress in relation to managerial and relationship factors than do female professionals. This difference potentially explains why male professionals are more likely to experience frustration than are female professionals. On the other hand, female construction professionals often experience considerably more barriers to career progression than do their male counterparts (Dainty *et al.*, 2000). They tend to experience more gender and career advancement-related stressors compared to their male counterparts, such as being treated differently, bullying, lower rates of pay and underpromotion (Sunindijo and Kamardeen, 2017; Loosemore and Waters, 2004). The gender-specific stressors experienced by female construction professionals are likely to lead them to experience diminished self-confidence and self-esteem. The between-professional groups analysis showed that architects reported more frequent experience of the strain effect of anxiety than did the other professional groups. Research indicates that factors relating to the architectural profession could be contributing factors in mental health concerns, such as dysfunctional design teams, poor interpersonal relationships, and perceived career decline (Oyedele, 2013). Attention is also drawn to fact that limited research has investigated factors contributing to the declining mental health of architects.

The highest-ranked sociological strain effects in terms of frequency of experience were strain on personal relationships and strain on professional relationships. This result aligns with previous research finding that poorer quality of interpersonal relationships is a key outcome of workplace stress (Leung *et al.*, 2008). Female professionals reported significantly higher frequency of experiencing strain on professional relationships. This result resonates with research evidence that female construction professionals frequently experience stressors relating to professional relationships, such as poor relationships with superiors, social or physical isolation from others, and working with colleagues from the opposite sex (Sunindijo and Kamardeen, 2017; Loosemore and Waters, 2004). This perhaps reflects the male-dominant nature of the construction industry, which leads females to develop a sense of isolation and difference by working in the industry.

Counter-measures

The highest-ranked physical counter-measure in terms of perceived effectiveness and preference of use, is non-competitive sporting activity and walking. Similarly, Chan *et al.*, (2012) reported that exercising and going for walks were frequently used as coping strategies by expatriate construction professionals to discharge negative

emotions. The between-gender analysis indicated that female construction professionals considered walking and dancing significantly more effective in countering stress than did male professionals. It seems that female professionals have a higher tendency to use low-intensity physical activity to alleviate stress compared to male professionals.

The highest-ranked intellectual counter-measure regarding perceived effectiveness and preference is travel. Iso-Ahola (1983) suggested that travel enables an individual to escape the routine and stressful personal and/or interpersonal environment and gain personal and/or interpersonal intrinsic rewards. This process helps individuals to maintain optimal levels of arousal. Consistent with Iwasaki *et al.*, (2005), this research shows that female professionals have higher preference to engage in arts and cultural activities (i.e. painting and sketching) as a means of coping than do male professionals. Between-professional group analysis revealed that architects reported significantly higher effectiveness for the coping mechanisms of music appreciation, watching TV, and painting and sketching that did other professional groups. One possible explanation is that the creativity involved in these art forms appeals to the embedded creative nature of architects, more than to other construction professionals.

The highest-ranked maladaptive lifestyle counter-measures regarding effectiveness and preference is increased caffeine intake. Low doses of caffeine have been shown to reduce anxiety (Haskell *et al.*, 2005). However, excessive intake can lead to negative effects; symptoms include anxiety, nervousness, restlessness, insomnia, psychomotor agitation, dysphoria, and a rambling flow of thoughts and speech (Gilliland and Andress, 1981). No significant between-gender differences or between-professional group differences were identified in lifestyle counter-measures.

CONCLUSION

This study identified the main physiological, psychological, and sociological workplace strain effects experienced by construction professionals in South Africa as well as the main physical, intellectual, and lifestyle coping mechanisms adopted by construction professionals to mitigate the harmful effects of workplace stress.

The results indicated that physical fatigue, psychological frustration and sociological strain on personal relationships were the most frequently experienced strain effects by construction professionals, reflecting the construction project environment, which is typified by high workload, complexity, adversarial relationships, requiring cooperation between participants, and work-life imbalance. The results highlighted several differences in the experiences of strain effects between male and female construction professionals, which are primarily attributed to the gendered work experiences in the male-dominant construction industry. The between-professional group analysis revealed the higher levels of anxiety experienced by architects compared to other professional groups. More research is warranted to examine the declining mental health of architects.

Non-competitive sporting activities, travel and increased caffeine intake were considered as the most preferred and effective coping measures by professionals. While non-competitive sporting activities provide alternative focus for individuals to deflect thinking about work-related stress, and that travel helps individuals to escape routine, stressful environments to get recharged, the impact of caffeine intake is unclear, as negative effects are associated with excessive caffeine intake. The results showed that female professionals were more likely to adopt low-intensity physical and

arts and cultural activities to counter stress compared to male professionals. The between-professional group differences in counter-measures are minimal although architects were found to have higher preference to art forms of activities.

While there are clear implications for construction professionals to be personally responsible for mitigating the strain effects of their workplace stress; there are also implications for employers and professional and industry associations in the industry. Some reactive measures are already in place, such as stress management seminars and counselling, but a more proactive approach is also needed, whereby industry processes and expectations (such as constant time pressure) are scrutinised with an intent to introduce mitigating change. The construction industry must make "duty of care" an enacted, and not an espoused, value.

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INSTITUTIONAL PRESSURES AND DECOUPLING IN CONSTRUCTION PROJECTS: AN ANALYSIS OF BUILDING INFORMATION MODELLING IMPLEMENTATION

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Most existing research on built environment policy has focused on the independent variable - policy formulation - and assumed that the prescriptions that follow are readily accepted by a multitude of stakeholders. Less focus has been placed on the dependent variable - the projects where those policies are applied. Studies on practical implementation of new policies, such as Building Information Modelling (BIM) mandates, however, have suggested that implementation has not happened as envisaged. In this paper, by drawing on institutional theory, specifically the concept of decoupling, we adopt the perspective of the implementers of built environment policy approaches to explore how projects respond to the environmental pressure of a BIM mandate and the implications of such responses to the wider transformation of the sector. Through an inductive research design and by conducting multiple case studies on BIM Level 2 projects in the United Kingdom, we observed that two variances of a decoupling phenomenon are happening across projects - policy - practice decoupling and means-end decoupling. Our findings revealed that the decoupling phenomenon manifested in the responses employed by projects when implementing the 'new working practices' part of the policy mandate. Those responses included non-implementation of practices, violation of implementation and assimilation of the practices but not their meaning. Underlying reasons for such responses were also identified. By adopting an implementers' perspective on built environment policy design and implementation, we contribute to the construction management literature by providing new insights on the slow transformation of the sector, differing from what is generally envisaged by built environment policies. Our findings call attention to the consideration of implementers' prior knowledge, by institutional designers, when designing policy.

Keywords: BIM, institutional theory, policy implementation

INTRODUCTION

Reform of the architecture, engineering and construction (AEC) industry has been an ongoing concern for governments (Smiley *et al.*, 2014). In recent years, the implementation of Building Information Modelling (BIM), for example, has been widely acknowledged for its potential to improve productivity and to transform

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construction practice (Dainty *et al.*, 2017; Papadonikolaki 2018). In the last decade, several governments have established plans for the mandatory use of BIM as an attempt to drive transformation in the construction industry (Aksenova *et al.*, 2019). The adoption of BIM has been mandated in the US and a range of European countries such as the UK and some of the Nordic countries (Papadonikolaki 2018). In the UK, BIM is central in both the government's construction strategy and its industrial strategy. The construction strategy, published in 2011, defined a number of objectives; in particular, the achievement of BIM Level 2 maturity on all public sector asset procurement with equal applicability to private sector buildings (BSI 2013).

Despite the overemphasis on the potential of BIM policies to transform the AEC industry, scholars have started to acknowledge that there is still a need for more critical perspectives addressing the diverse implications of BIM policy approaches (Dainty *et al.*, 2017; Aksenova *et al.*, 2019). In fact, some recent research has shown that national BIM approaches have not led to a systemic change as envisioned; for example, the case of Finland as investigated by Aksenova *et al.* (2019). In the UK, surveys of industry practitioners have revealed that, despite an increase in BIM awareness and adoption, the implementation of the standards, which is a central aspect of the BIM Level 2 policy approach, has not increased to the same level (NBS 2019).

Indeed, diffusion in and of itself does not equal legitimization of practices (Scott 2014). Institutional scholars have acknowledged that, in actual practice, organisations mediate the impact of coercive pressures such as mandates and construct the meaning of compliance (Suchman and Edelman 1996). Organisations within an industry can be similar in their formal structure (adoption) but show much diversity in actual practice or implementation (Meyer and Rowan 1977). Some previous studies have already acknowledged that the organisational context has an important influence on BIM adoption and implementation (Dainty *et al.*, 2017). Previous research, however, has not extensively explored how organisations and projects mediate the implementation as envisaged. In fact, most existing research has assumed that the BIM discourse and the prescriptions that follow it are readily accepted by a multitude of stakeholders (Smiley *et al.*, 2014).

The gaps between the formulation, implementation and outcomes of built environment policies, however, are not a new phenomenon (Muller 2016). Built environment policymaking can be 'messy', especially because there is a disconnection between those situated in government organisations who make policies and those 'on the ground' who are expected to implement them (Foxell and Cooper 2015). Extant literature on built environment policy, however, focuses mostly on policy design or the independent variable, with less attention to elaborating the dependent variable—the projects and organisations that implement those policies. Most existing research has focused on the ways in which policy problems are framed, as opposed to how policy is used (Simmons 2015). However, organisations and construction projects are not passive receptors of imposed practices, and an understanding of what happens within projects when new practices are adopted as part of those policies is in a nascent state. Thus, by drawing on institutional theory (Meyer and Rowan 1977; Bromley and Powell 2012), in this paper we explore how projects respond to the environmental pressures of a BIM mandate, the differences in how implementation occurs and the reasons for such differences. How organisations respond to environmental pressures has been of interest to institutional scholars for many years but remains an under-theorised phenomenon in construction management literature.

By investigating institutional responses to the BIM policy approach in the UK through the lens of institutional theory, this study aims to contribute to extant literature in different ways. First, extant literature on the changes driven by BIM has mostly adopted a deterministic approach (Dowsett and Harty 2019). The deterministic change agendas that have permeated the industry, however, often fail to account for the structural challenges which await such prescriptions, and there is still a limited number of studies exploring the 'real world' implementation of BIM in organisations and projects (Dainty *et al.*, 2017). The technological merits of BIM are still perceived as being central to industry transformation, and it remains necessary to analyse the diverse implications of BIM policy approaches (Aksenova *et al.*, 2019). Thus, in alignment with recent research challenging the perceptions of BIM enactment as a linear process (Dainty *et al.*, 2017), our findings suggest new insights on the complex conception of a mandate's impact. Moreover, scholars have called attention to the need to understand the relationship between the making of built environment policy and its intended or unintended consequences (Foxell and Cooper 2015). Our findings also provide insights on why the proclaimed benefits of BIM policies have not always been realised as an outcome of a 'symbolic' implementation of the policy approach.

Second, while previous studies on the spread of innovation in construction and changes caused by BIM have used multiple perspectives, including innovation diffusion models, institutional research calls attention to the need for traditional diffusion models to be modified to recognise the agency of individual organisation adopters and the importance of distinguishing between formal adoption and actual implementation (Scott 2014). By looking at real implementation, our findings suggest that the environmental pressures of a BIM mandate influence project practices in a process that is framed by project stakeholders' pre-existing beliefs and practices.

Finally, project management scholars have acknowledged that institutional theory can enrich project management thinking (Bresnen 2016). Thus, by drawing on the concept of decoupling, a central concept of institutional theory (Meyer and Rowan 1977; Bromley and Powell 2012), we provide a new perspective on the transformation of the sector as shaped by implementers' responses.

The remainder of this paper is structured as follows. The next section provides a brief overview of the literature on built environment policy and the conceptual background of organisational responses to institutional pressures, which lays out the foundations for the research design. The research method is then presented, followed by a discussion of the results—a proposed categorisation of responses adopted in projects and identified underlying causes of such responses. The paper ends with a brief discussion of the findings and the main contributions.

Policy Innovation Within the AEC Industry

Built environment policies are usually seen as 'hero stories' and the sector is endowed with the imagined capacity to 'save society' (Janda and Topouzi 2015). Scholars have started to acknowledge, however, that the realistic limits of policy objectives need to be recognised and that the gaps between policymaking and real practice need to be filled (Foxell and Cooper 2015).

There is a consensus that policy needs to be well designed to be effective, and that this design should occur collaboratively to fill the gap between design and implementation (Foxwell and Cooper 2015). Policy co-design involving stakeholder communities and experts has been suggested as an alternative that could address the design-

implementation gap (Foxell and Cooper 2015). Another common suggestion to reduce the existing gaps is for policy design to be evidence-based. Scholars have argued, however, that the production and provision of evidence do not automatically lead to better-informed policymaking (Muller 2016). Evidence is powerful for defining issues to which policy should attend, capturing the attention of decision-makers and testing outcomes, but evidence-based policy is not always truly evidence-based (Simmons 2015).

Recently, studies focused on policy implementation have criticised the traditional and rationalist view of policy design and the design-implementation link. They have suggested that policy design and implementation can be framed as a political process through the lens of institutional theory, where the institutionalisation of a new practice is framed by actors' actions in supporting or counteracting the attempts to transform or replace existing institutions in their institutional environment (Rasmussen *et al.*, 2017). Indeed, institutional theory provides a useful lens with which to explore change processes and has been widely applied in management research to explore how organisations respond to environmental pressures, which has been mostly investigated through the lens of the decoupling concept, as described next.

Organisational Responses to Institutional Pressures

The seminal work of Meyer and Rowan (1977) has inspired a number of scholars to explore the deviations between adopted policies and the actual practices in organisations, which has been conceptualised as policy-practice decoupling (Bromley and Powell 2012). Indeed, the concept of decoupling has been a long-standing topic of discussion in institutional research and a dominant explanation for the post-adoption heterogeneity of practices (Bromley and Powell 2012).

Decoupling has been mostly conceptualised as a rational response to two organisational-level problems—the contradiction between the institutional pressure and internal organisational efficiency and the contradictions amongst multiple institutional pressures (Boxenbaum and Jonsson 2008). Thus, decoupling is usually viewed as a rational response employed by organisations (Boxenbaum and Jonsson 2008). Recent literature on built environment policy has also held this assumption and has posited that the construction industry can be considered a social space and that actors produce strategic activities that affect the implementation of changes in their institutional environment (Rasmussen *et al.*, 2017).

However, recently, scholars have started to challenge the assumption that decoupling between the adoption and implementation of practices is always an intentional and strategic response to external pressures (Gondo and Amis 2013). Most existing research on the adoption and implementation of practices adopts the assumption that if relevant actors accept the need to adopt a particular practice, implementation should occur nonproblematically (Gondo and Amis 2013). However, organisations are not passive receptors of legitimate ideas, and what happens within organisations when new practices are adopted remains a 'black box' in the literature (Gondo and Amis 2013). The literature on project management has also acknowledged that projects have been treated as 'black boxes', with the low level of concern for interior processes and how they interact with wider institutional issues being a major weakness of current theorising in connection with real practice in projects (Soderlund and Sydow 2019). Thus, in this research, we adopt institutional theory and the decoupling concept as a lens to open the 'black box' of projects and explore what happens within those projects in the process of implementing a BIM policy mandate.

METHOD

The exploration of how the BIM Level 2 mandate has been implemented in projects and the identification of the reasons why projects and organisations have responded to the policy mandate in the way that they have are conducive to inductive theory development. The employment of inductive reasoning means that data collection was used to investigate the dependent variable (projects) and identify patterns in the way that the BIM Level 2 policy has been implemented in practice to create a conceptualisation of responses.

The context of analysis in this research is the UK. The UK was selected because it has been considered a highly mature country on BIM adoption. Additionally, by considering the aim of exploring a variety of possible responses employed by projects and identifying possible patterns in such responses, a multiple-case design was chosen as a research strategy because of its capacity for demonstrating replication.

Previous research on BIM adoption has found that when BIM adoption and implementation is driven by internal drivers, implementation is more collaborative and flexible than when implementation occurs simply to comply with external demand (Papadonikolaki 2018). Thus, we selected cases in which implementation occurred for both reasons, aiming to identify whether the responses employed differed. Nine construction projects from four client organisations were analysed longitudinally in this research. We selected institutional construction projects (school and university buildings) because BIM implementation is well disseminated among those types of projects. Also, we selected projects from organisations that had a similar context and could be easily and accurately compared.

Multiple data collection techniques were employed to collect data on enactment of the BIM Level 2 policy mandate, including observations and shadowing of project stakeholders, semi-structured interviews with stakeholders directly involved in the implementation, document analysis and secondary data analysis. The research started with an analysis of five construction projects within the first organisation under analysis (organisation A) and progressed with data collection sequentially in the other organisations—organisation B (one project), organisation C (two projects) and organisation D (one project). The shadowing process helped in the identification of practical enactment and supported the design of semi-structured interviews that were performed afterwards with a range of stakeholders—project managers, information managers and BIM coordinators, from both the clients' and contractors' side. The semi-structured questionnaire included open questions related to aspects of practical implementation in each stage of the project life-cycle and information delivery cycle, according to the PAS 1192 suite of standards (part of the BIM Level 2 policy approach). Additionally, a range of project documents was analysed for all projects, including Employer Information Requirements (EIRs), Asset Information Requirements (AIRs), BIM Execution Plans, etc. Some secondary sources of data were also considered.

The analysis involved two main stages—a within-case analysis and a cross-case analysis. In the within-case analysis, the 'what', 'how' and 'why' of implementation were analysed. The 'what' involved the content of implementation, the 'how' involved the way implementation occurred, and the 'why' involved the causes underlying implementation. Data was triangulated to build on those different elements. The cross-case analysis involved comparing the cases and the 'what', 'how' and 'why' of implementation for identification of patterns. The coding process for the

data analysis involved clustering the data and creating second-order themes, which formed the categories of responses. The second-order themes were then clustered into aggregated dimensions of decoupling (i.e. policy-practice and means-end decoupling). The underlying causes were also aggregated in second-order themes, as presented next.

RESULTS

Projects' Responses to the BIM Policy Mandate

The analysis of how project stakeholders are responding to the mandate revealed that a number of the rules as prescribed by the BIM Level 2 suite of standards have been violated or not implemented, characterising policy-practice decoupling. In other circumstances, although implemented, some of the adopted practices did not necessarily lead to the intended outcomes because of a lack of assimilation of their meaning. In other words, although the 'letter' of the standards has been followed, the goals for which those rules have been defined (or the 'spirit') have not always been achieved. Our data revealed that, when confronted with the institutional pressure of the mandate, project stakeholders adopted four different responses.

Non-implementation

The first possible way that projects responded to the BIM level 2 mandate identified across the cases was through non-implementation. The content of implementation or the 'what' varied in terms of breadth and depth. Non-implementation occurred in two main forms: i) lack of adoption/implementation of a principle, standard or document as prescribed by the principles of BIM level 2 maturity (BSI, 2013); and/or ii) although adopting the principle, standard or document, some of its clauses/prescriptions and respective processes/activities have not been implemented. That included, for instance, the non-definition of an organisational information requirements (OIR), or the adoption of a BIM protocol (document).

While some of the processes have not been implemented as a consequence of being early stages of BIM adoption, other aspects were either intentionally or unintentionally unimplemented. On the other hand, we also identified that having all processes and activities in place as recommended by the standards did not necessarily mean full compliance, as revealed by another type of response, as discussed next.

Violation

For some processes and activities, although the standards were followed, some of the recommended practices were violated or ceremonially implemented. In other words, the clause/process/activity has been violated or its implementation has not complied with the 'letter'. By analysing the 'how' of implementation this pattern of response has been observed across a range of processes and activities over the information delivery cycle. Those included, for example, EIRs and AIRs not having all the specifications necessary, such as guidelines on the handover process between CAPEX and OPEX and procedures for maintaining the asset information model. The data revealed that the ceremonial adoption was an obstacle to the realisation of the envisaged benefits, leading to rework and waste.

Assimilation

The data also revealed that, on some occasions, project members enacted the BIM policy by assimilating the new practices or the new knowledge of the standards into existing ways of doing things, differing many times from what was initially meant by the standards. Project stakeholders' sensemaking, therefore, was identified as a

critical mediating link between shifting logics in the environment as established by the mandate and practice change at the intra- and inter-organisational levels.

Indeed, the implementation of policy involves interpretation (Spillane and Callahan 2000). Individuals might make sense of new information through existing knowledge and beliefs rather than merely replacing previous knowledge with new information (Spillane and Callahan 2000). The data revealed that project stakeholders constructed what Spillane and Callahan (2000) called 'form-focused' understandings of 'messages' of the policy or formal structure. That is, project members understood and implemented the standards in terms of incorporating new practices but did not make the related structural changes in related institutions (the causes of decoupling as discussed next) necessary to completely and successfully implement those practices. In other words, they enacted the standards fitting existing underlying assumptions, which led to a symbolic implementation of the policy.

Processes and activities that were assimilated included, for instance, the definition of information requirements. The information requirements were defined following the existing normative and cultural-cognitive systems in place and existing within the construction industry, i.e., by adopting the traditional division of labour in projects or considering the existing assignment of roles. Thus, although the 'letter' of the standards was achieved, project stakeholders enacted it in a way that the intent of policymakers was missed, representing decoupling between the means and the ends.

Accommodation

Finally, although the lack of reconfiguration of existing institutions led to unintentional decoupling in many processes, in other occasions, project team members also engaged with the standards, implementing the standards as intended. In other words, as pointed out by Coburn (2004), implementers focused on underlying assumptions of the standards. Although full compliance with the 'letter' and the 'spirit' of the standards was not found in any of the analysed projects, this type of response was mostly observed on the organisation's C projects. The accommodation, however, started to occur after the implementation of BIM Level 2 in the first project, which served as a learning experience. The leading cause for the low accommodation of the new practices was a lack of reconfiguration of existing institutions, as discussed next.

The Underlying Causes of Decoupling

The data revealed a range of causes underpinning the observed responses, including aspects related to both the organisational context of project organisations and the industry context. Those causes are briefly outlined next, due to space limitations.

Early stages in the adoption process

At the early stages of adoption of BIM Level 2, the lack of knowledge and experience of the supply chain was a cause of decoupling from the standards' recommendations, or on other occasions, violation of the standards. This is aligned with existing management literature positioning that policy-practice decoupling is more likely if it is early in the adoption process (Bromley and Powell 2012).

Client organisation's existing structure

Another identified reason for non-implementation or violation of the standards was the client's organisation current structure. In the case of organisation B, for example, the fact that the organisation does not operate its estate limited the efforts to adopt BIM during the operational phase.

Weak capacity - lack of resources, skills and knowledge

Previous decoupling studies have identified that despite many organisations adopt formal structures to attain legitimate standing, many of them lack the capacity to put those structures in practice, even if it is not early in the adoption process, which may result in a ceremonial adoption. Decoupling from the formal structure, therefore, takes place not only because of a lack of will but also because of a lack of capacity (Bromley and Powell 2012). Indeed, in the analysed projects, a lack of skills, resources, technical knowledge, and lack of practical, experiential knowledge led to decoupling. The data showed that, for example, a lack of human resources with technical knowledge (e.g. an information manager) and skillset within the client organisation, led the client organisations to appoint an external party to provide support in some activities, such as the identification of information requirements, which resulted in decoupling. Lack of technical resources (e.g. an appropriate computer-aided facility management system), and human resources with necessary skills to manage the data during the operational phase, for example, was also highlighted in the interviews as a reason for non-implementing some processes.

The weak capacity and subsequent behaviour of project stakeholders when enacting the BIM Level 2 standards in practice can also be related to the maintenance of existing institutional elements. As previously mentioned, project members used their existing knowledge to make sense of the policy message, which led them to assimilate new knowledge of the standards into existing ways of doing and reproduce habitual dispositions, routines, procedures, power systems, etc., as discussed next.

Lack of reconfiguration of normative, cultural-cognitive and regulative institutions

The data also revealed that existing normative rules that introduce a prescriptive, evaluative and obligatory dimension were a cause of non-implementation, violation or assimilation of process and practices as prescribed by the standards. Existing structures within the construction sector, operation of projects and at an organisational level include existing normative systems that comprise both norms and values. The data revealed that, for example, a lack of reconfiguration of expectation for existing roles or expectations regarding how specified actors are supposed to behave led to assimilation of the processes and activities and consequently symbolic implementation and decoupling from the intended outcomes. Lack of reconfiguration of existing codes of conduct, as for example regarding how designers work, also led to decoupling in some projects. In other words, authority systems, codes of conduct, roles played by project team members (specified goals and activities for particular individuals, social positions) have not been reconfigured as needed when implementing the new practices. Moreover, the data has shown that existing cultural-cognitive institutions - for example, the roles or templates for particular types of actors and scripts for action - have been followed. Actually, cultural-cognitive systems operating at both the level of organisations' culture, such as the client organisation, with its common frames and patterns of belief, and at the level of organisations' fields have been followed, leading to decoupling between the means and the ends. Finally, regulative elements, including reward and cost structures, governance systems, power systems and procedures were also found as elements that have been reproduced and have led to both types of decoupling. In terms of rewards and cost structures, for example, contractors noted that because of the dominant cost and reward structure of the industry and the way that subcontractors get paid in projects, they tend to perform their work as quick as possible, and they have not used the information models to support decision making during the project, which is actually one of the purposes of

using new technologies and having new information management processes. The lack of reconfiguration of existing structural elements, therefore, even if unintentionally, was identified as a major issue to the successful implementation of the BIM mandate.

CONCLUSION

Previous studies have already identified a range of barriers to the successful implementation of BIM, such as lack of skills and knowledge. By approaching BIM implementation as a policy mandate, our findings demonstrated a range of responses employed by projects to the environmental pressure of the mandate. A range of reasons caused those responses, some already identified in previous literature on technology implementation, such as in the case of a weak capacity to implement it. Also, in alignment with previous decoupling studies, our data revealed that failure on implementation might also be a rational response. For example, as a critical agent in the implementation process, the client organisation may decide not to implement a BIM policy extensively due to poor fit with, for example, its existing structure.

However, while acknowledging those conventional explanations for implementation heterogeneity and decoupling, our data has also shown that if project stakeholders do not understand the spirit of the BIM policy advanced through the standards and implement the necessary institutional change, the implementation will not occur in a way that resonates with policy makers' intent. Decoupling, in this case, was observed as an unintentional response, as project stakeholders failed to transform the existing structure for not realising it. Our findings suggest that although project stakeholders assimilated the BIM policy, they drew on their tactic worldview and assumptions to construct their understanding of the content and implications of the policy, increasing the likelihood of decoupling and heterogeneity in responses, which turn influences the pace of the transformation of the sector.

Thus, we observed that the rules of the policy mandate are socially constructed in action, as project stakeholders enact the meaning of the BIM mandate (the meaning of the standards) in a cycle of interpretation and action. The way that those rules have been enacted in practice calls attention to the role played by the formal structure itself (or the policy) and its content, in shaping the implementation and transformation of the sector, and its interaction within existing institutions as an essential aspect to be considered by institutional designers. The knowledge generated through the investigation of a BIM policy practical implementation can serve as the basis for thinking about policy design in a way that the implementation that follows will perform as envisaged, as policy and reformers rarely take account of implementers' prior knowledge when designing policy.

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THE FOURTH INDUSTRIAL REVOLUTION (INDUSTRY 4.0) AND THE FUTURE OF CONSTRUCTION

ISSUES TO BE ADDRESSED WITH CURRENT BIM ADOPTION PRIOR TO THE IMPLEMENTATION OF BIM LEVEL 3

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Whilst the uptake and requirement for BIM to be implemented on construction projects is growing, there is evidence to suggest that confusion exists throughout the industry with regards to the requirements of the varying levels of maturity. This confusion could potentially bring rise to legal disputes, particularly as the UK Government further emphasises BIM implementation on public sector projects under the ‘Digital Built Britain’ strategy. The aim of this study was to investigate the problem areas which will require attention in order to allow progression to further levels of maturity, with attention to the issues which have arisen through the current BIM Level 2 adoption from the perspective of the BIM practitioners. The research was undertaken in the form of semi-structured interviews with cross-disciplinary BIM stakeholders, where qualitative data was collected to highlight the views garnered from across the UK construction industry. The findings identified a level of dubiety in the interpretation of the BIM maturity levels throughout the industry, with participants highlighting issues with communication of client requirements. The results also identified that a large proportion of the construction industry, particularly the private sector where the costs of BIM implementation are considered as very high, is resorting to traditional systems of work. Notably, all participants in the study felt that the implementation of BIM Level 3 is unlikely to come to fruition in the near future as a result of the issues encountered during the current adoption of BIM Level 2, such as skillset inconsistencies and software coordination. Based on this, we propose a way of presenting the benefits of BIM to Clients in order to avoid resorting to more traditional approaches and call for a development of an adoptable standardised system for Clients to communicate their Employer Information Requirements in order to reduce the concern and potential disputes over sharing of information.

Keywords: Asset management, regulation, corporate strategy, design management

INTRODUCTION

The UK construction industry is a key contributor to economic progress and was expected to grow 70% between 2013 and 2025 (HM Government 2013). Although this growth is uncertain given the Brexit requirements (Malik *et al.*, 2019) and the need for a coordinated method for driving the economy post-Covid-19 pandemic (Tang *et al.*, 2020), there is still a continuous drive for collaborative development in the way in which information is delivered and managed within the industry (Ashworth

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et al., 2019). One of the major methods adopted for further advancements in the construction sector is the implementation of the Building Information Modelling (BIM) process on construction projects. The BIM process aims to define a method for all design members of a construction team to collaborate effectively with shared information to be used throughout the life-cycle of a development from conception to decommission - usually via a multi-dimensional model of different complexity (maturity level; Figure 1, Thompson 2017) which provides both visual and physical properties of every aspect of a built asset. Since 2016, the UK Government specifies the legal obligation for collaborative working on publicly funded projects on the assumption that 'the majority of departments have already met the requirements for BIM Level 2' (HM Government 2016). Furthermore, the UK Government now seeks to implement BIM Level 3 with a vision of providing a skilled, digitally enabled workforce, an advanced digital infrastructure, an improvement on the sharing of technologies throughout various sectors, and an effective education programme for the development of future skills (HM Government 2015).

However, there is evidence to suggest that whilst BIM Level 2 implementation has been adopted throughout the UK, there remains confusion in the industry on the BIM level definitions (Winfield and Rock 2018), due to contrasting interpretations of Level 2 requirements and a lack of clarity in definition of the Level 3 requirements on creation of a set of new 'Open Data' standards and proposal for a new contractual framework which will ensure consistency and encourage open collaborative working (HM Government 2015). There is a lack of consistency between this requirement and the Level 2 requirement for facilitating 3D models which contain both design and parametric information which would be shared using an online digital exchange platform which is known as a Common Data environment.

Martin *et al.* (2019) indicate that whilst BIM Level 2 is widespread amongst industry, it is 'often poorly exploited.' This is further echoed by Siebelink *et al.* (2020) who highlight a lack of motivation to change as well as a need to define processes and standards as barriers to BIM execution. Additionally, the current BIM obligations, rights, and risk allocation appear to be unclear, which could potentially be the result of poor information requests from the Employer (Ashworth *et al.*, 2019) and could lead to litigation and inclusion of BIM implementation-related risks in future development of contractual agreements (Trant Engineering Ltd v. Mott MacDonald Ltd 2017).

With BIM Level 3 adoption expected by the mid 2020's (HM Government 2017), it is of great importance to consider the issues which have hindered BIM Level 2 adoption progress and the changes that will affect both contracts and insurance for parties. The rise of collaborative working has the potential to 'blur traditional responsibilities, making risk allocation more difficult', (Lesny and Reidy 2013) and, as such, it is essential that members of industry are clear on their obligations as well as the risks moving forward.

The aim of this study is to investigate the potential issues that may arise in the implementation of BIM Level 3, based on issues identified through the ongoing BIM Level 2 adoption. To achieve this, in this study we will investigate where difficulties have arisen through analysis of projects working to BIM Level 2 from the 'on the ground' perspective of different parties involved in the process. Adopting this novel perspective, we will also identify how differing contract, procurement, and insurance methods may be affected by the BIM adoption process and highlight areas where development is required to ensure BIM Level 3 adoption in line with the delivery of

Digital Built Britain. Noting the extensive literature on the topic of BIM adoption, we felt that the practitioner's view on the current alignment with the progression to Level 3 is understated and we believe that it is crucial to account for the views of those implementing the process on a day-to-day basis and their perspective on how likely the industry is to meet the Government's ambition in time.

METHODOLOGY

Qualitative research has been selected for the method of data collection and analysis for this study as the most appropriate for capturing thoughts, feelings and personal experience (DeJonckheere and Vaughn 2019) of a multi-disciplinary group of professionals with variable inputs and requirements in a collaborative working environment such as the BIM process. The objectives outlined for this study will have differing effects on each party involved, therefore investigation of each role involved is of importance to find patterns in the views and behaviour, as well as areas of potential discord among the roles. Highlighting the areas of contention will be critical for analysis of topics such as legal issues to reach conclusions on the changeable effects across the design team.

A series of semi-structured interviews were carried out with professionals and management from multi-disciplinary consultancies across Scotland, selected on the basis of their experience with the BIM process at different maturity levels. To ensure robustness and representability, the interviewees represented the major parties involved in the BIM process: Client, Architect, Contractor, Civil and Structural Engineer (C&S), Mechanical and Electrical Engineer (M&E), Quantity Surveyor / Project Manager (QS / PM) and Insurer. One participant from each of the above nominal categories was interviewed, resulting in six interviews in total (numbered and further referred to with numbers 1 to 6, in order to maintain confidentiality and anonymity of the interviewees). All interviews were carried out between normal working hours of 9 - 5pm, Monday to Friday. Candidates were contacted via email initially to garner interest and then issued the questions in advance, which allowed some pre-digestion of the questions and for the candidates to confirm their own suitability with regards to the data collection.

The chosen research method is highly flexible as it allows the participant to adapt and develop upon the topics posed. It is recognised that much of the opinion driven areas of this research topic allow for open-ended responses with regards to the array of answers which may be produced from various members dependent on their outlook on the subject area. It is highly probable that some of the interviewees may be able to provide better insight on particular questions than others, and that some may contradict the opinion of another party due to the varying personal interests on the subject matter. With this, we focussed towards analytic generalisation rather than statistical generalisation as per Kong *et al.* (2020). The authors recognise that deeper analysis would require additional interviewees and multiple members from the same discipline to allow further and more definitive comparing and contrasting of views.

During the interviews, the participants were asked to list any specific issues in confirming their requirements to fulfil BIM Level 2 from job to job within their organisation (Question A) and in communication with the Client (Question B), and thus shed a light on Employer's Information requirements identified as unclear in the literature (Ashworth *et al.*, 2019). In order to identify how differing contract, procurement and insurance methods may be affected by the BIM process the interviewees were asked (Question C) for opinions on alternative procurement

methods for collaborative projects and specific procurement paths proven beneficial in implementing BIM. In order to ascertain how ready the industry feels for the changeover to fully collaborative working, the interviewees were asked for opinions on legal issues such as ownership, contracts, data reliability, licencing, and information requirements (Question D), also identified as poorly researched in the literature (Siebelink *et al.*, 2020).

RESULTS

The background information on the interviewees is shown in Table 1 as it is considered that the positions of the candidate and the experience of their employers may offer explanation for any parallels or variation in the data captured.

Table 1: Background information on interview candidates

	1	2	3	4	5	6
Nominal Category	Client	Contractor	Architect	Engineer	PM/QS	Insurer
Job Title	Construction Director	Senior Design Manager	Architect	Senior Civil Technician	Associate Director	Vice President
No. Staff in Organisation	200+	5000+	20+	75+	4600+	30,000+

The analysis of the data collected for *Question A* returned three distinct themes from the opinions gained across the categories: (i) Standardisation, (ii) Varying interpretations amongst other consultants on standardisation, (iii) Client's communication of requirements; in addition to this there was a relationship identified between Interviewee 5's opinion that Consultants understand BIM as being software-driven and the response of Interviewee 3 who noted a lack of clarity in the definition of maturity levels (Figure 1). All six interviewees commented on the presence of a standardisation with regards to BIM Level 2. The results indicate an equal difference of opinion across industry with Interviewee's 1 and 3 feeling standardisation is lacking, 2 and 4 feeling a certain level of standardisation is present albeit improvement is required, and 5 and 6 feeling that the requirements of BIM Level 2 standardisation are clear and sufficient at present.

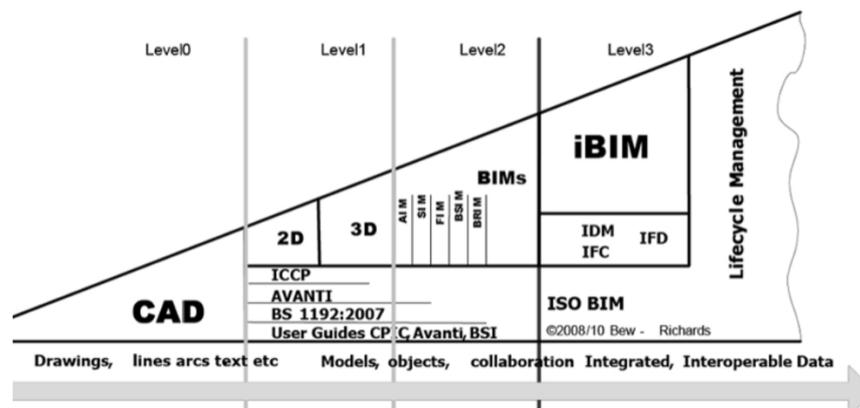


Figure 1: UK BIM Maturity Model (Bew and Richards 2008)

The level of BIM-related training of the design team members was a prevalent theme in each of the responses of the relevant parties. Interviewee 4 stated that there is a lack of clear understanding throughout the industry as a result of 'too many people

taking different views', while Interviewee 5 went further to suggest that Clients usually lack relevant training and understanding - a view shared by 60% of the interviewees. Contrasting this view, the Client (Interviewee 1) suggested that confusion stems from consultants having differing views on compliance with BIM Level 2:

You have this problem, particularly in the construction industry where different teams work on different jobs, a transfer of knowledge doesn't happen.

The multi-disciplinary composition of the design teams is a plausible reason for a lack of standardised views across the industry and could prove as being an issue in confirming the requirements on different projects within organisations. The final theme which was recognised by the interviewees was the lack of clarity (Interviewee 2 and 5) in Client's requirements from the outset of a project - an issue that the Client (Interviewee 1) suggests could be solved by a standard layout or form which will convey the information to varying design teams and projects. This solution may reconcile the opposing understanding of BIM between Interviewee 5 (process-driven) and Interviewee 3 (software-related).

Following the analysis of *Question B*, four distinct themes were identified with regards to improving Client involvement: (i) Assistance required from design team to confirm Client's requirements; (ii) A need for a systematic approach or system for facilitating the presentation of requirements; (iii) Greater clarity from industry on the cost of BIM adoption compared to traditional methods; (iv) A need for more examples or case studies for Clients to understand benefits.

Four out of the 6 professionals interviewed recognised a need for the design team consultants to assist employers in developing and confirming their requirements. All interviewees recognised the difficulties facing the Clients in communicating requirements with a lack of hands-on knowledge in information production. Interviewees 3 and 5 accepted it should be the responsibility of consultants to assist Clients in building the Information Requirements. Interviewee 2 confirmed that their company have already acknowledged this issue and have begun to take measures to assist Clients in creating Information Requirements. The Contractor confirmed that there is a lack of training on the information production side as far as the Client is aware, it is therefore imperative that the consultants make them aware of this:

A lot of Clients believe this is a simple output of the model without understanding the work that goes into producing this next level of information.

With regards to what could be done to assist employers, three of the participants provided ideas: Interviewee 1 suggested that the creation of a 'plan of works' (similar to e.g., RIBA 2020) which could aid delivery of projects implementing BIM could assist Clients understanding of the information they must communicate to various parties at each phase of a project. It was suggested that by creating a flow chart defining set steps of a BIM project for various phases, a greater focus could be set for all involved:

It just needs one person to take ownership of it and to produce it and then for everyone to buy into it.

Interviewee 4 suggested that BIM is made a mandatory requirement on all projects similarly to the CDM Regulations (Health and Safety Executive, 2015). Finally, a 'shopping list' approach was suggested by Interviewee 5 based on their view that:

We are sort of swinging from full COBie to nothing, with nothing in between at present.

With this 'shopping list' approach, designers would create a scope of services indicating different stages with transparently set costs for the additional work. If Clients could see a list of requirements at set stages, they will again be better enabled to confirm their requirements.

The cost of BIM implementation was raised as an issue by two of the interviewees. Interviewee 5 followed on from their 'shopping list' approach idea to confirm that more could be done by designers to help Clients understand what they will charge for different applications of BIM. It was suggested that even with projects which are not implementing BIM, some of the software advantages are still being utilised, therefore a degree of the additional expense of BIM implementation is not justified:

Let's be honest, a lot of companies now do so much in the way of Revit you are getting certain elements anyway.

The need for understanding of costs was resonated by Interviewee 2 who noted that Client's need to express their needs in order for consultants to confirm costs and also to confirm time requirements it may add to a project. If this is not indicated by a Client at an early stage, consultants may be reluctant to produce additional information to meet the Clients requirements retrospectively.

The need for examples and evidence of the benefits of BIM adoption was highlighted by Interviewee 5 and 6 who suggested that Clients are interested in the model elements and visualisation produced, and do not fully appreciate the process side or understand examples of its use. However, as BIM becomes more and more common, Clients will begin to see the benefits for themselves:

Clients glaze over the moment you discuss processes.

Until you are involved in a project which fully utilises BIM, it is difficult to grasp what is involved as it is quite a departure from the previous model.

A full set of data for analysis is not available for the enquiry on preferred procurement routes (*Question C*) as only half of the participants opted to share their views. Most of the respondents did not see a significant benefit in a particular alternative route. Interviewee 6 highlighted the benefits of America's Integrated Project Delivery (IPD) route - a strategy which aimed to harness all design team members, systems and business assemblies (The American Institute of Architects, 2007) - and insisted that they see this becoming a more common approach within the UK especially in that having an umbrella cover for a full design team could lead to leniency in work ethics:

Why would they put so much effort in if they know that another policy that someone else has paid for would protect them without affecting their own insurance?

Interviewee 1 also stated that any procurement method could prove beneficial as the success of a job is based on the communication of those involved rather than the type of contract. This response echoes the collaborative route of the BIM philosophy that problems are overcome by communication and collaborative attitudes rather than separation (Liu *et al.*, 2016). To this effect, the majority of the respondents saw early Contractor engagement as a means of ensuring that the Client requirements are confirmed prior to going into contract (Interviewee 2, contractor), and the design team will focus on their deliverable requirements. Interviewee 1 and 3, Client and Architect, suggested that although communication is of paramount importance for project success, there are limited benefits in Contractor involvement unless it was a particularly specialist project. Each of the participants that shared a negative view on

this topic were influenced by factors relating to cost rather than the technical advantages to the process of early Contractor engagement:

Specifically paying for a pre-contract service is worth it, I see limited benefit. (Interviewee 1)

The time taken running these (Clash Detection) had additional costs which wasn't actually a benefit. (Interviewee 3)

From this, it could be said that the Contractor does assist in promoting the efficiency of confirming requirements and assisting in technical aspects. However, there is a cost implication which Clients may be reluctant to commit to.

From the opinions gained as a response to *Question D*, it was clear that BIM Level 3 can only be implemented after a better grasp on the requirements is achieved and the issues surrounding BIM Level 2 are addressed. The themes of the issues identified by the interviewees were: (i) Skillset inconsistencies- particularly with regards to Subcontractor input; (ii) Limitations on software coordination; (iii) Hardware requirements to allow smooth running of large sized models. The point that perhaps resonated most firmly with regards to the implementation of BIM Level 3 was a hesitancy from the design team parties in sharing information across the project. This issue was highlighted by Interviewee 5 and brings some concern to the future of collaborative working as design teams are seemingly unwilling to part with their own information at present. This may become a serious issue when working within one shared model or database in the future:

If people can't let go of and feel comfortable with issues surrounding what is theirs and how they retain the rights to it, then they are never going to make that leap.

CONCLUSION

The aim of the study was to investigate the BIM Level 2 adoption issues to be solved in order to implement BIM Level 3. In order to facilitate the achieving of this aim, extensive research was carried out among multi-disciplinary BIM delivery professionals in order to gauge their opinions as well as understand and pinpoint where problems have arisen as a result of the execution of the BIM process.

The results of our study highlighted a lack of understanding on the exact requirements of the various BIM Levels as the main issue. This was followed by a difficulty in communication of Client's information requirements. Finally, a lack of both awareness and interest in the process element of BIM was identified.

Acknowledging that without a deep understanding of BIM it is hard for Clients to create and lead a detailed EIR (Dakhil *et al.*, 2019), the findings of this study further support the findings of Mickovski and McKeever (2019) who found that only 38% of their respondents were aware of EIRs in Scotland, where the present study is also located. These findings contradict the view of HM Government (2016) that most departments have met the requirements of Level 2, and appear to highlight that the barriers highlighted are more pertinent to the private sector than the public sector.

Furthermore, our results showed that, whilst specific procurement routes may not be overly beneficial, early contractor engagement is pivotal to project delivery when implementing BIM. This is likely to become more and more common towards BIM Level 3 where the Contractor will oversee and coordinate all works in the integrated model. There is an understanding that the presence of the Contractor at an early stage focuses the design team on their requirements, similarly as in NEC contracts (Mickovski *et al.*, 2013) and IPD is likely to become more common in the transition to

BIM Level 3. The use of this type of contract heavily depends on acceptance of a team working ethic which goes hand in hand with both communication and the cohesive working methods of BIM. Wang *et al.* (2018) claim that Early Contractor Engagement is a preferable method of working and suggest that where Contractors involvement comes later, design teams are less likely to redesign work based on the suggestion of the Contractor which, in theory, would remove them from the collaborative BIM process. The use of IPD for BIM projects was highlighted as beneficial (Forgues and Becerik-Gerber 2013; Wang and Chong 2015) because of the effective cooperation of all parties from design, through completion, and beyond in a projects life-cycle. However, recent case studies (e.g. Nývlt and Novotný 2019) have suggested that further study is required on the benefits of IPD and its performance across various projects with views from those professionals using the system. This was highlighted by Mesa *et al.* (2019) who suggested an empirical study is required once a suitable number of projects have been completed which would inform those producing standards on structuring organisations, contracts, and operational systems. This, however, may mean that it is too early to assume that IPD, under its current definition, will be the most suitable delivery mechanism for future projects.

Finally, our study revealed that there is currently concern over design team's unwillingness to share data in a collaborative manner which is perhaps the greatest barrier to the implementation of the Government's open data vision of BIM Level 3. Additionally, there is a requirement for improved education and skillsets in producing the required information to facilitate a full BIM Level 3 project, specifically with regards to Subcontractor input. Concerningly, nobody spoken to in industry feels that we are in a position to move to Level 3 anytime soon - this may be a hindrance to the eventual roll out of Digital Built Britain. The sharing of data is also regarded as an issue by Harty and Laing (2010) who describe shared data as not sitting well with industry. Contrasting this opinion and the findings of our study, Liu *et al.* (2015) found that out of government staff, industry staff and students that nobody in their study regarded information sharing as the greatest barrier to implementation, but noted an incomplete national standard as being the greatest barrier in their study.

Based on the findings of the study, we feel that in order to smoothen the eventual transition to BIM Level 3 and beyond, there is a requirement for a more systematic approach which would provide greater clarity with regards to maturity levels as well as standards throughout the industry. Concerningly, the results of our study highlighted a particular problem with industries understanding of information which is a major hindrance in the progression to future levels and we would argue that any misunderstanding in the process element of BIM must be addressed. Providing good reference examples (both process- and technology-focussed) and guidance with regards to EIR preparation, as well as a standardised form or template for the Clients to use in communicating their information requirements to different teams and projects (e.g. Ashworth *et al.*, 2019) may be an efficient way of addressing the issue of clarity of maturity levels, EIR, and standards.

It would be beneficial to commence a further study which would look to assist employers with a template system and guidance for the creation of Employer's Information Requirements (EIR's). The study would need to take account of a multitude of needs for both private and public sector clients, as any template of its kind would need to be as flexible as possible to meet the varying needs of Clients, whilst being robust enough for industry to respond and provide sufficient information to meet the Client's needs. In addition to this, a similar study would look to provide a

staged system for all parties involved which clarifies the information releases required, having a standard with regards to this sharing of information may assist where there is currently a reluctance to share data.

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BENEFITS OF BIG DATA APPLICATION EXPERIENCED IN THE CONSTRUCTION INDUSTRY: A CASE OF AN AUSTRALIAN CONSTRUCTION COMPANY

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The fourth industrial revolution (Industry 4.0) has contributed to technology uptake in the global economy. It is suggested to make industries effective and efficient. The technologies in the revolution include internet of things, augmented and virtual reality, cloud computing, smart sensors, artificial intelligence, automation, robotics and big data. These have given rise to high rate of generating massive amount of varied data, which are analysed for process improvement: Simply termed as big data. Current studies on big data in the construction industry have recommended some benefits based on inference from other industries. However, the actual benefits is silent in the discourse amongst construction management practitioners and researchers. Using a phenomenological research method through a single case study, this study answers the question, what are the benefits of big data to the construction industry? The selected case is a tier one construction firm and known to be technology-led company in the Australian construction industry. Construction personnel in different portfolios, years of experience and at various level of hierarchy were interviewed through semi-structured interview to share their experiences on big data as far as their respective practices were concerned. Data were analysed through first level coding and self-reflections by researchers. The preliminary findings reveal the benefits of big data in management of claims, project monitoring and control, and procurement on projects. By implication, the findings provide real experiences of big data in the construction process. This study contributes to the discourse on the promises of big data as an element of the fourth industrial revolution and the future of the construction industry.

Keywords: big data, Australia, Industry 4.0, qualitative

INTRODUCTION

The fourth industry (Industry 4.0) is technology driven, which is aimed at improving and transforming business operations across all sectors of the economy (Department of Industry, 2019). The technologies include internet of things, augmented and virtual reality, cloud computing, smart sensors, artificial intelligence, automation, robotics and big data. These have contributed to the high rate of generating massive amount of varied data, which are analysed for process improvement: Simply termed as big data.

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Adoption of technologies, like big data in the construction industry continue to suffer a major setback (Low *et al.*, 2019), though Cheng *et al.*, (2020) indicated that failing to “ride the wave” of Industry 4.0 will affect the survival of businesses. Current studies on big data in the construction industry have recommended some benefits (Bilal *et al.*, 2016) and big data capabilities (Atuahene *et al.*, 2018) based on inference from other industries. However, the actual benefits of big data are silent in the discourse amongst construction management practitioners and researchers. This empirical study explores the benefits of big data in the construction industry.

LITERATURE REVIEW

Big Data

A perfect definition of big data has become a major challenge due to different interpretations. However, the concept of big data has two main components at the metalevel: The characteristics of data, and the technology (to store and process the data). There is a consensus on the technology component but dissenting views on the characteristics of data that defines big data. The definition of Davenport (2014) is adapted for this study because it provides a holistic description of big data and widely cited as well, thus:

the collection and interpretation of massive data sets made possible by vast computing power that monitors a variety of digital streams - such as sensors, marketplace interactions and social information exchanges - and analyse them using ‘smart’ algorithms.

Component of big data

The two main components can further be decomposed into the three stages of data management life-cycle. The three stages of the data management life-cycle include big data sources, big data storage and processing, and big data analytics.

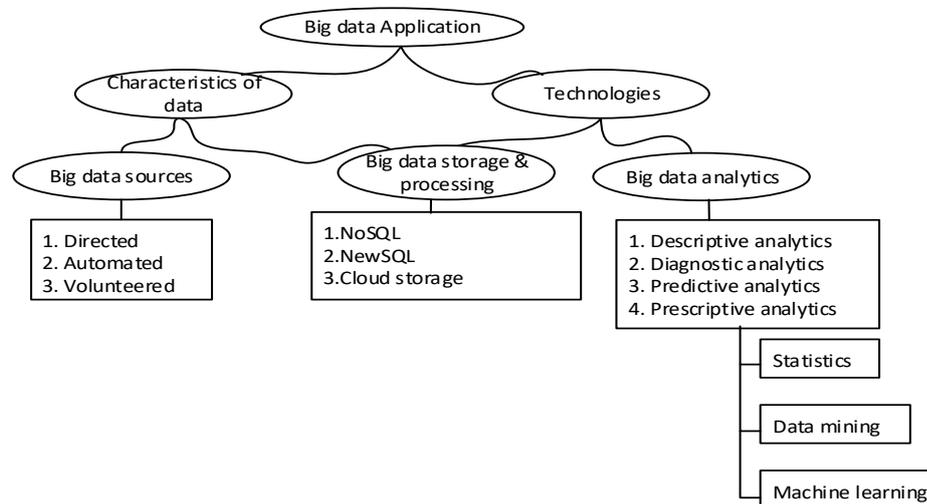


Figure 1: Deconstructed big data concept (Kitchin, 2014; Bilal *et al.*, 2016; Strohbach *et al.*, 2016)

Big data sources: The characteristics of big data relate to the sources of data and storage as shown in Figure 1. Kitchin (2013) classified the sources of big data into directed, automated and volunteered. The directed sources are from “digital forms of surveillance” like the drones and Time Lapse Cameras etc., which are used on construction project (Han and Golparvar-Fard, 2017). The automated data are generated from digital devices, machines, sensors and actuators embedded into objects

like phones, smart wearables, RFIDs. The volunteered data are those available on social media platforms and crowdsourced data, as used in construction studies (Kanjanabootra *et al.*, 2019). Whilst the traditionalists (Russom, 2011; Davenport, 2014; Bilal *et al.*, 2016; Han and Golparvar-Fard, 2017) - a term for some researchers in the context of this study - consider the characteristics of data to be 3Vs, thus large amount (volume) of heterogeneous (variety) datasets, generated at a faster speed (velocity), the progressives (Demchenko *et al.*, 2013; Wamba *et al.*, 2015) - used in the context of this study - accept the traditionalists view of 3Vs but believe the relevance of valuable information (value), and the authenticity and trustworthiness of data (veracity) should be included. The characteristics of data depends on data capturing technologies, the frequency and rate of use, and the security of the data.

Big data storage and processing: This includes data storage either through the cloud server or traditional storage device, and management of data using Hadoop Map/Reduce and Spark. Different formats of captured data require appropriate storage and management technologies. Many forms of state-of-the-art technologies are available for storing and managing data depending on the types (Strohbach *et al.*, 2016): NoSQL (Not only Structured Query Language) is a distributed database designed to handle a wide variety of data and perform well at the same processing time, should there be an increase in workload (scalability), other than the relational database management system (RDBMS). NewSQL is a modern form of RDBMS which combines the benefit of NoSQL's scalability and the traditional RDBMS's strong consistency. Cloud storage has become relevant in modern times due to amount of data created, replicated and used daily.

Big data analytics: The analytics process and analyse the data by providing insight that guide management in making decisions, which depends on the level of analytics. The levels of big data analytics include descriptive, diagnostic, predictive and prescriptive analytics. These levels provide insight from data on what is happening, why it happened, what is likely to happen and what should be done respectively. These analytics are achieved by performing machine learning, Natural Language Processing (NLP), Business Intelligence or Cloud Computing. Construction practitioners are not trained as data scientist to perform those analytics, however, construction practitioners can be trained to developed expertise in the big data concepts (life cycle), which are integral to the performance of their duties, like data capture and application of the data.

Benefits of big data experienced in other industries

Russom (2011) revealed the benefits of implementing big data in organizations through a survey. Though the study did not include construction practitioners, but some benefits identified from those industries would be beneficial to the construction industry. These include accurate business insights, automated decisions for real-time processes, fraud detection, leverage and return on investment for big data, risk quantification, planning and forecasting and identifying root causes of cost. Table 1 summarizes benefits of big data applications identified from other industries as well. The benefits are classified into strategic and operational, which are aligned and inspired by the classification of Raguseo (2018) and Wang *et al.*, (2018). These two main benefits can be seen from the project and organizational level in the context of construction, though there is an over-lapping relationship between them. In the organization level, the operational benefits from the project(s) level accumulate to enable top management to design plans and make informed decisions (strategic

benefits) on achieving its goal and mission. These decisions are intended to make the organization competitive amongst the other industry players. And the competitiveness of a construction organization is a measure of the number of contracts won and the number of completed projects within a time period. Construction organizations like those in other industries are in business to maximize profit and minimize cost. At the project level, the decisions (strategic benefits) made by top management are put into practice. At this level achieving the project objectives of time, cost, quality and safety become the focus. Every bottlenecks are addressed to contribute to the overall efficiency of the project.

Table 1 Benefits of big data experienced in different industries

Benefits	Description	Industry	Authors
Strategic benefits	Competitive advantage on cost and services; provide comprehensive view of service delivery for innovation	Health	Wang <i>et al.</i> , (2018); Lin <i>et al.</i> , (2018)
	Provide better products or services; aligning IT with a business strategy; enabling a quicker response to change; improve customer relations; create a competitive advantage; establish useful links with other organizations	Health/ Retail/ Services	Raguseo (2018)
	Enables decision making based on customer behaviours	Tourism	Miah <i>et al.</i> , (2017)
Operational benefits	Improvement in workflow efficiency; monitor quality; improve costs and outcomes; explore new insights in improving productivity; reduce time of patient travel; immediate access to relevant data to analyse; predictive and diagnostic capability leading to improved decisions	Health	Wang <i>et al.</i> , (2018); Lin <i>et al.</i> , (2018); El-Shafeiy <i>et al.</i> , (2018)
	Predicting fault in shop floor scheduling; reduce operating costs; enhance employee productivity; savings on supply chain management; increase return on financial assets	Manufacturing/ Retail/Services	Raguseo (2018); Ji and Wang (2017)
	Diagnosing potential faults in reciprocating compressors	Petroleum	Qi <i>et al.</i> , (2018)
	Detecting credit card frauds	Banking	Melo-Acosta <i>et al.</i> , (2017)

RESEARCH METHODOLOGY

The main concepts of the study are based on big data and construction process. The big data concept was gathered from big data literature, which is still evolving. Though big data research is positioned in the data-driven science (Kitchin, 2014), especially when large amount of data is being analysed but the current study considers the managerial aspect of big data. Phenomenology is employed in the study of learning within and outside the field of education, like exploring the experiences of people (Bowden, 2000; Mapp, 2008). Using a phenomenological research method, this study explored the benefits of big data experienced in the construction process, which is part of a broader ongoing PhD research.

The empirical research concerns a single case that voluntarily consented to participate in the study and known to be technology-driven in the Australian construction sector. The case has the capacity to be a unit of analysis on its own (Eisenhardt and Graebner, 2007), and in order to avoid biases and understanding of the concept (Papadonikolaki and Wamelink, 2017), data were collected from seven (7) employees at different hierarchical levels in the organization.

Review of articles in the domain area contributed to the formation of the research questions, which were validated, and reliability established on three stages. The first stage went through a review by an expert in Internet of Things to check the content and construct, which went through one iteration. The second stage was a review conducted by two construction management faculty members in our university. The

third stage was done after receiving ethics approval for the study, where four construction professionals - a Construction Project Manager, a Civil Engineer, and two faculty members who worked as Mechanical Engineer and a Quantity Surveyor - were piloted for the study. The piloting exercise help in restructuring the questions to make it easier and simpler for construction professionals to understand without altering the aim of the study.

The questions were about the technologies used, data management and application of the data in their substantive roles as far as a project is concerned. Some of the questions include: What technologies, smart devices, apps and software do you use in your role? Where are the data from these technologies stored? How does the data from the technologies help you in performing your role and responsibilities? The semi-structured interview was administered by the first author through face-to-face, Skype and telephone. The data for this study is based on preliminary analysis of the application of big data in the construction process through the structural coding approach. Structural coding is appropriate for studies with multiple participants, exploratory study and semi-structured interview (Saldaña, 2016), like the case of this study.

RESULTS

Case description

The case is a tier one construction firm, operational in almost every state in Australia and involved in the construction of buildings in every sector of the Australian economy: Residential, defence, health, industrial etc. Table 2 describes the details of the respondents for the study.

Table 2: Description of interviewees for the study

Position	Abbreviation	Hierarchical level	Years of experience
Head of Unit	HU	Senior	12years
Project Administrator	PA	Middle	11years
Contract Administrator	CA1	Middle	15years
Contract Administrator	CA2	Middle	11years
Project Engineer	PE	Middle	10years
Site Engineer	SE1	Junior	4years
Site Engineer	SE2	Junior	2years

The HU is in charge of the operations within the geographical unit. HU ensures that all projects within the unit’s jurisdiction are delivered to the expectation of the client and the firm, as well as ensuring that people, resources and equipment are properly allocated to all projects. The PA, CA1 and CA2 perform contract administration roles for the unit on projects assigned to them. Relationship management, procurement of subcontractors and suppliers, vetting and approval of subcontractors claims form part of the administrators’ roles. The PE is in-charge of design management on projects. The SEs are primarily responsible for all forms of data capture on site and its associated technologies, contractor - subcontractor relationship, as well as safety and quality checks. The captured data by the SEs are managed and processed on the firm’s platform, which becomes the go-to fact check spot for CAs, HU and senior level staff in the firm’s regional, state and national headquarters. The interviews revealed a closely-knit relationship amongst the professionals in solving the puzzle of data management in the construction process.

Case analysis

Three main benefits of applying big data in the roles of these construction professionals are discussed here: Management of claims, project monitoring and control, and procurement.

Management of claims

Management of claims emerged from the interview data. A demand for payment or compensation within a contractual framework is called claim (Project Management Institute, 2017). Contractors and subcontractors receive their payments after claiming for work done. Conflict is an inevitable issue associated with working with different stakeholders especially on construction projects. Whittling-down conflicts in the issuance of subcontractor's claim require material of evidential value, to respond to the claims, the CA1 stated:

I use time lapse camera and drone footage data to assess or respond to subcontractors payment claim in the first step. So if a subcontractor say 90% of the work done and the footage also say 40% has been done, there is no thing argument about it when it is a visuals (CA1)

Concerning its relation to big data, the data are generated from directed and automated streams of big data sources on construction projects. Though the construction professionals are not experts in technical component of big data but are aware of the data management processes in the project setup. Availability of the time lapse camera data on site can reduce the time for physical inspection on site because validation of claims can be done remotely by any member of the contract administration team without necessarily being on site. As admitted by CA1 "I just watch the footage to make sure when I walked around the site what I think I have seen is what I have seen". The reliance on these data might not override the presence of the contract administrator on site as indicated by CA: "I do walk around the site and compare percentages completed and what we can claim...we get to see what's happening, we get a demo file..." But the data could override the presence of the contract administrator on site, when the site engineers are directed to capture some portion of the work done onsite. The drone(s) and the time lapse cameras could then be adjusted to focus on the completed work, which is claimed by the main contractor or subcontractors.

Project monitoring and control

The construction process is benefiting from big data through project monitoring and control. The purpose of having project monitoring and control mechanisms is to achieve efficiency, as admitted by the HU in relations to the benefits of generating data on construction project "...try and identify issues before they become issues. I think the primarily drive is efficiencies and main is efficiency". Buttressing the point of efficiency, the HU acknowledged that "...we capture data around defects and non-conformance... and again is the case of analysing the data and deciding whether or not if there is any deficiencies, so any red flags in terms of what the data is telling us". Defects affect the progress of the project, thus the ability to identify defects at the earlier stages of the project help to reduce the cost of rework at later stages of the project, as well as having a behind-schedule project. The PE admitted that "we go generally around the day to take photos of all reinforcement in the day...and sometimes it comes like we have a few incidence where a bit of the post tension is burst and we go back to the photos and see what was installed in the slab and pick up on if there is a bar missing that is why it got burst". These mechanisms enable the

contractor to have an eagle-eye on the project and rectify every defect within the process, thus, delivering and handing-over a quality project becomes the hallmark of the contractor. SE1/2 use the smart devices assigned to them like the iPads to capture defects and safety incidence and assign them to the responsible subcontractor(s) and the responsible team member from the contractor's side to rectify and/or address them immediately. This was admitted by SE2: "On site we use BIM360 fields and we synch all that onto our server for our BIM360 field and populate data onto our intranet system, where management, CAs and others that can see the data, tell us whatever they need... It just gives them an easy and quick way to any issues or how well or poor we are doing on a project. The contractor also achieves efficiency on the project by comparing the data on subcontractor attendance and the duration worked as against the budgeted labour performance. The sign-in and sign-out data are recorded through the "Whos On Location" app, which is synchronised with the contractor's intranet system by providing statistics on daily attendance and hours worked. These statistics enable staff both on-site and off-site who have access to the intranet system to have a near to real-time updates on the progress of the project. This was accounted by SE1: "...the intranet system is an overview and graph on certain stuff, let's say how many subcontractors were on site as compared to how many were predicted on site at this point in time and things like that". The statistics offer the main contractor the opportunity to query subcontractors absenting themselves from sites. Attendance are recorded to check for absenteeism on-site and a mechanism for ensuring that every individual have evacuated from site should there be an accident on site, as well as juxtaposing the actual cost of labour as against the budgeted cost of labour. Reassignment of resources becomes the strategy, if the earned value analysis suggests the project is underperforming, in-terms of working behind schedule or spending over budget.

Procurement

Procurement is a function of bidding for the right project based on organizational resources and selecting the right subcontractors. Those are the two main application of big data identified in the context of procurement in the study. Data from old projects offer an insight and guidance to CAs and HU in selecting and awarding contracts to subcontractors. In real life, no individual will be happy to forge and work with "messy subcontractors" upon knowing their capabilities and attitude towards work. This was admitted that "... the next time we want to select a subcontractor we have worked with before, it pulls up to say that subcontractor has done 10 - 15 jobs with us before, these are the values and the time they did it so that we are able to figure what the subcontractor can handle" (CA1). No builder is in the position to associate itself with abysmal and poor output of work, because their ability to survive depend on what they have been able to achieve from previous projects. And a tier one company would not risk its reputation by awarding a demanding job to an underperforming subcontractor. Accumulation of data serve as organizational memory in situations where some staff might have left the organization. The availability of such data provides an insight in inviting the capable subcontractors in tendering for a project and selecting the best.

In addition to subcontractor's procurement is the contractor's aim to bid for new projects. An organization that refuses to learn from its previous project performance will fail to grow and not survive in a dynamic and turbulent industry. Stored data on earlier projects do influence bidding for new projects, as admitted by the HU "We pull all our data to understand what job will cost us and going forward and how long it will

take us... a good example is on waste, we will capture data on the amount of waste that we produce on a particular project maybe it is an aged care project, and we can use that data to make an assessment of what the cost is going to be in the next aged care job we gonna do and that's probably the benefit ...". Under-pricing for a project affects the contractor's ability to win or lose a tender due to the selection criteria of tender, making it imperative to rely on the massive amount of available data. Tendering for projects is very competitive and the contracting firm's ability to gain valuable insights from existing data strengthens its competitive advantage edge over others.

In summary, big data contributes to achieving efficiency in the construction process through management of claims, project monitoring and control, and procurement. In the broader sense of the classification in Table 1, management of claims, and project monitoring and control are operational benefits, whilst procurement is strategic benefits. Meanwhile, these big data benefits can be deconstructed further based from the above discussion:

1. Management of claims:
 - a. Reduces conflict amongst project stakeholders.
 - b. Reduces time spent on contract administrators' inspection on site.
2. Project monitoring and control:
 - a. Enables "near to real time" communications and updates between site and head office.
 - b. Contributes to quick response to issues on site.
 - c. Contributes to the identification of defects and its causes.
 - d. Contributes to achieving project objectives: Time, cost, quality and safety
3. Procurement:
 - a. Contributes in the selection and award of contract to responsible and capable subcontractors.
 - b. Contributes to submitting competitive bid for projects.

CONCLUSION

Big data application in the construction industry is inevitable in the current dispensation of the fourth industry. Sophisticated technologies will continue to evolve and the construction industry should strategize and ride on the wave of big data since the industry's rate of technology adoption is slow. This empirical study identified three benefits of big data in the construction process thus, claim management, project monitoring and control, and procurement. By implication, the findings provide real life experiences of big data in the construction process. This study contribute to the discourse on the promises of big data as an element of the fourth industrial revolution and the future of the construction industry.

From the forgoing, there is the need for practitioners to rethink and employ best practices and develop data management competencies as far as the industry is concerned. Aside the benefits identified from the study, it would be highly recommended to conduct further research on the barriers and capabilities of big data application in the construction industry. Such research will provide a comprehensive view and understanding of big data to both construction management practitioners and researchers.

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DATA-LED LEARNING: USING NATURAL LANGUAGE PROCESSING (NLP) AND MACHINE LEARNING TO LEARN FROM CONSTRUCTION SITE SAFETY FAILURES

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Failures happen. Innumerable sources stress the importance of learning from these mistakes. However, within the construction industry, there is heavy reliance on learning from case-studies of catastrophic events and a lack of attention to the more frequent, lower consequence and yet repetitive failures. These smaller failures can have huge cumulative impact, not to mention their effects on the individual(s) involved. The Health and Safety Executive in their 2018 Annual Report estimated that safety injuries on site cost £490M to the UK economy. Part of this historic inattention is due to difficulties in analysis and sense-making of these failures. While information is collected about the failure event, the data tends to be in the form of free text, which is notoriously difficult to analyse. To begin addressing this, we present an attribute-based method which uses Natural Language Processing (NLP) and Machine Learning to structure text data collected after a safety failure on-site, including near misses and incidents. This structured data allows systematic analysis of these data to improve construction site practices and facilitate data driven decision-making that will reduce safety incidents. Using descriptions from 2345 safety reports, provided by a UK based construction company, we manually refine a set of attribute-based event descriptors from the text descriptions of the incidents and train an NLP model to automatically predict these in new descriptions. As well as presenting a working example of this method, factors affecting the prediction accuracy were also explored. This critique found four aspects which need deliberate consideration in application of NLP to construction safety text. These are (1) the number of attributes; (2) data class imbalance; (3) inclusion of near-miss data as well as incident reports; and (4) algorithm selection and optimisation. This method also anonymises the reports, allowing potential industry-wide data sharing and learning.

Keywords: AI, Machine Learning, Natural Language Processing (NLP), safety

INTRODUCTION

To improve its safety performance, the industry must learn from mistakes. At present, this experiential industrial learning is mostly limited to case-studies and alerts (Baker *et al.*, 2018). However, there is a wealth of information contained within accounts of

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more frequent, lower consequence incidents and safety observation reports of near misses or unsafe conditions. Historically, these data have been largely inaccessible for analysis due to issues of physical accessibility and the format of unstructured text data, requiring time consuming manual intervention.

In the last decade, these safety reports have been increasingly captured digitally, removing a barrier to physical accessibility. Meanwhile, the rise of digitally available data worldwide, including natural language and text data, has sparked an emergence of many new analysis methods. Natural Language Processing (NLP), also known as computational linguistics, is now being applied to text data in many industries for tasks such as information retrieval, knowledge discovery and analysis.

Previous research, such as that of Tixier *et al.*, (2016), Zhang *et al.*, (2019a), Zhong *et al.*, (2020), has explored application of NLP to construction safety documents in an American context. However, application in the UK has been limited to retrieval cases and keyword expansion, such as Zou *et al.* (2017). The research laid out here explores how NLP can extract valuable knowledge and facilitate learning from unstructured data. It also explores the challenges to doing so and uncovers some of the barriers and difficulties that need to be overcome. This is part of a larger investigation exploring learning from failure on construction sites that has previously been reported at ARCOM (see Baker *et al.*, 2018, and Velikova *et al.*, 2018).

BACKGROUND

Safety in Construction

Safety research in construction is a rich field. Safety measures, like Accident Frequency Rate (AFR), in developed nations have dropped significantly but are now, by and large, plateaued. Meanwhile, safety research has moved from retrospective (lagging) measures to include more proactive (leading) measures and safety culture. To this end, there has been recent interest in data-led safety initiatives like predictive analytics and risk libraries.

Previous research has shown the advantage of using safety event attributes to predict safety event outcomes, where attributes are descriptors of the situation before any safety event has occurred (Esmaeili *et al.*, 2015). However, methods of extracting these attributes are specific and time consuming. Tixier *et al.* (2016) developed a rule-based AI method to predict 30 precursor attributes. While this achieved extremely high accuracy values, the method was time consuming and may be specific to American English and American construction terminology.

However, in application of an attribute-based method, there are several key points of information which need addressing: what are the 'attributes' we need to identify? How can 30 attributes truly describe the complexities of a construction site area? And, do these methods still work in a UK context?

Natural Language Processing (NLP) in Construction

Natural Language Processing (NLP) is a rapidly developing multi-disciplinary field, using concepts from linguistics and data science including machine learning. As well as applications in audio recognition and machine translation, NLP is used for tasks such as text retrieval, sentiment analysis and semantic analysis.

Converting the unstructured free-text into a structured representation is the first step in most NLP analyses of free-text data. In the last 20 years, empirical 'Bag of Words' (BoW) representations (also known as vector space models) have dominated the

research space due to their notable results when trained on large datasets (Hirschberg and Manning, 2015). These representations are based on the numerical frequency of unique 'tokens' contained within the training vocabulary. 'Tokens' are generally words but also may also include punctuation or numbers. The resultant representation is a very long, sparse vector. An example of vector space transformation for a limited 7 token vocabulary is shown in Table 1.

Table 1: Example of text transformation to BoW vectors

	the	excavator	parked	in	walkway	was	blocked	path	digger
The excavator parked in the walkway	2	1	1	1	1	0	0	0	0
The path was blocked	1	0	0	0	0	1	1	1	0
The digger blocked the walkway	2	0	0	0	1	0	1	0	1
Total	5	1	1	1	2	1	2	1	1

The main limitations of vector space representations are that (a) word order is not preserved, and (b) semantic similarity is ignored as semantically similar words (e.g. 'excavator' and 'digger') occupy orthogonal dimensions in the vector space. Both limitations restrict the semantic meaning which can be gained from analysis of the text; however, these can be mitigated in the pre-processing stage. Specific mitigation methods are discussed in the method section.

Baker *et al.* (2020) found 12 examples of Natural Language Processing applied to construction safety incident reports. Nine of these used the vector space representations and three experimented with word embeddings, a method of representing text using deep learning. To date, no significant advantage to accuracy has been achieved using deep learning methods, despite the increase in complexity. This research employs vector space representations.

Once a structured representation of the text has been achieved, further analysis and machine learning tasks can be performed, such as text retrieval or classification. Classification tasks using machine learning classifiers can be performed for both binary and multi-class classification. Meanwhile, vector similarity can be mathematically evaluated to rate the similarity of a vector against another in the corpora allowing similar documents to be retrieved.

In recent years, a number of academic studies have showcased NLP use in construction for both text retrieval and classification tasks. Chokor *et al.* (2016), Goh and Ubeynarayana (2017), Tixier *et al.* (2016) and Chang *et al.* (2019) all use NLP methods to classify safety documents, while Kim and Chi (2019), Yu and Hsu (2013) and Zou *et al.* (2017) retrieve accident report cases. The most recent relevant example is Zhong *et al.* (2020) who used safety text descriptions to predict the incident causal category, e.g., 'falls', and applied topic mapping to find key labels associated with different categories. Key identifying words and phrases were extracted for each class.

Outside the domain of health and safety, there are fewer examples. However, Soibelman *et al.* (2008) used NLP to classify construction management documents and Marzouk and Enaba (2019) did the same for contractual documents.

METHOD

This research is formed of two parts: development of the attributes through systematic labelling of the safety report dataset, followed by application of NLP and ML to predict attributes in new safety event descriptions. This approach is adapted from

protocols developed and observed at the University of Colorado, Boulder (for example (Tixier *et al.*, 2016b).

In this section, following introduction of the data set, the method for development of the attributes and data labelling is described. Then, the method for development of automatic prediction of the attributes from new text is introduced.

Data

The data used in this analysis consists of 2345 safety reports, near misses and safety observations from 28 infrastructure construction projects in 10 sectors. 879 of these were accident reports. These projects took place between 2011 and 2019.

Safety Event Attributes and Data Labelling Method

Precursor attributes were defined as attributes which are identifiable before an incident occurs and contribute to the incident occurring. These were separated into three categories: objects - materials, tools and machinery; actions - actions being undertaken which contributed to the incident; and worksite descriptors - defining features of the workspace or area of incident.

Precursor attributes were manually labelled by four researchers at the University of Edinburgh, within the School of Engineering, using Microsoft Forms to collate the data. Bearing this in mind, it is vital to recognise the impact of these researchers on the development of the attribute dataset. By using personnel familiar with construction and engineering, rather than linguists, they should have been able to more accurately identify the pertinent information in the text. However, previous experience of construction could also have resulted in unconscious bias where individuals have preconceived notions about what is important on construction sites. Table 2 demonstrates the labelling process from unstructured text to precursor attributes.

Table 2: Examples of safety event descriptions and labelled attributes

IP slipped down temporary steps. The steps were wooden and wet which made them slippery.	Objects: Stairs Actions: Moving around Worksite descriptors: Slippery surface
IP was cutting the old safety barrier with a cut off saw. He went to step over the barrier to make a new cut when the saw, which was still running, slipped causing an abrasion to his left thigh.	Objects: Barrier, Powered Saw, Sharp Edge Actions: Cutting Worksite descriptors: None

Attribute Prediction Method

This sub-section describes the method used to process the text data and the classification algorithms used to predict the attributes.

The data was split into three sets. A validation set of 10% was set aside to test for final accuracy results. Train and test datasets were made using K-fold split with K=5 on the remaining data. This means that the train/test data was split 80:20 and the algorithms trained five times, using a different 20% of the data to test each time. The accuracy scores are then averaged. Model parameters were optimised on this train/test data, before final accuracy testing using the validation set.

First, the raw text is pre-processed then transformed into a TF-IDF (Term Frequency - Inverse Document Frequency) vector space representation. To elaborate:

1. Tokens were created by splitting text on whitespace and punctuation.
2. To decrease vocabulary length and integrate some semantic relationships into the model, the lexical stem of each token was extracted using the Snowball algorithm (Porter, 2001). For example, 'management' and 'managing' would both map to 'manag'.
3. To mitigate against word order loss, bigrams (pairs of words) which occur more than 5 times in the training set were found and included as tokens. For example, 'circular saw'. Less frequent and larger phrases were not included as this would increase the vector length and sparsity to such an extent that it becomes difficult to fit any model.
4. At this stage, stopwords (words which are deemed not to add semantic meaning to text), punctuation and numbers were removed.
5. TF-IDF transformation scales the term frequency (i.e. number of token counts) by log (inverse document frequency) i.e., $\log(\text{number of documents in total} / \text{number of documents containing the word})$. These logarithmically scaled word counts identify defining words for the document (Jones, 2004). This transformation can be considered standard for initial investigations using NLP vector space representations.
 For example, transforming the first entry in Table 1, 'the' would have a count of $2 \times \log(3/3) = 0$ while 'excavator' would have a count of $1 \times \log(3/1) = 0.477$.

These parameters, e.g., vocabulary and TF-IDF transformation coefficients, are calculated on the training dataset then applied to the test and validation set.

For prediction of attributes from the safety event description text, each attribute was considered independently. Binary classification algorithms were trained using the TF-IDF text representation with their associated classification for that attribute. Table 3 gives brief explanations of the algorithms investigated.

Table 3: Machine Learning classification algorithms

Algorithm	Short Description
Naïve Bayes	This purely statistical classification algorithm relies on application of Bayes Theorem to calculate the probability of “ <i>the class</i> ” given the tokens vs the probability of not “ <i>the class</i> ” given the tokens.
kNN (Next Nearest Neighbour)	This classification method uses vector distance to identify the closest example in the training set, then adopts this example's classification. If $k > 1$, an average is used. Here, $k=5$.
Decision Tree	Decision trees split the data using binary 'queries', repeating this until each end point only contains one data class. The 'split' or branches are optimised by maximising the entropy gain.
Gradient Tree Boosting	This ensemble method regularises the base algorithm by training several shallow examples and averaging the results. Regularising algorithms reduces their potential for overfit.
SVM (Support vector machines)	SVM relies on graphical divisions to separate classes of data. In 2-D, this could be represented as a line best dividing the classes.
SVM Bagging	Also known as bootstrap aggregating, bagging is an ensemble method where the base model is trained several times on different bootstrap samples of the training data, and the results averaged. Bootstrap sampling involves sampling without replacement.
Hard Voting - Gradient Boosting & SVM Bagging	Hard voting is a stacking ensemble whereby two or more classification algorithms are trained, and the classification result is 'voted' on. In this case, both algorithms would need to predict an attribute for the attribute to be predicted.

An initial set of algorithm parameters were tuned using the test dataset. The final accuracy of each algorithm for the validation set was recorded. By classifying each as 'attribute present' or 'not present', this binary classification was the prediction of the individual attribute. This process was repeated for each attribute, creating a list of attribute predictions for each text in the test set.

Three values for accuracy were calculated during this analysis: recall, precision and F1 a harmonic average. These values are calculated as follows:

$$Recall = \frac{TP}{TP + FN} \quad Precision = \frac{TP}{TP + FP} \quad F1 = 2 \times \frac{Recall \times Precision}{Recall + Precision}$$

where $TP = True\ positives$, $FP = False\ positives$ and $FN = False\ negatives$

Equation 1: Recall, Precision and F1 calculations

Imbalanced classes, when one class dominates the dataset, can confuse machine learning algorithms (Haixiang *et al.*, 2017). A method employed for dealing with this is data sampling for the training dataset where the imbalance is addressed by artificially changing the ratio of the classes. Examples of methods employed include deliberately oversampling the positive counts or under sampling the negative ones. Oversampling of the positive counts is employed in this investigation.

RESULTS

Attribute Development

In development of the attributes set, 553 precursor attributes were identified in the labelling exercise. Many of these attributes were similar and, therefore, the next iteration combined attributes which had the same, or extremely similar, semantic meaning. Examples include 'animal', 'rat' and 'mouse' attributes, identified during the labelling exercise, all map to a single 'animal' attribute for analysis.

In total, 250 unique precursor attributes were identified. This is a much higher number than the 30 previously identified by Tixier *et al.*, (2016). Additionally, only 58 attributes (listed in Table 4) occurred in 1% or more of the safety descriptions.

This high proportion of infrequent attributes is indicative of the complexity of a construction site environment, which often sees specialist tools, materials and activities. Although most construction personnel could probably name the frequent activities and their main components, terminology differs across the country, increasing the complexity of the labelling task. These factors can also affect the accuracy of text classification, as discussed in the next sub-section.

Despite the complexity, there is still great potential in this method. Figure 1 is included to illustrate possible further analysis unlocked with this attribute method. The figure shows a network of co-occurring attributes. Only those co-occurring more than 30 times are included for graph clarity. Transforming the unstructured text descriptions into structured data in the form of attribute features allows network analysis methods to be performed. Other possible further analyses unlocked by this method include risk analysis, graphical analytics, learning, and finer trend analysis.

Attribute Prediction using NLP and Machine Learning

For attribute prediction, only attributes which were observed in 1% or more of the training dataset were considered beyond an exploratory run of the classification algorithms. This is partly due to the inability of the models used to deal with the

extremely imbalanced data classes, and partly because there is a high chance that they are completely absent from the test data.

Table 4: List of precursor attributes

Attribute Type	Attributes			Number
Actions	Cutting	Driving	Using a tool	9
	Cleaning	Exiting/entering	Lifting (by machinery)	
	Lifting/pulling/manipulating (manual)	Striking/stripping (i.e. formwork/shuttering)	Walking/moving around	
	Alarm	Cabin	Cable	
	Concrete	Crane	Door	
	Electrical source	Formwork	Gate	
	Guardrail	Hand size pieces	Hazardous substance	
	Heavy vehicle	High fence	Light vehicle	
	Lumber/Timber	Machinery	Manlift	
Objects	Mobile Phone	Mud	Object on the floor	36
	Piping	Pressure systems	Rebar	
	Scaffold	Sharp edge	Small machinery	
	Airborne particles	Stairs	Steel Sections	
	Storage tank	Unpowered hand tool	Vegetation	
	Vehicle	Water source	Object at height	
	Adverse weather (storm, rain)	Congested/confined work space	Excavation	
	Exclusion zone	Insufficient edge/fall protection	Slippery surface	
	Poor Housekeeping	Railway	Vehicle Movement Zone	
Site Descriptors	Uneven surface	Unstable support / surface	Wind	13
	Working at height			

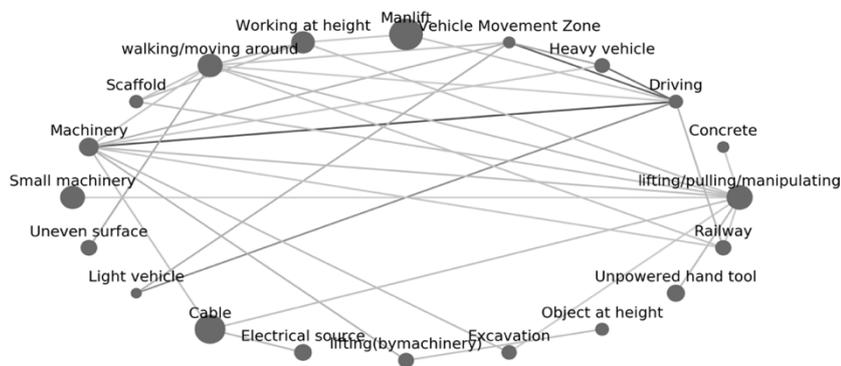


Figure 1: Network Graph of Attribute Co-occurrence (attributes with >30 co-occurrences)

To mitigate against the class imbalance, deliberate oversampling of positive examples in the training set was used for training the algorithms. In each case, the positive examples were duplicated until they accounted for a minimum of 10% of the training data. This resulted in an average increase of 0.11 to the F1 score, however, 20 / 58 attributes were adversely affected by this process. The investigation would have benefitted from a more sophisticated sampling method.

The accuracy results for the 58 attributes which occur in 1% or more of the training data is shown in Table 5, after oversampling. The best values for each are underlined and in bold. For actions and site descriptors, SVM Bagging proved to be the best option, yielding the highest F1 score. For objects, this was marginally beaten by Gradient Boosting.

In both cases, where a base and ensemble algorithm were investigated i.e., Decision Tree and Gradient Boosting and SVM and SVM Bagging, the stacked model equalled or exceeded the F1 score for the root algorithms. Also, while resulting in a lower F1, using a hard-voting algorithm increased the precision of the prediction. This is to be expected; however, it has implications for choosing methods for practice where precise results are more important than recalling all possible attributes.

Table 5: Precision, Recall and F1 scores for attribute prediction

Classification Algorithm	ACT			OBJ			SIT		
	Precision	Recall	F1	Precision	Recall	F1	Precision	Recall	F1
NB	0.29	0.05	0.08	0.40	0.12	0.16	0.35	0.12	0.18
kNN	0.27	0.28	0.25	0.26	0.45	0.30	0.22	0.41	0.26
DT	0.41	0.39	0.38	0.48	0.50	0.48	0.34	0.39	0.35
GBoost	0.52	0.32	0.38	0.59	0.54	0.54	0.50	0.38	0.41
SVM	0.54	0.38	0.43	0.59	0.51	0.52	0.45	0.33	0.37
SVM Bagging	0.57	0.39	0.45	0.61	0.50	0.53	0.51	0.37	0.41
Voting (GBoost & SVM Bagging)	0.60	0.25	0.34	0.68	0.43	0.50	0.58	0.27	0.35

What affects attribute prediction accuracy?

Set against other recent research, these accuracy values may seem comparatively low. For example, Zhong *et al.* (2020) achieved an average F1 = 0.59 using SVM classification on word embedded text representations, achieved via word2vec with skip-gram. Meanwhile, Baker *et al.* (2020) achieved F1 = 0.72 using TF-IDF representation and SVM on a set of 6 incident types. These authors also achieved marginally higher F1 average using deep learning classifiers. There are four identified reasons these prediction tasks, on similar data, may have a higher F1 accuracy.

Firstly, these predictions had significantly fewer categories. For example, Zhong *et al.* (2020) predicted only 11 categories. Also, these were not attributes but incident categories, e.g., 'electrocution', 'falls'. Fewer categories mean that outlier accuracies can more significantly affect the average. In this case, 'electrocution' predicted with F1=0.92 brings the average from 0.46 to 0.59.

Secondly, having fewer categories may indicate a lower-class imbalance. This is also indicated in the category types. 'Incident category' or 'type' tends to be a multiple-choice option on safety incident report forms and is compulsory in most cases. This means that not only are there fewer categories, but every incident must contain at least one of them. Additionally, Baker *et al.* (2020) employed a tailored oversampling factor for each class. Oversampling was shown to have a significant effect on the accuracy results and this application could benefit from further optimisation.

Furthermore, the data used in both previous papers mentioned contained only incident reports, not near-miss or observation data. These reports tend to be more carefully filled out, using more formal English. It can also be postulated that it is easier for both those capturing the data and researchers labelling the datasets to identify precursor attributes in the case of an incident as there is less subjectivity in identifying key situational descriptors before a specific incident than in the case of unsafety.

Finally, the granularity of optimisation in these papers was much finer than used during this investigation. As stated by Bottou *et al.* (2018), "optimization is one of the foundations of machine learning"; this includes not just optimisation during the training process but optimisation of the learning parameters. Optimising algorithm

parameters has a significant effect on the accuracy results. In this investigation, SVM parameters were tuned, increasing the accuracy of prediction on the test set up to 15%.

CONCLUSION

In conclusion, presented here is an attribute-based method to transform unstructured safety incident and observation data into structured data, to be used in further analysis of construction safety. Attributes identified were objects, actions or site descriptors within the text which directly contributed to the incident or unsafety observation.

Manual annotation identified 250 unique attributes, of which 58 occurred in 1% or more of the dataset. Manual annotation is time-consuming and this task, labelling 2345 safety incident/observation descriptions, took over 300 solid man hours (not including breaks or moving from one description to another). Manual annotation is therefore not suitable for deployment. Automatic detection of these attributes is required to make this method viable in industry.

To automatically predict attributes from text, Natural Language Processing (NLP) was used to process the text into vector space representations, otherwise known as 'Bag of Words'. Machine learning classifiers were then trained to predict the attributes from these inputs. Of those investigated, ensemble classifiers performed best, notably SVM Bagging. Factors identified as influencing the accuracy of results are imbalance of classes and how these are dealt with; inclusion of less formal data types e.g., safety observation data alongside incident reports; and granularity of algorithm optimisation. Future research should carefully consider and address these points.

The use of NLP for analysis of free-text safety reports has been shown to be an emergent but potentially reliable science. While this research demonstrated the promise such methods hold, it also indicated the need for application by experts who understand the nuances of the methods and data biases. Additionally, a layman could be easily seduced by claims of high accuracy which could lead to the selection overly simplistic methods. This could have the unintended consequence of poor safety outcomes. There is more work to do before results can be relied upon.

This research is part of a piece of wider doctoral research which will optimise the methods employed and investigate further the potential knowledge discovery of this data for UK construction.

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CRITICAL SUCCESS FACTORS, BARRIERS AND CHALLENGES FOR ADOPTING OFFSITE PREFABRICATION: A SYSTEMATIC LITERATURE REVIEW

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Egypt suffers from huge deficit in low-income housing despite several mitigation attempts. The housing deficit has reached 3.5 million units in 2017 due to several issues including high population increase rate, overcrowding, slum dwellings, poor housing stock and poor performance of construction sector. In order to address these challenges, offsite prefabrication has been proffered as an innovative solution to provide decent housing to the least advantaged households. This paper presents the findings of a systematic review of selected literature on adopting offsite prefabrication in several developing and developed countries. The review concluded that the housing deficit would not be reduced through conventional construction methods; hence, a new construction approach is needed that integrates manufacturing with construction. On the other hand, the critical success factors for successful adoption of offsite prefabrication include governmental support, adopting new building codes, integration of private sector, industrial capabilities and social and cultural factors. It is concluded that offsite prefabrication can leverage low-income houses delivery in addition to improving the performance of the Egyptian construction sector.

Keywords: Egypt, housing, offsite prefabrication, success factors

INTRODUCTION

Providing low-income housing to the least advantaged households has always been a major challenge to housing authorities especially in developing countries. Several factors are associated with this challenge including the rapid increase in population in addition to the deterioration of the current housing stock. Other factors include low quality, insufficient funding, delivery duration, governmental policies and legislations, sustainability, occupiers' satisfaction and social and cultural factors. Egypt as developing country and one of the largest countries in the world in terms of population, ranking 14 in the world population, suffers from significant housing crisis where traditional methods are insufficient to fill the deficit of low-income housing. However, far too little attention has been paid to implement innovative construction methods to increase the housing supply rate rather than conducting research on the challenges and deficits in housing supply.

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On the other hand, improvements to the construction industry have been under continuous research and development. Off-site Prefabrication (OSP) has always been considered as an innovative method of construction by taking the advantages of improved factory conditions to the building sites. Transition to OSP has been the aim of developed countries to improve and speed up the delivery of low-income and social housing projects. The adoption of OSP has passed through different stages of development to successfully implement it in the construction industry. This review intends to highlight the critical success factors, barriers and challenges that will be the foundation of adoption framework for offsite prefabrication in Egyptian low-income housing projects.

RESEARCH METHOD

An extensive review of the literature on two main study areas has been conducted. Egyptian housing supply and demand and Egyptian construction industry as the first study area. The chronological development of adopting offsite prefabrication in housing projects in a selection of developed countries, United Kingdom and United States of America, in addition to developing countries in Middle East and North Africa (MENA) region, Saudi Arabia and Algeria as the second study area. The review of the first study area has been performed in order to identify the critical factors affecting the supply of low-income housing units including the policies, rate of supply and demand and the challenges facing them. The second study area is aimed to provide the lessons learned countries that have a long history of utilizing offsite prefabrication in housing projects. It will provide the factors associated with the adoption process as well as the challenges and barriers to it. The combination of factors from those two study areas will be the foundation of implementation framework for successful adoption of prefabrication in the Egyptian housing projects.

The literature has been reviewed systematically through selecting the relevant peer-reviewed journal articles, conference papers, governmental reports and market research reports. A preliminary internet research has been conducted using keywords "offsite + prefabrication + housing" to identify the relevant articles and reports. Several online libraries and construction management related journals were also searched in order to provide an overview of the research topic. Critical assessment has been performed to the selected resources to narrow down the articles related to the study. The selected resources have been critically analysed and synthesised in order to identify the patterns and key factors relevant to the research in addition to identify the gaps in the body of knowledge.

Housing in Egypt

Egypt has always suffered from shortage of social and low-income housing supply especially in Cairo, the capital. Since 1950s the government is the main supplier of low-income housing in Egypt. It established housing institutions such as Housing Fund and General Organization for Building and Housing Co-operatives as well as establishing construction companies. In addition, the Ministry of Housing was responsible for the planning, design and management of public housing projects. From the late 1990s to mid-2000s, low-income housing projects were concentrated into two main mega projects, "Youth" and "Future" housing projects. "Youth" project started in 1996 and supplied a total of 84433 units through the period until 2004. On the other hand, "Future" project supplied 15636 units from 1998 to 2001 (New Urban Communities Authority, 2020). During the period from 2005-2011 the National Housing project was initiated to provide 500,000 units with annual supply of 85000

units. According to CAPMAS (2019), the annual supply of economic and middle level housing units had been less than 100,000 units, except in 2015, by the public sector.

On the other hand, with average 2% annual increase in population the gap between supply and demand in housing especially for the low-income level keeps increasing (IHS Global, 2020). According to EEDC (2015), Egypt requires more than 550,000 houses annually between new households and the replacement of slum dwellings. The backlog in housing resulted from this gap reached around three million units, as announced by the government, aiming to supply 300,000 units annually for new households as well as around 254,000 units to overcome the backlog from the past. Besides, the current low-income housing conditions have been severely deteriorated due to lack of maintenance and poverty. This generated slum dwellings need to be replaced although most of the population cannot afford buying new houses where the houses price to income ratio has reached 18.4 years (EEDC, 2015). In 2014, the Social Housing Program was announced by the government to build one million low-income houses in collaboration with the World Bank who is lending the government \$500 million. However, only 296,022 has been built by the end of year 2019 with approximate annual supply of 59,000 units (Ministry of Housing, Utilities and Urban Communities, 2017). Furthermore, the majority of the private sector's housing developments are targeted to the high-income and luxury market especially in the new urban communities. Therefore, to fill this gap cheap houses are being built by the informal sector where families build their own houses without legal permit leading to the increase of improper housing which is most of the time considered unsafe (Marzouk and Hosny, 2016).

Construction industry

The dominant construction method in Egypt is the traditional method of concrete and brick. According to Marketline (2017), the construction materials market is concentrated on cement (concrete), steel, aluminium and bricks with few substitutes available. The industry has serious issues in the workforce skills and productivity. Initially, the majority of the workforce comes from the rural areas and villagers to cities where most of the construction work is conducted; therefore, most of them lack proper training. There is only one big construction company in Egypt that has a proper training system while other companies on governmentally educated labour which is poor and insufficient (EL-Gohary and Aziz, 2014). There are concerns about quality in construction projects where the industry is categorized as poor quality. The main quality issues are lack of technological background, lack of training and experience and the industry officials' dereliction in establishing specific rules and classifications of contractors and defining their responsibilities (Abdel-Razek, 1998). Moreover, projects delays have been one of the main concerns in the Egyptian construction. The main causes of delays are shortage of construction materials, cost related issues, shortage of labour and low productivity (Marzouk and El-Rasas, 2014). Moreover, Abdel-razek (1998) argues that quality control measures adopted in Egypt have been inverted from the techniques developed in the West and Far East without any adaptation to the characteristics of the Egyptian industry leading to poor application of quality control measures and failures in ensuring high-quality end products. These issues have serious impact on the quality of buildings that hardly can be improved by the traditional methods. In terms of health and safety, a comparative study between the performance of Egyptian and US companies showed that the Egyptian's suffered from incidents and injuries almost 7 times higher than the US's

(El-Safty *et al.*, 2012). The research discovered serious issues with the industry's health and safety performance such as lack of training and orientation for workers, lack of medical facilities onsite and lack of general awareness of health and safety procedure even for personal protective equipment.

Chronological Development of OSP

Developed countries

United Kingdom

According to Gibb (1999), prefabrication origins goes back to the twelfth century where it was mentioned in several studies concerned about housing construction, it is the era that witnessed the implementation of industrial methods in construction. The interwar period witnessed the major development of prefabricated houses especially the 1920s houses (Powell, 1996). However, it faced public opposition and technical failures which resulted in limited supply (Hughes, 2002). Other manufacturers proposed different structural materials such as pre-cast concrete, cast iron and shredded wood and concrete. The drivers which influenced the development and adoption of prefabrication as stated by Hashemi (2013) are the World War, Modern architecture in addition to massive housing programmes initiated by housing authorities that had been larger than the traditional methods builders' capabilities, whether resources or skilled labour.

After the Second World War, the demand on housing increased facilitated by houses being destroyed or uninhabitable, slum clearance and increase of population. Therefore, the government lead by Winston Churchill declared the production of 500,000 temporary houses as an objective (Hashemi, 2013). However, only 156,623 prefabricated houses were delivered in the post-war period instead of the 500,000 that had been announced consisting of only four types of single storey houses. That was most likely due to the shortage of mechanical plant and factories in the post-World War era resulting in shortage of fulfilling the required capacity. These houses had several technical failures such as thermal and sound performance, condensation and quality issues. In addition, they were economically infeasible when compared to traditional houses despite the governmental support (O'Neill and Organ, 2016).

The period from 1950s to 1980s witnessed significant changes to the methods of construction to be more industrialised. This enthusiasm to industrial buildings and non-traditional methods was driven by the special post-war conditions and huge reconstruction demand especially in housing (Hasehmi, 2013). Consequently, volumetric construction methods were employed in this era that included manufacturing of building in the form of boxes to be assembled onsite prefabricated by light-weight frames from steel, timber or concrete. Due to several failures such as Ronan Point collapse, the government introduced tighter design codes and established governmental bodies such as National Building Agency (NBA) that encouraged the use of system buildings in addition to emphasising on research and development of modern methods of construction (BRE, 2002).

Offsite prefabrication has been remarkably encouraged in the 1990s to the present time by governmental research/reports which resulted in the public starting once again to reconsider alternative modern construction techniques (BRE, 2002). These initiatives include the Latham Report 'Constructing the Team' in 1994, the Egan Report 'Rethinking Construction' in 1998, the Barker Review in 2003. They encouraged the use of offsite prefabrication in constructing high quality houses required in the UK alongside with a policy promoting this type of construction. In

order to bypass the negative public perception of offsite prefabrication approaches, the term MMC 'Modern Methods of Construction' had been introduced to describe non-traditional construction methods instead of prefabricated systems. MMC has been supported by political, economic, environmental factors to improve the image of the industry and increase productivity (O'Neill and Organ, 2016). This governmental support encouraged the private sector to invest in MMC alongside with the tightened building regulations and planning by emphasising on sustainability and environmental performance.

United States

Following the World War II, house builders employed industrialized techniques in traditional housing system such as assembly-line process. The development of prefabricated systems was mainly in the 1940s through inventing wood-stud panels system followed by the development of trailers by an aircraft company to produce the first designed trailer as a house (O'Brien *et al.*, 2000). In 1974, mobile homes were granted official recognition through Department of Housing and Urban Development (HUD) by obtaining congressional approval to implement a construction code. Nevertheless, mobile homes were ceased from production afterwards as a result of shifting towards manufactured homes by amending the construction codes. Modular houses started to emerge in the 1980s and 1990s gaining the consumers' confidence as it developed through the years (O'Brien *et al.*, 2000). OSP currently has developed and became more reliable in the US construction industry driven by the advance in technological innovations to build high quality and sustainable buildings. The private sector is the major employer of manufactured houses by 66% driven being almost 50% cheaper than traditionally built houses (MHI, 2018). However, being cheaper does not mean that they are lesser quality as HUD revised the regulatory codes to ensure its efficiency in terms of design, quality, energy efficiency and environmental performance.

OSP in MENA region

Saudi Arabia

OSP is considered to have very limited adoption in residential projects which almost negligible. The OSP techniques implemented are mainly prefabricated concrete panels for bridges and overpasses used in highway and road projects, wall and façade panels for high rise projects and temporary structures such as site offices. However, these panels are not manufactured in permanent factories, they are casted in site. Thus, those workers involved in this process were untrained on production process and mass production techniques (Aburas, 2011).

Recently, few companies in Saudi Arabia are trying to implement affordable prefabricated housing such as Abdul Latif Jameel by introducing uniquely designed houses constructed from pre-manufactured components (Abdul Latif Jameel, 2018). However, there are no accurate figures about how much these houses are implemented which are more likely to be still in its trial versions. The uptake of OSP is limited due to several barriers. Firstly, the lack of legislations and governmental willingness for innovative methods in construction. Moreover, the reliance on traditional concrete and steel which acts as a barrier for transport and handling of prefabricated components due to its heavy weight. Eventually, the general perception on prefabricated houses is low quality and temporary houses (Aburas, 2011).

Algeria

Starting by the National Development Plan (1974-1977), several national companies were allowed to import industrialised building systems as thought by the government to be an absolute solution to the housing shortage. In order to control and organize the industrialisation process, the government established the Ministry of Urban Planning, Construction and Housing (MUCH) in 1977, which was responsible for setting the organizational framework of housing policies and urban development. The (MUCH) initiated an urban development policy (ZHUN) to provide mass-produced new houses using industrialised systems (Behloul, 1991). ZHUN policy included the implementation of large-scale urban developments created as standardised five-storey flat blocks by employing European architects and building companies. Foreign companies had imported heavy prefabrication systems in order to provide standardised dwellings associated with its public amenities to create urban communities by using mainly French 'Grand Ensemble' designs. However, these developments lacked success to satisfy the housing requirements for the Algerians for several reasons (Hadjri, 1993).

The houses were designed according to European standards and norms that did not meet the Algerians social identity. In addition, building materials utilized were not adequate for the hot climate conditions resulting in poor thermal and waterproofing insulation. As a result, habitants started to make changes and modifications to their houses in order to meet their social and economic needs such as privacy and the need for more space (Hadjri, 1993). Consequently, the ministry decided to stop the importation of heavy prefabricated systems and choose another alternative to provide houses. The ministry decided to develop local building companies that utilizes smaller industrial units of prefabrication techniques such as the panel system, framework construction or hybrid systems (Behloul, 1991). Eventually, the ZHUN developments failed to fulfil its targets as a solution to housing shortage due to lack of appropriate utilization of prefabrication techniques to the local construction industry in addition to economic difficulties.

DISCUSSION

Adopting OSP in the construction industry in developed countries has not started recently, it took decades to have its current influence on the industry where it started in the United Kingdom and the United States in the 1800s. However, OSP implementation can be considered a failure rather than successful in the early stages as it was mainly based on trial and error. It has been implemented driven by industrial and environmental factors as well as the increased demand resulting from increased population, where the Industrial Revolution in the 1800s in the UK and USA had its effect on the construction industry. However, in this early stage the aim was to introduce industrial method to the construction industry without considering other factors affecting home building such as socio-cultural factors, training and skills development.

The post-WWII era could be considered the renaissance era for OSP in developed countries. Different methods and types of prefabricated houses emerged as a faster solution to provide decent housing. It was mainly driven by massive demand for housing after WWII, shortage in trained labour and materials in addition to political aim to enhance industrialization. However, these factors were not enough to succeed despite governmental support. Lack of building regulations and codes in the USA and shortage in manufacturing capabilities in the UK were all factors that hindered

successful implementation of OSP alongside with high initial cost and negative public perception of prefabricated houses in all these countries.

It can be noted that there are critical factors that lead to the current development and the increased share of OSP in the housing market. Governmental continuous insistence on implementing and developing OSP in the housing sector that can be witnessed through establishing governmental bodies such as the National Building Agency (NBA) and Building Research Establishment (BRE) in the UK and Manufactured Housing Institute in the USA that produced research and initiatives to encourage alternative construction techniques (BRE 2002, MHI 2018). Research alongside governmental initiatives have a significant role in adopting OSP emphasising on its technical, environmental and economic feasibility with respect to traditional construction methods.

Research in developing countries is very limited on OSP when compared to developed countries that mainly focus on improving the traditional construction methods. Nevertheless, research/initiatives did not focus on specific challenges such as how to improve the negative public perception of prefabricated houses that act as one of the major challenges to OSP globally. In addition to how to adopt different OSP methods to the culture to be implemented in as well as how to avoid the cultural resistance to change either from the public construction professionals. In the Algerian model in the 1970s, the techniques imported from Europe did not satisfy the socio-cultural requirements of the occupiers due to utilizing it with its original design and standards that does not meet the Middle Eastern conservative culture. It was considered unsuccessful resulting in ceasing importation and returning to the traditional methods.

Another form of governmental support to OSP is developing building codes and legislations that encourage adopting innovative and non-traditional methods of construction. This was backed by the disadvantages of traditional construction methods such as poor quality, shortage of skilled labour, health and safety issues and the impact of increased waste on the environment. Imposing new laws and building regulations is critical to successfully adopt OSP in developing countries. The Ronan Point collapse incident was one of the main reasons that UK introduced tighter design codes to eliminate such incidents. Laws and legislations will also increase confidence in OSP either to the public or construction professional. However, it is not easy to introduce new laws or building codes, so implementing OSP should comply with the existing building regulations to be adopted more smoothly in the current practices. To adopt OSP in a construction industry, the adoption framework should include how building codes to be modified to support its successful adoption.

One of the major challenges of implementing OSP is the high initial cost to establish the manufacturing facility. In addition to factories overhead cost is fixed despite the production which will be unfeasible if the produced quantities are small. In developed countries, governments tried to overcome this economic challenge by involving the private sector in the housing production. In addition to providing local authorities as well as private sector with subsidies to promote OSP to cover the initial cost. In developing countries, governments usually take full responsibility to finance low-income and affordable housing, thus, they look for the most cost-effective building solutions to build more houses. Therefore, there should be a methodological framework to integrate the private sector in emerging and developing countries in order to increase the financial capabilities to accommodate more innovative construction methods in housing projects. In order to successfully implement OSP,

the high initial cost should be absorbed in such a way that does not increase the overall building cost of housing projects.

Having an industrial and manufacturing capabilities can be a critical success factor to adopt OSP in developing countries. In the early stages to mass-produce prefabricated houses developed countries utilized its manufacturing facilities to create affordable solutions to the construction industry. However, there is no significant analysis in the literature of how to utilize the available manufacturing abilities to accommodate OSP techniques in housing projects. Although it is dependent on the techniques to be implemented, to develop a framework for utilizing the available manufacturing capabilities including training the workforce. Precast concrete factories have been in business in Egypt from long ago, thus, it can be the cornerstone of a comprehensive offsite solution to mass-produce low-income housing units by developing this industry with the latest prefabrication technologies.

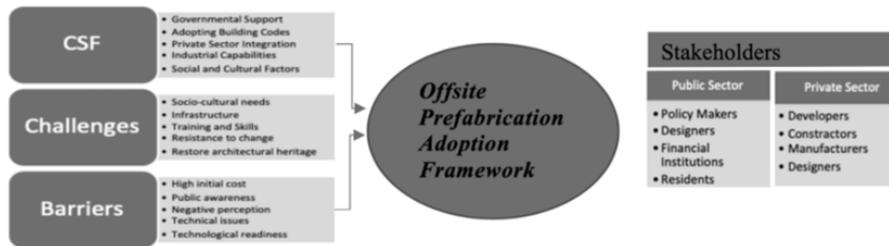
In the literature there were no emphasis on the social and cultural aspects with respect to adopting OSP. Although each country, UK and USA, implemented OSP according to its economic, political and manufacturing aspects, the cultural aspect was not analysed critically. By contrast, in Algeria the cultural and social aspect was one of the major factors that caused implementing prefabrication in housing to fail and cease to exist. The Egyptian cultural and social fabric suffers from complex issues including high unemployment, high poverty, religion conservative, family correlations, etc. In addition to the rich architectural heritage that is almost lost due to lack of maintenance and economic constraints. The framework to adopt OSP in Egyptian housing project must address these factors as it is essential to its success. Despite this, it is not only the occupiers social and cultural aspects that need to be considered, also the construction professionals and workers as well. The cultural norms and manners to be also considered in developing OSP adoption framework in order to integrate in the current construction practices.

One major issue in Egypt's low-income housing projects research that it is concerned about the drawbacks of the current practices rather than finding innovative delivery methods. Research has consistently been analysing the current drawbacks and problems associated with traditional construction methods in terms of quality, sustainability, delays and health and safety. With respect to latest governmental reports and rate of housing delivery, it can be proven that the current practices are insufficient to supply the needed number of units. Prefabrication has been widely researched and proffered as potential solution to increase supply of standardized housing units alongside its noted benefits such as cost reduction and quality improvement. However, in order to adopt OSP an adoption framework must be developed taking into consideration the critical factors affecting its adoption with respect to the country's specific conditions.

In order to successfully adopt OSP in housing projects, it must be integrated with the current practice to overcome potential barriers and challenges. These challenges and barriers alongside success factors identified from the lessons learned from developed countries that have been widely implementing OSP in their projects needs to be articulated with the economic, social, cultural, and technical capabilities and needs of the country to be implemented within. These critical success factors, challenges and barriers to be associated with the adoption framework of OSP are summarised in Figure 1. These factors are developed from the analysis of the literature within the context of Egypt which could be adopted to other developing countries. It includes

the main stakeholders involved in OSP adoption process who have significant roles to successfully implement the framework.

Figure 1: critical success factors, barriers and challenges to adopt OSP



CONCLUSION

The purpose of the current study was to determine the major issues in the Egyptian low-income housing sector in order to develop a framework for adopting OSP in housing projects. To do so, systematic analysis of the literature on housing supply and construction industry has been done to identify the current challenges, barriers and factors affecting low-income housing provision. On the other hand, the chronological development of OSP adoption in several countries has been analysed to determine the critical success factors, hindrances and lessons learned. The analysis was used to identify the critical success factors and challenges that need to be considered in developing OSP adoption framework including the stakeholders to be involved.

The study has shown that in order to develop a successful framework it is essential to have an in-depth analysis of the country's economic, social and cultural factors as well as the manufacturing capabilities not only the construction industry. The study highlighted the major challenges and barriers that can hinder OSP implementation and could lead to failures and prevention. The most obvious finding to emerge from this study is that there is potential to implement OSP application in the housing sector in Egypt. The improved quality, speed of delivery and mass production of housing units are all documented benefits of OSP that the housing sector in Egypt needs. Egypt has the manufacturing capabilities, infrastructure and market size that will act as factors of success. This study is considered as the base of future research on implementing OSP methods in Egypt or other another developing country. Further study and in-depth analysis are required to determine the specific method to be implemented and developed.

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EMBODIED ENERGY CONSIDERATIONS IN A BIM-ENABLED BUILDING DESIGN PROCESS: AN ETHNOGRAPHIC CASE STUDY

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Built environment carbon emission reductions have been focused on operational energy reduction. Successes in this area have increased the significance of embodied energy and carbon (EC); however, this is not addressed by legislation. United Kingdom (UK) construction industry fragmentation creates further challenges that undermine the consideration of EC. It has been hypothesised that Building Information Modelling (BIM) empowers information management and collaboration amongst professionals, thereby potentially facilitating consideration of EC during building design. As both BIM and EC pose new challenges to design teams, this research investigates the role of EC in building design and how this is realised in practice, particularly for a BIM-enabled project. An ethnographic approach which included interviews, meeting attendance and document analysis was adopted for a UK BIM-enabled building project case study. The investigation considered: 1) barriers and enablers for EC target setting and realisation and 2) BIM application and information management. A socio-technical perspective was adopted as a lens to generate conclusions and inform further data analysis. This will inform practice and policy to enable EC consideration in building design for BIM-enabled projects.

Keywords: BIM, socio-technical theory, design process, embodied energy

INTRODUCTION

Carbon from buildings can be distinguished into two main categories: operational and embodied (OC and EC respectively). The former relates to the building's operation and the latter to building construction, which includes the manufacture, transport and installation of building materials (Sassi 2006). Until today, OC has been the main focus of carbon reduction efforts as it has historically accounted for a greater proportion of the overall building life-cycle carbon emissions. However, as more efficient building designs have a reduced OC, their EC has an increased proportion in their overall building life-cycle carbon (Capper *et al.*, 2012; Shrivastava and Chini 2012). Although the importance of EC is growing, there is still lack of a legislative EC reduction requirement in the UK. Industry guidance on Whole life carbon assessment for the built environment has now become available through a professional statement by the Royal Institution of Chartered Surveyors (RICS 2017). However, EC remains a low or non-existent consideration for building design (Orr *et al.*, 2019).

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The various barriers to tackling EC have been discussed more extensively in (Banteli and Stevenson 2017). These include the UK AEC industry's observed diversity and fragmentation and EC assessment complexity. In recent years, Building Information Modelling (BIM) has been introduced to the UK construction industry as a new collaborative way of working. It is defined as both a process and a tool to enhance stakeholder collaboration through improved data management and a single digital model that is accessible to all professionals throughout the building's life cycle (Shrivastava and Chini 2012). Thus, BIM is considered to improve information management across the design team and reduce the complexity of addressing EC (Capper *et al.*, 2012). Current literature relating to both EC and BIM has predominantly focused on the technical aspects of EC assessment facilitation through the use of the BIM model. However, there is a lack of research taking a holistic approach that adopts a socio-technical perspective. This paper investigates EC facilitation through BIM by asking the question: 'How are EC considerations set and realised in a BIM-enabled building design process?' It uses an ethnographic case study of a building project and draws observations during the design stage. The results have been analysed through a socio-technical perspective that considers people, process and tools and gives new insights about the interactions between these three themes.

Theory

Socio-technical system (STS) theory was originally developed at the Tavistock Institute of Human Relations and focuses on the interdependencies between people, technology and environment. As technology has been incorporated to all industries and STS applicability extended to almost any organizational situation, STS has been widely applied to most industrialised nations (Appelbaum 1997).

BIM has been considered as a collaborative environment where people and information work together through defined processes and technology (RICS 2014). Therefore, by definition, BIM is not merely a software application as it involves social and technical characteristics. There is an extensive body of literature that focuses on the technology side of BIM. The studies that take an STS approach mostly focus on BIM implementation and its barriers (Alreshidi *et al.*, 2017). Oesterreich and Teuteberg (2019) use STS to analyse barriers to BIM adoption and indeed to the causes of these barriers. The study demonstrates that although many barriers are task or technology related, the causes of those barriers show a significant shift towards social aspects of the system, mainly people and social arrangements (structure) within the construction industry (Oesterreich and Teuteberg 2019).

New environmental problems that have taken a global focus in the last decades have been characterised as socio-technical due to their complexity and the fact that they entail new technologies and changes in policy as well as user practices and cultural meanings (Verbong and Geels 2010). Tackling EC in building design can be considered as part of these new environmental problems. EC has mostly been addressed in literature as a technical problem, with studies focusing on estimation methodologies databases and tools (Azari and Abbasabadi 2018). However, there are exceptions. Moncaster *et al.* (2019) used a socio-technical perspective to consider contexts that influence design decisions that aim at EC reduction. The study focused on enablers at the policy and project levels for case studies that are innovation examples in reducing EC building impacts. At the policy level, in the lack of national UK regulations, regional authorities played an important role in EC target setting for

the project. At the project level, professional leadership shown by the design team resulted in the use of structural timber instead of a steel frame material. Orr *et al.* (2019)'s study is also an exception to the technical focus of EC related literature and focuses on practitioners' views on material efficiency. The study used a survey addressed to engineering (structural and civil) practitioners to examine the culture and practices in design relating to material efficiency. The results showed that EC is not a high priority in structural design and a lack of consensus across the sector regarding material efficiency.

Other studies that looked at the technological transition for sustainable building construction (Rohracher 2001) and transitions in environmental sustainability, energy systems and policy have also been analysed through the STS approach (Markard *et al.*, 2016; Geels *et al.*, 2017). As both BIM application and EC considerations in building design form new challenges for the construction industry, a transition in current practices is required. However, literature that combines BIM and EC has taken a technical approach and has focused on incorporating carbon data into the BIM model (Capper *et al.*, 2012), BIM and Life Cycle Assessment (LCA) tool interoperability (Soust-Verdaguer *et al.*, 2017), comparisons of EC results from LCA tools and BIM plugins (Bueno and Fabricio 2018), and visualisation of environmental potentials of building designs through BIM (Röck *et al.*, 2018). There is a lack in the literature that considers BIM and EC under a socio-technical perspective.

This research aims to address this gap by adopting a socio-technical approach to analyse the elements that affect EC target setting and realisation in BIM-enabled building design. As both BIM application and EC considerations in design require a transition in current practice, STS is deemed a suitable theoretical lens for studying this transition. "People, Process and Technology" are part of Leavitt's socio-technical Diamond model for creating change in an organization and have been identified as key elements for process improvement (Leavitt *et al.*, 1962). Therefore, this research considers people, process and technology to enable a holistic view of EC considerations in a BIM-enabled building design.

METHOD

Ethnography is useful when exploring unknown or new behaviours and aims to create a deep understanding of behaviour within a specific context (Punch 1998). This research looks at EC considerations in BIM-enabled building design through a socio-technical perspective, which hasn't been addressed so far. Therefore, an ethnographic approach was adopted to explore the nuances and create a deep understanding of the observed phenomenon. The case study was selected through purposive sampling to ensure that the building project enables an investigation of the research focus (Miles 1984). It is a BIM Level 2 project with a BREEAM 2014 Excellent target. Although EC is not a separate target, it forms a part of the overall BREEAM target. The researcher engaged with the project for 14 months, from the end of the project's brief stage/ beginning of concept design stage until the end of the design stage/ start of the construction stage. The fieldwork included attendance of key meetings, document analysis and interviews with relevant project stakeholders. Overall, the researcher attended 12 meetings resulting in 40 hours of meeting observation which covered the project design team, progress meetings and meetings that related to sustainability and BIM. During the meetings, the researcher made notes of what was being discussed. For a further 4 meetings when attendance was not feasible, meeting minutes were analysed. Project document analysis included the feasibility report, end of design

stages reports (2 documents which included project brief), BREEAM end of design stages reports (3 documents), the BIM execution plan, the Master Information Delivery Plan, the Model Production Delivery Plan, the Architectural Outline Specification, the Design and Access Statement and National Building Specification material specifications (55 documents). Acquiring information from key stakeholders didn't always take the form of a formal interview, but rather as informal discussions during the meeting breaks or emails. These discussions involved the client, architects and sustainability consultant and took place at least once per design stage. The research data collected have been anonymised.

RESULTS

Analysis of the data included organising them into three main topic areas, 'EC considerations and target setting', 'EC target realisation' and 'BIM application and information management'. During the analysis, three main themes emerged: People, Process and Tools. This relates to the key elements "People, Process and Technology". In this research, Technology has been replaced with Tools to encompass other technical tools such as secondary data lists and benchmarks. Informed by the data analysis, the broad themes of People, Process and Tools were broken down into sub-areas as follows (also shown in Figure 1):

- People (Pe): This area refers to the client and the professionals that comprise the design team. This area is further divided into sub-areas of (i) collaboration (C) between the teams and the client, (ii) skills, knowledge and expertise (S), and (iii) values/ professional ethics (V).
- Process (Pr): This area refers to the available standards, protocols, rating schemes, guidance documents, as well as building contracts, project management and scheduling. This area is further divided into sub-areas of (i) high-level (H) and (ii) project level (P).
- Tools (T): This area refers to (i) software (S), and (ii) information sets such as benchmarks, datasets (I).

People

Values

The client is responsible for team appointments which highly influences sustainability considerations for a project. Team appointments for the project informally considered sustainability input that the professionals could bring to the project. According to the Sustainability Consultant (SC): 'So there won't be anything in the brief that says 'you need to have sustainability criteria' but they have been appointed because they have that. The whole project team is working towards the same aim.' (SC, Concept Design Stage). Although this project's team appointments considered sustainability expertise and included an SC from an early stage, EC was not a high consideration for the project and building's whole life carbon impacts were not considered at all due to SC's lack in Life Cycle Analysis (LCA) expertise.

Although the appointment of an LCA consultant was requested by the SC at the end of Concept Design Stage, this was not provided. A "BIM and Information lead" appointment requested by the design team at Concept Design was also not provided. The BREEAM target was the main sustainability driver, with a "lowest capital cost" approach taken to achieve the target. The SC's role was to achieve the BREEAM target 'comfortably': 'We've got the realistic opportunity to go up to 80%, but we need 70% so my overarching role is to get us comfortably to 70%. Also mindful that

there are options that cost a lot and others that don't, and that's what I bring to the table, so I will comfortably get us a rating of 70%, it's how we collectively play with these figures' (SC, Concept Design Stage). The architects held consultation sessions with the client and users and to ensure that the design would respond to their requirements. However, this opportunity was not taken to discuss sustainability priorities beyond compliance with the BREEAM target.

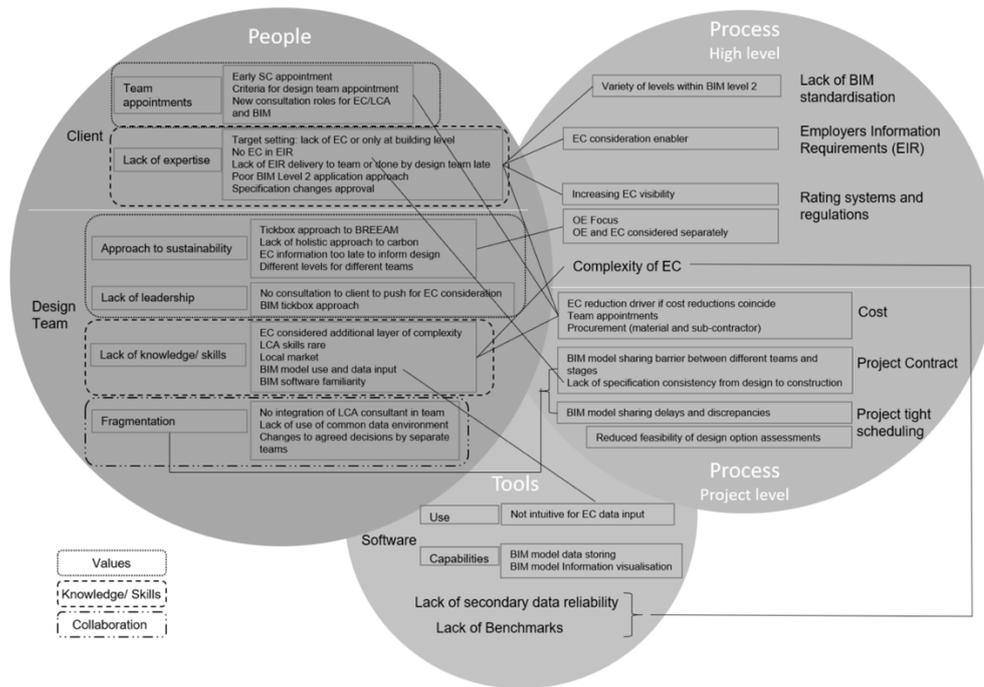


Figure 1: People, Process and Tools: Themes and interactions

Skills, Knowledge and Expertise

The client is responsible for setting targets for EC and BIM approach; however, may not have sufficient knowledge, understanding or expertise to do this. In this project, this resulted in a lack of Employer's Information Requirements (EIR) and EC targets, as well as a poor BIM approach. The project design team demonstrated a variation to sustainability approaches from the different professions. The structural engineer team considered EC impacts from an early design stage; however, prioritised cost and local supply chain familiarity over reduced EC. The architects only mentioned EC impacts for specific building elements at the final design stage and did not let it inform the design. This may be because of the lack of knowledge and skills related to EC, which resulted in EC being considered as an additional layer of complexity and cost to the project delivery. EC was not included as a requirement for material specification by the design team at the end of the design stage (Architectural Outline Specification document). Therefore, the client will be responsible for approving any material changes proposed by the contractor during construction. This returns the responsibility of the final material selection to the client, who is not expected to have any specific sustainability knowledge. Similar issues were experienced in relation to the BIM model which was only used for spatial coordination. One aspect where BIM has been expected to facilitate EC consideration in projects is through providing reliable material quantities. However, the Quantity Surveyor team lacked familiarity with BIM software; therefore, the SC did not consider the material quantities in the BIM model accurate enough to be used in EC assessment of building elements for this project.

Collaboration

Fragmentation was observed in the design team and the common data environment for the project was not used, possibly due to late introduction. In particular, agreed decisions were later changed by separate teams.

Process

Higher Level

The poor BIM approach adopted in the case study can be related to the lack of standardisation which allows for flexibility in the way that Level 2 BIM is realised in building projects. Although EIRs have been identified as a potential enabler for EC inclusion in targets and project design, EIR creation falls within the responsibility of the client. EIR creation depends on the client's expertise to firstly deliver these requirements and secondly to include EC considerations and targets within the EIR. The heavy focus of regulations and building rating systems on Operational Energy (OE), and the separate consideration of OE and EC is a barrier to a holistic approach to carbon reduction by the design team. Although the case study had a proactive and consistent approach to BREEAM target achievement, EC considerations were low during the target setting and were considered too late to inform design. LCA was mentioned as an intention but was not actioned. This shows that even when following a consistent approach to BREEAM, it is not sufficient for EC to be thoroughly included and realised for the project.

Project level

The main themes that stood out in the case study were project cost, contract and scheduling. The project cost was identified to be an important factor that affected EC reduction efforts, team appointments and project procurement. In relation to EC reduction, cost was found to be an enabler if cost reductions were coinciding with carbon reductions. However, for the team appointments and procurement, when further costs would be incurred due to new role appointments (for LCA and BIM) or material and sub-contractor selection, cost was a barrier for EC reduction. With regards to selecting structural timber as a material, it was mentioned: '[structural timber is] not yet commonplace in the UK and requiring new site skills, anticipated costs are higher than the more traditional concrete and steel options. Providing a timber option was therefore discounted at early Stage 2 design development' (Concept Design end of report). The project contract caused a barrier to BIM model sharing between different design teams at different design stages due to legal implications of novation. In regard to specification, the lack of consistency between what is specified by the design team and what is actually built by the contractor was also a barrier that was related to the project contract. Tight project scheduling resulted in delays of sharing the BIM model and caused discrepancies between the different professional teams. It also resulted in reduced feasibility of undertaking cost assessments for alternative design options. Project contract and scheduling further contributed to the fragmentation observed amongst the different professions of the design team.

Tools

Although BIM software tool capabilities of data storing and information visualisation were identified and considered as an enabler for EC considerations, the complexity of their use and the lack of an intuitive way to add the required information and to produce meaningful results was considered a barrier by the design team: "I don't trust the BIM model, I like to manually understand what my volumes, my areas my weights I can trust the section drawing, what I don't trust is the BIM model to automatically

populate all these items, I know some aspects are volumes and not the materials in it' (SC interview, Concept Design Stage). This can be linked to the theme of skills as the design team lacked the skills related to BIM model use and data input. The SC highlighted lack of reliable secondary data and benchmarks for EC as a barrier for EC considerations during the design process: 'we cannot specific targeting, because we don't have a benchmark to compare against' (SC interview, Concept Design Stage). This can also be related to the complexity of EC calculation and assessment process.

DISCUSSION

The client is very important in both EC considerations and BIM application as project target setting, BIM EIRs and project team appointments are dependent on them. The importance of clients was also acknowledged by Orr *et al.* (2019) in their investigation on efficient material use for the EC reduction in buildings. They highlight the need to align incentives of clients, design team and policy makers to achieve reduced EC in building structures. The need to incentivise and educate clients was acknowledged by Schweber and Haroglu (2014). They urged policy makers to adopt a capacity building approach for enabling sustainable building construction. The study showed that clients might lack sustainability expertise and tend to prioritise decisions on the basis of reducing the capital cost of the project. This could result in the lack of setting EC target, EIRs and required BIM and LCA consultant appointments. This creates discrepancy between what is expected by standards and guidance documents, and what actually happens in a real context. This discrepancy is also evident for the Quantity Surveyors who are expected to be the profession most involved in tackling EC due to their familiarity with project material quantities (RICS 2012). However, in the case study, they were found to be the least involved in EC considerations and lacking BIM software familiarity for the inclusion of material quantities in the model.

Considering the lack of client expertise, design team appointments are important for enabling the inclusion of sustainability in building design. In particular, early appointment of a SC has been considered critical for the inclusion of EC in design considerations (Banteli *et al.*, 2018). However, the design team in the case study has shown lack of leadership in providing consultation to the client to push for a more thorough approach to EC reduction and a stronger BIM implementation. Their EC and BIM actions were characterised by a lowest capital cost approach to BREEAM target realisation and BIM information management. This was also encountered in Schweber and Haroglu's (2014) study of BREEAM assessment during the design process, where interviewees characterised the BREEAM assessment process as a 'box-ticking' exercise. This demonstrates that high level (or top-down) processes alone are not enough to enable the change required, and design team professionals need to adopt a 'middle-agent' approach to influence EC inclusion in design considerations and a stronger BIM application. This approach was also suggested by Janda and Parag (2013) where building professionals were considered as middle agents of change to implementing low carbon innovations and practices. The contribution of individual team members in driving innovation was also demonstrated in the study by Moncaster *et al.* (2019) where the design team pushed for innovative use of materials for EC impact reduction. Innovation that emerges in niches through dedicated actors has been highlighted in the socio-technical transitions literature (Verbong and Geels 2010). However, variations to sustainability approaches from the different professions of the design team, as observed during the fieldwork, hindered a unified approach to the reduction of the case study's carbon impacts. Lack of

consensus in relation to material efficiency for EC reduction has also been identified amongst engineering practitioners (Orr *et al.*, 2019).

At Project level of the Process theme, cost and scheduling need to be reconsidered as they have been found to have several implications on EC considerations. Project costs need to be revised to enable new roles and required expertise (BIM manager, LCA consultant) to be appointed. This could enhance information management of projects and collaboration amongst the design team (as BIM was intended to do) and undertaking a whole building life cycle carbon approach. Project schedule needs to be revised to enable alternative design options to be assessed in relation to both carbon and cost, during all design stages. The above issues link back to the skills and values of client and project manager, who need to include these considerations when budget and project timetabling is devised.

Lack of benchmarks and reliable secondary EC databases have been found to cause complexity in the overall EC calculation process. The BIM model has the potential to address this complexity and facilitate the whole building EC calculation, as it can aggregate EC impacts from element level to whole-building level (Capper *et al.*, 2012). However, unmanaged and fragmented model data input can make the BIM model unreliable. The professionals' unfamiliarity with the software hinders its use and contract implications hinder BIM model sharing between teams.

As seen from the above discussion, 'People' appears to be the predominant theme affecting EC target setting and realisation as well as BIM application. Process and Tool elements can become barriers or enablers depending on how people enact and use them. This was also conveyed by Alreshidi *et al.*, (2017), where the focus on 'actors' was considered crucial for successful BIM governance. Oesterreich and Teuteberg (2019) also found that for BIM adoption barriers concerning tasks and technology, the cause of those barriers was traced back to social dimensions that related to people and organisational structure.

CONCLUSION

Following the socio-technical approach, this study has given new insights into how EC considerations are set and realised in a BIM-enabled process. It has offered a holistic view which considered the role of people, process and tools in EC target setting and realisation, BIM application and information management. The study identified links between the themes of 'People', 'Processes' and 'Tools' and highlighted the importance of 'People' for the effective use of tools and processes that can facilitate EC considerations in building design through BIM application. It has also highlighted the need for design teams to act as 'middle agents' and 'actors of influence' for educating the client in relation to EC target setting and BIM application. Further, the design team might need to provide consultation in relation to project budget and timetabling to enable new roles for the required expertise to be appointed and alternative design options to be assessed in relation to cost and carbon. Using a real-life context, the study also revealed discrepancies between expected practices by guidelines and standards relating to EC and BIM, and what is observed in practice. This calls for future EC reduction policy and BIM standards to adopt a more pragmatic approach by establishing a better understanding of current industry practices and capabilities. The study therefore contributes to both practice and policy by providing insights into how EC considerations are set and realised in a BIM-enabled building design process. Finally, the study also contributes to the STS theory by using key elements from Leavitt's socio-technical Diamond model as themes and

introducing sub-areas for the 'People' and 'Process' themes to analyse the research findings. Future research will include three further case studies, enabling cross-case comparison of the factors affecting EC considerations in BIM-enabled projects. Similarities and differences between case studies will be identified and will enable further understanding of what affects EC considerations during target setting and realising those targets in BIM-enabled projects.

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CONSTRUCTION INDUSTRY 4.0: ENTANGLING COLLIDING PRACTICES

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Industry 4.0 (i.40) transforms traditional manufacturing and industrial practises with new smarter technologies. Within construction it has a very challenging adoption curve. The aim of this paper is to understand why i4.0-technologies have problems being exploited in construction practices. The interaction of new technologies within the workspace and how it is organised is known as sociomateriality. Using the concept of performativity, we will examine the enactment of new technologies both in the supply chain and implementation on site. The data collection method includes 10 action-oriented interviews with i4.0-technology-vendors, specialised in technology for the construction industry. The research results show that there are colliding practices. One practice at the construction site and another practice is the designers of the automation solutions. However, the existing knowledge and experience from i4.0 is also an opening for experimentation with new approaches based on the interaction between the different practices and technology.

Keywords: Industry 4.0, automation, practice, design, sociomateriality

INTRODUCTION

In the construction industry, different indicators suggest that conventional construction methods have reached their technical performance limits. Worldwide, automation and robotic technology are considered a key element of the future of the construction industry (Pan *et al.*, 2018) and its ability to improve productivity, safety, and product quality (Chu *et al.*, 2013). Despite a focus on new technologies, the sector has so far not experienced large-scale real-world implementation (Pan *et al.*, 2018). The construction practise's difficulty to change is referred to as an inertia in construction (Buhl, Andersen and Kerosuo 2017). So, the construction industry is under pressure. Historically, there has been a focus on process improvements, e.g., Lean principles and methods have had a long-standing role as an embraced concept for developing construction processes. The critical studies reveal a piecemeal adoption of Lean and long-term adaption to practice and lack of needed reorganisation. That leads to an overrating of the impact on productivity. These kinds of commentaries are opening up assumptions previously taken for granted (for example, on the normativity of the research and technology determinism) or providing

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alternative ways of interpreting the field by expanding the methods and research approaches used for making research on construction practice (Koch, Paavola and Buhl 2019).

Worldwide, automation and robotic technology are considered a key element of the future of the construction industry to improve productivity, safety, and product quality. Construction practices are influenced by information technology (IT) and automation technologies, the latest trend is the German high-tech strategy i4.0. The i4.0 strategy originates from general manufacturing industries (Bock 2015), addressing an industrial revolution within large manufacturing companies and related industries, increasing the use of information and automation technologies (Oesterreich and Teuteberg 2016). The promises and premises of i4.0 should be understood in this context. It is a very different practice compared to current construction projects or even an industrialised construction process. Adding and connecting the i4.0 technologies (robotics, additive manufacturing, sensing, cloud computing, machine learning, big data analytics, Internet of Things (IoT), augmented and virtual reality, and so forth) seems not to have revolutionised the built environment yet.

Our research aims at creating understanding of design and implementation processes informed by practice theories that can improve automation in construction. The sociomateriality concept "performativity" nails our ambition fine. Performativity is not the same as performance. Where "performance" refers to the action of an activity (such as when a physician "performs" a medical examination or the musician "plays" in front of an audience), performativity refers to "enactment". For sociomaterial researchers, it draws attention to how relationships and boundaries between humans and technology are not predefined or fixed, but "enacted" in practice. It is often referred to as the "practice turn", which is based on an understanding of: "how boundaries and relations are enacted in recurrent activities.... In this view, an organisation is held to be a recurrently enacted and patterned set of relations, reproduced over time and space" (Orlikowski and Scott 2008: 462).

The purpose of this paper is to investigate how i4.0 vendors view the practice they are trying to automate. Phrased as three research questions: - How do sociomateriality approaches give us new perspectives and understandings of i4.0 design and implementation? - How do i4.0 vendors develop their solutions to the construction practice? - How do i4.0 vendors understand technology development (design processes) in construction?

METHODS

Exploring technology in a broader context can be seen as a need to experiment with technology in order to get experience with technology in use. During the past decade, we have made several research projects about automation in construction. The overall theme for our research is technology implementation (literacy) and understanding of construction practice. The research is embedded in an environment focusing on innovation and experimentation as part of an applied science research strategy. To develop our socio-technical approach we have studied practice theories, starting with Cultural-Historical Activity Theory (Engeström 2008; Buhl, Andersen and Kerosuo 2017), ANT/boundary objects (Fox 2011; Buhl, Andersen and Klitgaard 2019) and now sociomateriality (read next section). Our interaction study of practice is action research, we would like to produce/create knowledge together with actors in practice (stakeholders from practice). Construction practice is influenced by many. We aim to do away with technology determinism and "process improvement culture", and

instead investigate openings towards new practices in construction collaboration and use of technologies. We combine a process lens (experimental action research) and practice lens (sociomaterial practice theory) to study how construction practices can be developed. Our normative stance is to transform the construction sector from a technology deterministic understanding of “improving processes” to a relational understanding of the complexity and dynamics of entangled practices creating “sociomaterial agency” (Buhl, Andersen and Kerosuo 2019).

For this paper, we have conducted "action research interviews". The interview in an action research optic is a planned dialogue that seeks to explain local actors' perspectives on perceived challenges in their own context. Directed by a known and accepted purpose, the action researcher, with interviews as a method, seeks to create an analytical basis for making choices targeted to this: to increase both individual and collective action in relation to the challenges experienced. In other words, the interview is orchestrated as a method for creating reflective space for a potentially transformative common learning experience for researchers and study participants (Nielsen and Lyhne 2016). An important difference from the classical qualitative interview (Kvale 1997), where the information achieved might be validated by the interviewee. The researcher will do the interpretation based upon their wisdom and training. In the action-oriented interview, the interpretation of the interview is done (as much as possible) together with the interviewee. Analytical concepts used in the interpretation with participants will be related to the used theory. As part of the interpretation of the interviews, the researcher returns to the interviewed (Nielsen and Lyhne 2016: 60).

We have conducted 10 interviews with vendors, specialised in technology for the construction industry. We became aware of these vendors through a regional robot development cluster. They are on the way to market with new solutions within the scope of i4.0; covering solutions like robots for assembly of brickwork, windows and drywall installation, drones, exoskeletons, field-scanning technologies, machine control and support for digital solutions like BIM.

In the first round of interviews, we have been concentrating on their understanding of construction practice and the build environment and the interplay concerning their technologies. In the second round of interviews (after COVID-19) the focus shall be on creating a reflective space for a potentially transformative common learning and performativity.

Approaching our participants for an interview, we framed the interview as a talk about i4.0 (Construction automation), its innovation potential through “re-configuration” or possibly a paradigm shift in the industry's way of organising building processes. For instance, the development of new industrial processes and products, organisational structures, management, business models etc. This shall require a change process and a new practice in order to fully realise the potential. We asked questions on: How does your solution/product create value in construction and contribute to automation (digitisation)? What experiences do you have in designing, implementing and disseminating your solution? How is the solution being received by the various parties in construction? How do you work on implementing your solution in construction? What do you see as the biggest challenge for your solution and for automation (i4.0) in construction?

The analysis strategy is to look at how participants view the practice they are trying to automate: What problems do they see, what will they achieve, what opportunities do

they see, who are the actors/stakeholders and their relationships (entanglement and performativity)? Our aim is to be open for anything that the participants overlook that is or can reduce their understanding of the complexity of the practice they will automate.

Sociomateriality Perspectives

Orlikowski has discussed sociomateriality in many recent papers. She examines sociomateriality through a practice-lens as “Sociomaterial assemblages” that are “situated and recursive process of constitution” (Orlikowski 2000: 409). Social and material are deeply connected and “there is no social that is not material, and no material that is not also social” (Orlikowski 2007: 1437). Orlikowski (2009) recalls that materiality largely ignored in studies of organisations and technology is either being dealt with as “absent presence”, “exogenous force”, “emergent process” or “entanglement in practice”. Absent presence means that that materiality is not acknowledged and accounted by researchers in their studies.

When technology is an exogenous force, it is investigated as “hardware”, a discrete artefact constituted of machines and instruments, or a thing separated from humans and organisations. Technology can also be treated as an abstraction, i.e., characteristics of tasks in assessment of workgroup effectiveness. As an exogenous force, a device that transmits, manipulates, analyses and exploits digital information. The criticism of technology as an exogenous force concerns the lacking role of history, social context and human agency. Consequently, the dynamics and situations of the constitution of technology have not been considered in practice. “We have a tendency to talk of [technological] artefacts as if they were a piece—whole, uniform, and unified... as if they were single, seamless, stable, and the same, every time and everywhere... such technologies are rarely fully integrated, flawless, unfailing, and they can often do break down, wear down and shut down” (Orlikowski and Iocono 2001: 131).

Technology, as an emergent process, accounts for material artefacts as socially defined and produced in social and institutional contexts. A situated and a reciprocal process of interpretation and interaction with particular artefacts are required for the technology to emerge. Technology is discussed in its general meaning without any specific characterisation. It may mean devices, software programs etc. and can be equated with materiality. However, the approach of the technology as an emergent process has been criticised for a tendency to downplay the specific technological properties of an artefact. Orlikowski (2009) suggests entanglement in practice lens could better account for both technology and social in studies of technology.

Although an ontological priority is given either on technology or on social there is an underlying assumption in both approaches related to the ontological separation of the technology and the social that she calls “ontology of separateness”. According to Suchman (2007), the ontology of separateness is “an ontology of separate things that need to be joined together” (Suchman 2007: 257).

Whyte and Harty (2012) introduce alternative approaches to study sociomateriality of artefacts. Leonardi and Barley (2010) separate the social and the material analytically to examine the relations and connections between them. Gherardi investigates sociomateriality as embodied within and across social and material artefacts (Gherardi 2012). Sociomateriality is, in this context, about developing ways of thinking, reflecting and talking about the social and material world as entangled in concrete practices (Suchman 2007). Harty (2008) uses the term “relative boundedness” to

study innovations during the shift from non-IT artefacts to 3D IT-tools in the construction industry. Relative boundedness “considers the ways that processes of innovation can bring in or exclude a wide range of actors and material artefacts as they play out” from the perspective of actor network theory (Harty 2008: 1029). This means that more or less effectively stabilised material and social relations can be studied in all techno-logical artefacts such as bridges or buildings during their design, construction and use.

Leonardi emphasises human enactment in the understanding of sociomateriality and how the social and the material become entangled. He writes: “(Whereas) materiality might be a property of a technology, sociomateriality represents that enactment of a particular set of activities that meld materiality and institutions, norms, discourses, and all other phenomena we typically define as ‘social’... Coordinated human agencies (social agency) and the things that the materiality of a technology allows people to do (material agency) and become interlocked in sequences that produce empirical phenomena we call ‘technologies’, on the one hand, and ‘organisations’, on the other” (Leonardi 2011: 34-35).

According to Leonardi, the sociomaterial entanglement is, therefore, enabled by the ability of a human agency in the realization of one’s goals and the capacity of material agency embedded in technologies social practices. The metaphor of “imbrication” initiated by Leonardi (2011) suggests how social and material agencies become entangled. The verb imbricate has a Roman origin referring to roof tiles “tegula” and “imbrex” tiles being interlocked in waterproof roofs. Leonardi (2012) assures: Social and material agencies, though both capabilities for action, differ phenomenologically with respect to intention. Thus, like the tegula and the imbrex, they have distinct contours and through their imbrication they come to form an integrated organizational structure” (Leonardi 2012: 37).

Sociomateriality approaches and vocabulary (e.g. performativity, enactment, entanglement and imbrication) provide an analytical understanding of the connection between technology and practice. Technologies are formed in practice and used in many ways, and there is not a one-to-one relationship between design, application, and function. Users are well-informed and creative on their own terms, far from the simple twist that the concept of the user assumes them to be (Krippendorff 2006; Buhl, Andersen and Kerosuo 2019). Sociomateriality approaches can help to explore the challenges of designing and implementing new technologies in construction and to create knowledge for an active intervention (action research). Because it can inform our understanding why i4.0-technologies have problems being embedded in construction practices.

FINDINGS

There seem to be some common features in the way development processes and automation of solutions take place. Automation and robotic companies are the drivers, typically by looking for potential opportunities in practice as the first step to develop ideas, which may lead to the development of new technology solutions or the further development of existing technology solutions. The development process often goes through tests by prototyping multiple laps, a method which positions the technology as an outside force trying to adapt to practice.

An example of this is a company, working on the development of transformative technologies for the construction industry, including the development of a cutting

robot for heavy pavement tiles. The company strategy is to generate new technologies, developing a basic concept and subsequently developing it into a prototype that is sent out to the user for the purpose of testing the idea. If the idea is received favourably, the development process can continue. In this specific example, the prototype evolved by having the cutting robot tested seven times by a contractor on various sites before the company decided that they had a product that could be finalised.

The prototyping process results in several different actions. Among other things, the contractor had promised to supply a generator on-site so that the prototype could get power. It turned out that the generator and prototype power connectors did not fit together. That resulted in the prototype being equipped with its own generator to meet this problem going forward. Similarly, at one of the workplaces, water could not be obtained, and the prototype was then equipped with a 100-litre filtered water tank before the next site visit so that the water could be recycled. A third challenge through the prototyping process was to get the tile close enough to the cutting robot for machining. Therefore, both the trailer and the conveying robot, as well as the cutting robot, were equipped with a small 125-kg crane.

Another example is a company that worked on the development of a semi-automated lifting machine for the installation of interior glazed walls in office environments. The company developed the idea for the robot based on being able to get in contact with a large Danish construction company (specialising in mounting ceilings and wall systems). As a result, the company in the subsequent process ended up developing three prototypes, all of which were tested on a construction company's construction sites. Feedback from the craftsmen brought about various mechanical changes in the process. Along the way in the development of the prototypes, the robot vendors also realise that construction sites are complex.

There are two ways to test; one was to drag it out on to the construction sites, and the other was that we had our own little laboratory where we set up simulations and mounted walls. The goal was that we could mount in under 3 minutes.... we could.

The interviewer then tells about the real-life issues they encountered at the construction sites, space conditions, and the challenge that several different trades work in the same areas at the same time. "The environment we experienced on the construction sites actually caught us out".

One company stands out compared to the others. The company is developing a voice-controlled plasterboard cutting machine. Atypical of the other participants interviewed, the idea developer and driver is a carpenter who, based on his own practise, seeks out a local robotic environment where he presents the idea. For the first meeting, everyone looks at the "chrome-plated solutions", which indicate that they (the robot designers) do not know their practise. As a result, the carpenter must explain that he needs hands-free solutions. Development status is that prototype 2 is ready to be tested in the market. The test involves a service technician (formerly a carpenter), responsible for setting up and introducing the cutting machine; an observer focused on how the people on site handle the robot; and a developer collects ideas for improvement. The company expects improvements in this process on an ongoing basis before an actual product is ready.

In this case, the development of the prototype is based on a practise understanding through the carpenter's knowledge of specific interpretations of and interaction with plasterboard assembly. It places the technology as a product of the ongoing human

interpretations, i.e., as an emergent process where the understanding of technology is neither fixed nor universal but emerge from situations and reciprocal processes of interpreting and interacting with artefacts over time (Orlikowski 2012: 8). The example also illustrates that robot Vendors' understanding to begin development of ideas is based on the technical process and - solution-based thinking. If the technology positioned as an outside force, we will argue that the development and implementation process will be vulnerable, technologies are often rarely fully integrated, flawless and unfailing, and they can break down, wear down, and shut down (Orlikowski 2012: 10).

Our data collection shows that the companies' approach to developing and innovating in construction with automation solutions is built around prototyping and tests. The focus is a design and process challenge, which is reflected through the process with a continuing interest in solving immediate problems while also developing the design, a method that is reflected in a socio-technological approach. (Bjørn and Østerlund 2014: 19). In general, "our" participants understand that there are some complexity and challenges in practice, which they deal with through their focus on specific design processes, which includes both specific technical content and social process content, i.e., the user who applies the technology. It means, that "our" participants were "zooming in" on the socio-technical configuration related to how the technology is used.

The companies share some common challenges. To the question of what they see as the biggest challenges for your solutions and automation (I4.0) in construction, the general answers were: Long development processes, expensive development costs, and getting the technology out into practice, as one of the participants put it.

The biggest challenge is getting the mindset accepted. On-site they may well keep an excavator which costs DKK 600.000, which is not used all day, but it can be difficult to convince people to invest DKK 700.000 in a robot.

In this perspective, it seems to be interesting to focus on a change to work. We suggest a focal shift from the socio-technical approach on design processes, i.e., from design interest per-se to investigate the users work-practices as composed from a variety of different logistics and capabilities (actors, fields of knowledge, tools, products, activities, operations, complexities). Our first findings show examples on the missing understanding of the enacted practice. It cries out for sociomaterial design approaches and understandings of performativity (enactment) and entanglement (imbrication) that can provide connection between technology and practice. We have scoped a number of questions concerning the consequence of bringing new technology into practice. For instance: Roles and hierarchies in changing the construction; the new dynamics created, and the methods and work processes that are changed, not only are for the individual operator's work, but for other professional groups as well. Do they have to adapt to other technologies? Can architects and engineers in the design phase adapt their designs and construction solutions in relations to automation and robot technologies to the construction site?

CONCLUSION

This endeavour was started by a wondering - why do solutions for automation in the construction end up in a hidden corner at the construction site? As subscribers to a sociomaterial ontology we looked into practice to find answers.

In our interviews about how i4.0 vendors understand technology development (design processes) in construction, we came across colliding practices. One practice at the

construction site and another practice for the designers of the automation solutions. How are they colliding, and what can we learn about automation in construction?

The vendors understand predetermined processes (technologies in use), they do not capture the complexity of the site practice. That may be intentional, but it is not an advantage. The vendors improve processes and technology through a prototyping process. Their prototyping approach must be elaborated to understand the entangled nature of the construction site. They have discovered the practice (or have they?) - they're still working in their own laboratory to mature the technologies. As Birgitte Munch (Former professor from University of Aalborg) quote:

Technology is not a 'mist' that falls from the sky and blesses us with greater productivity and better design. Technologies are not born ready, and by the time they are 'finished' or 'mature' can be contested. Where can we go to buy an "IT system" that we just have to plug in - and then it "works?"

Technologies are enacted - performativity refers to how technology is enacted and performed in relationships and boundaries between humans, and are therefore not pre-given, but recurrently enacted in practice. How can sociomaterial thinking and vocabulary affect vendors? One cannot design affordance, but one can analyse the use of technology in the context in which it appears (in our second round of interviews, we shall bring up this theme about lacking understanding of the interaction between practices and technology - if the understanding of the social is very rational and instrumental the challenge is to find a way to talk about practice).

We think technology determinism plays a major role in understanding the problems of diffusion of i4.0 technologies. In our analysis of interviews, we have spotted traditional understandings of the social and the technical, that somehow affect the design and implementation process - prototyping is a common way to explain the development process (no one talks about themselves as "socio techniques"). The technology is present, but the understanding of the change processes in practice is absent.

Rethinking prototyping could be a way to work constructively with the collision between practices. A facilitated prototyping process could serve as an invitation to explore and test new practices by fostering interaction in a construction context. However, the existing knowledge and experience from i4.0 is also an opening for experimenting and implementing technologies. Prototyping serves as an invitation to engage and explore the i4.0 solution. The idea is to open up for an experimental approach based on the interaction between the practice (actors) and technology, an 'invitation' to inspire and challenge dominant perceptions of construction and futures. This involves navigating between existing realities and unknown futures to empower transitions of existing non-sustainable practices.

Furthermore, because i4.0 futures are not yet known, it is a specific challenge to create and qualify experiments with alternative future realities. The rehearsals of possible solutions become a key element in development. This directs attention to discussions about how uncertainties and alternatives are addressed to open up opportunities to explore sustainable futures.

In our ongoing action research project on i4.0 vendors' development of solutions to the construction practice, we work on how to entangle colliding practices by experimentation such as laboratories, prototyping and temporary interventions are applied to empower technology with the capacity to open opportunities to explore possible futures.

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CONSTRUCTION IN THE PLATFORM SOCIETY: NEW DIRECTIONS FOR CONSTRUCTION MANAGEMENT RESEARCH

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An emerging aspect of digital transformation in industry relates to the rise of digital platforms. While examples such as Uber and Airbnb are well-known, technological platforms that seek to coordinate demand and supply-side actors in the architecture, engineering and construction (AEC) sector are also developing. Examples include Wikihouse, Sidewalk Labs, and Bosch IoT Suite. Although there is a growing body of scholarship reviewing the concept of ‘platforms’, far less attention has been paid to reviewing studies of digital platforms in the AEC sector. This systematic review of 18 studies seeks to address this deficiency. The findings show that the focus has hitherto centred on engineering platforms, with researchers adding greater functionality to platforms in order to yield efficiencies in the production process. Current endeavours tend to be laboratory-based, with prototypes still to be tested in the real-world. In contrast to reviews in management and organisational studies, scholars of platforms in construction do not pay as much attention to the power of platforms as a strategic organising principle for coordinating markets. The review thus proposes a number of possible directions for construction management researchers to examine the strategic potential for platforms to drive competitive advantage in the AEC sector.

Keywords: digital platforms, disruptive innovation, strategy, systematic review

INTRODUCTION

Over the past two decades, technological platforms from the high-tech information technology sector have proliferated. Examples of these platforms can be found in retail (e.g. Amazon), transport (e.g. Uber), hospitality (e.g. Airbnb) and social media (e.g. Facebook). Recent statistics (see www.statista.com) show how powerful these platforms have become in coordinating markets across the world: for example, in 2019, the ride-sharing platform Uber generated over US\$14 billion in net revenue connecting more than 100 million monthly users globally; despite the controversies surrounding data and privacy infringements, the number of Facebook users keeps growing, linking more than 2.5 billion monthly active users in the 4th quarter of 2019 and generating over US\$70 billion in revenue that same year. According to Cusumano *et al.* (2019), this ‘platformania’ is evident in the market value of seven

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platform leaders - Microsoft, Apple, Amazon, Google, Facebook, Alibaba and Tencent represent a total valuation of ~US\$5 trillion in 2018.

By contrast, the Top 500 engineering design firms generated just over US\$101 billion in 2018 for projects undertaken around the world (ENR, 2019). Indeed, the architecture, engineering and construction (AEC) sector is well known for lagging behind in digital transformation (e.g. the European Commission, 2019). Nevertheless, platforms have also begun to emerge in the AEC sector (see Mosca *et al.*, 2020). Examples include Wikihouse that aims to simplify (and make accessible) the design, manufacture and assembly of high-performance homes (www.wikihouse.cc/About), Sidewalk Labs as part of Alphabet Inc. (parent company of Google) that uses digital technologies to transform the urban environment (www.sidewalklabs.com), and Bosch Internet of Things (IoT) Suite, an open-source IoT-based platform that connects in excess of 10 million devices worldwide (www.bosch-iot-suite.com).

The emergence of digital platforms has heralded a promising era where these instruments lead to disruptive innovation. Platforms that connect users on the demand-side and providers on the supply-side can help address failures in the market, while the rise of the sharing economy can help democratise the production process. Yet, while the term ‘platform’ has become ubiquitous in the business world, until fairly recently, the workings of digital platforms have not been paid sufficient attention in the field of management and organisational studies (Gawer, 2014). A number of critical reviews of the concept of ‘platform’ have since been undertaken to clarify what platforms are, what they do and their effects.

At a very basic level, platforms form the ground or launchpad for driving actions. In computing terms, a platform is the operating system that form the basis for other entities (e.g. software) to run. Thus, for Bogusz *et al.*, (2018), a digital platform is “one digital artefact that mediates as digital entrepreneurs build their venture”. It is through this technological entity that value creation happens by facilitating providers on the one hand, and users on the other (Leong *et al.*, 2019). Such entities, as Dolata (2019) explained, can be characterised as “digital, data-based, and algorithmically structuring socio-technical infrastructures that exchange information, coordinate communication or organize work, offer a wide range of services, or distribute digital and non-digital products” (p. 183).

Platforms are not just stable structures that simply act as intermediaries that broker relationships between demand-side users and supply-side providers. Scholars have begun to recognise that platforms go beyond facilitating two-sided benefits to consider how platforms dynamically shape and are shaped by network-level, multi-sided innovation effects (see Gawer, 2014). That is, for platforms to thrive, the platform owners must constantly grow its pool of users; to do so, platforms must not only attract more parties on both sides, but also develop integrative dynamic capabilities (Helfat and Raubitschek, 2018) and innovate themselves to in turn drive innovation among and across the parties to stimulate complementary innovations, which in return increases the value of the platform (Gawer and Cusumano, 2014). To illustrate this virtuous cycle, take Uber as an example. Its success was initially based on attracting more users to its platforms, both passengers and drivers, some of whom also play the dual role of a passenger and a driver. As it evolved, Uber used its digital infrastructure and algorithmic capability to diversify its offerings by attracting other complementary products such as Uber Eats, its restaurant/take-away delivery service.

Thus, in a platform society, social and economic relations are increasingly mediated through an ecosystem of interconnected digital platforms (de Waal *et al.*, 2017). In this ecosystem, processes of datafication to capture and circulate value representations, the commodification of value propositions to translate into tradeable entities, and the curation of value offerings to provide mass personalisation are the core mechanisms of the platform infrastructure (van Dijck *et al.*, 2018). As Grabher and van Tuijl (2020) noted, platform organisation serves to disrupt traditional production-based industrialisation by driving paradigm shifts in four main areas: A shift in value from one that revolves around ownership of assets to the ownership of access, a shift in governance from decisions surrounding make-or-buy to decisions to employ-or-enable, a shift from managing the back-end (supply side of making things) to managing the front-end (demand side of making matches), and a shift in labour from jobs to gigs.

To date, the concept of platforms has been reviewed mainly in business-to-customer (B2C) contexts - for instance, in healthcare (e.g. Isind *et al.*, 2019), financial services (Kazan *et al.*, 2018), (social) media and gaming (e.g. Rietveld *et al.*, 2019) - far less attention has been paid to reviewing platforms in business-to-business (B2B) contexts (Grabher and van Tuijl, 2020).

The construction sector is one such candidate for examining how platform organising works (or not) in a B2B context. This article therefore seeks to address this deficiency by systematically reviewing how platforms in construction have been studied. In so doing, this review finds that current studies on platforms-based organising in construction have tended to focus on engineering greater functionality of platforms, often based on building information modelling (BIM). In so doing, current studies ignore more strategic concerns of market coordination through digital platforms. Thus, this article concludes with future directions for construction management research to study the full range of problems and prospects of platforms as a disruptor to the status quo.

SYSTEMATIC REVIEW OF PLATFORMS IN CONSTRUCTION

Unlike conventional narrative reviews, systematic reviews which originated from the medical and health sciences is a thorough and transparent way of mapping and evaluating the evidence in a particular topic area (Tranfield *et al.*, 2003). Figure 1 below illustrates the process used to systematically review all the relevant studies on digital platforms in construction.

Two databases were consulted for the searches on 17 March 2020, including Web of Science and Scopus. The following keywords were used in the subject, title and abstract fields: (“platformi*” OR “digital platform*”) AND (“construction” OR “building” OR “built environment”). The choice of selecting “platformi*” as opposed to “platform*” was due to the fact that choosing the latter yielded results that had little to do with digital platforms, e.g., ‘oil and gas platforms’. Therefore, given how scholars who study the development of digital platforms outside of construction have recognised the importance of their dynamic evolution and the process of platformisation (Isind *et al.*, 2019), a choice was made to include a keyword search of “platformi*”. The initial search yielded 516 hits, including 197 hits on Web of Science and 319 hits on Scopus. By limiting the search to peer-reviewed journal articles published in English, the sample was then reduced to 113 articles on Web of Science and 148 articles on Scopus.

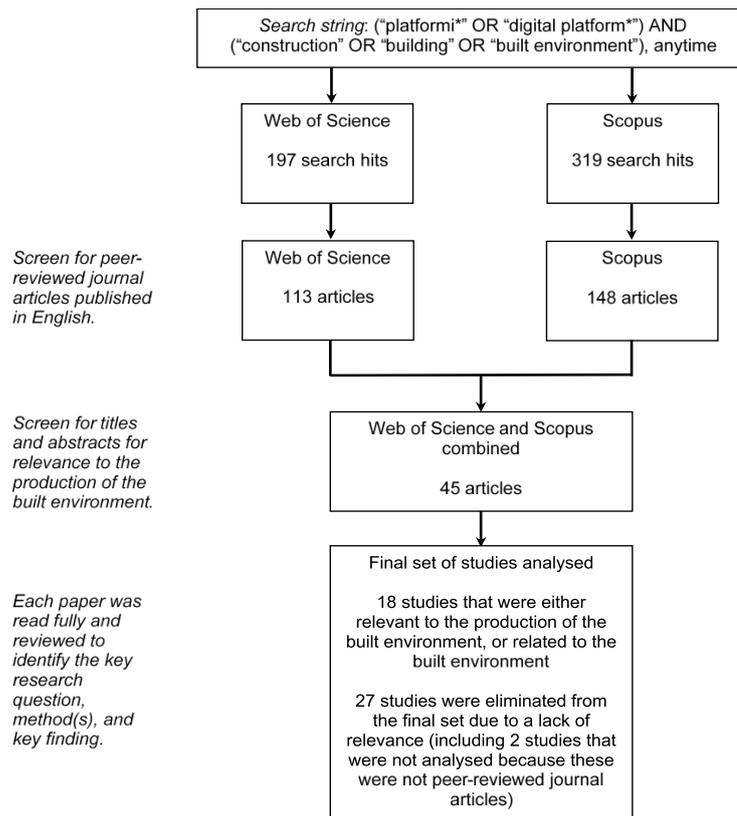


Figure 1: Process flowchart for the systematic review

A screening process was then undertaken by scanning through the title and abstracts of each article to establish relevance to construction and the production of the built environment. Those that were not directly related were eliminated, as were those that were found to be duplicated across both databases. This resulted in 45 studies selected for full review. Each of these 45 studies was then read fully to analyse the research question, method and key finding contained in each study. Through this process, a further 27 studies were eliminated; 25 of these studies were found not to relate specifically to the production of the built environment whilst 2 studies were not published in peer-reviewed journals. The remaining 18 studies - 12 that are directly associated with the production of the built environment and a further 6 that are related to the built environment more generally - therefore constituted the final sample of studies analysed for the review presented here.

RESULTS

Tables 1 and 2 below summarise the research questions, methods and findings of the 18 studies analysed in this review. Thirteen studies were published since 2018, indicating that digital platforms represent a nascent object of study in the field. The analysis reveals distinct interests between studies that are directly associated with the production of the built environment (Table 1) and studies that are related more generally to the built environment (Table 2). The former tends to be about technical developments (8 out of 12 studies), whereas the latter is more concerned about engagement with networks of end-users and citizens (4 out of 6 studies). Moreover, the central platform for studies connected with the production of the built environment is building information modelling (BIM) (7 out of 12 studies), whereas platforms that capture end-user or citizen experience tend to be the object of concern in more general studies about the built environment.

Tool-based focus: Designing functionality for production efficiency

Unsurprisingly, when it comes to studying platforms for the production of the built environment, the focus has been tool-based. Researchers have mainly considered how platforms can better support integration of information between the phases of design, construction and asset/facilities management. For example, using agent-based modelling, Fioravanti *et al.*, (2018) regarded BIM as the central platform that can be enhanced by introducing relational rules and goals that can enable better collaboration, communication and coordination between design and construction management and facilities management. Similarly, Di Tonno (2019), building on the Plan-Do-Check-Act cycle, also viewed BIM as the central basis for integrating project monitoring with information and communication technologies and enterprise resource planning during the operational life of a built asset.

Table 1 Summary of studies connected with the production of the built environment.

Authors (Year)	Title	Research question	Method	Key finding
Mahalingam, A., Yadav, A. K. and Varaprasad, J. (2015)	Investigating the role of lean practices in enabling BIM adoption: Evidence from two Indian cases	How do (lean) practices shape the adoption of BIM?	Comparative case studies of two metro projects in India	When BIM is adopted first as a tool, it is hardly used for decision-making. However, when BIM use is led by the (changing) coordination of practices, then BIM is used actively in decision-making.
Di Ludovico, D. and Fabietti, V. (2018)	Strategic environmental assessment, key issues of its effectiveness. The results of the Speedy Project	How can a digital sharing tool dedicated to addressing the Strategic Environmental Assessment directive be created to enable cross-border sharing of knowledge?	Reflections on the EU-funded SPEEDy (Shared Project for Environmental Evaluation with Dynamic governance) Programme 2007-2013	The platform is used to share information about the directive and experiences of making strategic environmental evaluations. The platform has potential to develop into more inclusive ways of engaging citizens to gather intelligence about the urban context.
Baydar, G., Komesli, M., Yilmaz, A. and Klinç, K. (2018)	Digitizing Lefebvre's spatial triad	How can Henri Lefebvre's ideas about the spatial triad be used in the development of a digital platform?	Development of a digital platform in two social housing projects in Izmir (Örnekköy and Uzundere settlements), combining architectural and planning information with perception data from stakeholder interviews	The digital platform can capture information about how the residents is interacting with the built and urban environment, and could potentially be used for decision-making.
Fioravanti, A., Novembri, G. L. (2018)	A theoretical framework to align lean construction techniques in the 4.0 building industry	How can lean construction techniques be aligned within Construction 4.0 developments?	Review and conceptual framework by using agent-based modelling	BIM is the central platform that can be enhanced by introducing relational rules and goals through agent-based modelling, which in turn can enable better collaboration and linkages between Facilities Management and Design and Construction Management.
Saygi, G., Agugiaro, G. and Hamamcioglu-Turan, M. (2018)	Behind the 3D scene: A GIS approach for managing the chronological information of historic buildings	How can holistic understanding of historical changes be applied beyond geometric, spatial and physical representations of historic buildings?	Using Geographical Information System (GIS) approach, the authors develop a digital 'container' as a 3D digital model for the archiving of a building's chronological information	A prototype was created that can help heritage specialists be more efficient in their future investigations.
Di Tonno, C. (2019)	Smart models for new management of the building process	How can a quality-driven SMART platform be developed to manage the building process in a Construction 4.0 context?	Reflection on platform development	BIM as the central basis to integrate ICT, ERP, Planning and Monitoring software, and project monitoring in the Plan-Do-Check-Act cycle
Fadli, F. and AlSaeed, M. (2019)	Digitizing vanishing architectural heritage. The design and development of Qatar historic buildings information modeling [Q-HBIM] platform	How can a sustainable and interactive archiving platform be created to capture information about Qatari built heritage?	Review to identify aspects of sustainable urban preservation, site analysis and interviews with experts and societal actors	A digital platform was produced to capture preservation policy, tools and processes.
Li, Y., Ding, R., Cui, L., Lei, Z. and Mou, J. (2019)	The impact of sharing economy practices on sustainability performance in the Chinese construction industry	What internal sharing practices with project stakeholders and external sharing practices with unfamiliar companies are generated through the use of digital platforms?	Questionnaire survey of 208 respondents from the Chinese construction industry	Firms are likely to share knowledge within their project networks than with unfamiliar firms from outside their network.

BIM can act as the central platform for enhancements in technical functions or features. One example of added functionality is the use of BIM as a conduit to link the cyber and physical worlds. For instance, McMeel (2019) conceptualised a platform ecosystem that combined augmented reality with robotics. Ness *et al.*, (2019) developed a prototype that facilitated data exchange that can enable circular building processes in which reusable building component can be identified, tracked and managed. Others have proposed a life-cycle information transformation framework (Succar and Poirier, 2020). Furthermore, functionalities that allow the capture of building information beyond the technical have also be introduced, e.g., in adding geographic information to facilitate better coordination between architects and

urban planners (e.g. Baydar *et al.*, 2018), or historical information to support preservation of heritage buildings (e.g. Fadli and AlSaeed, 2019). What these studies have in common is the assumption that these added technical functions are able to facilitate better integration between different professional stakeholder groups. That said, a recent survey by Li *et al.* (2019) suggests that platforms only serve to support engagement between stakeholders who are already familiar with one another rather than with parties who are less familiar but who would bring about more creative ideas.

The tool-based approach is also problematic for a number of reasons. First, 10 out of the 12 studies relating to the production of the built environment are researcher-led, rather than practice-led. Thus, these are conceptualisations of frameworks and models that are developed in the ‘laboratory’, rather than trialled and tested in the real-world. The utility of these tools is therefore questionable at this point. Second, and more critically, Mahalingam’s *et al.* (2015) comparative study of two metro projects in India showed that when the focus lies squarely on tools, then project participants are not likely to use these actively in everyday decision-making. Rather, project participants must first radically transform their practices and bring in new players in order to stimulate fresh questions and perspectives; only then will the usefulness of the platform (e.g. in visualisations of new, unfamiliar perspectives) be put to work.

Table 1 Continued.,

Authors (Year)	Title	Research question	Method	Key finding
McMeel, D. (2019)	Robots and AR: Towards a platform economy for construction	How can platform economies disrupt the construction sector?	Review of Platform 'Iglou', a collaboration between the Centre for Advanced Composite Material and the Faculty of Creative Arts and Industry in Auckland, New Zealand	A design platform was created using parametric design (in Grasshopper), and with augmented reality to help implement robotics in creating the structural elements for the 'Iglou'.
Ness, D., Xing, K., Kim, K. and Jenkins, A. (2019)	An ICT-enabled product service system for reuse of building components	How can a cyber-physical data exchange system be developed so that reusable building components may be identified, tracked and managed?	Developing an ICT-based data management system that connects RFID, BIM and Cloud-based data platform	The prototype developed was validated in an example of an internal glazed system. It is speculated that clients can be assured of the quality and performance of reused components.
Rashid, M. M. and Antle, K. (2020)	Geospatial platforms and immersive tools for social cohesion: The 4D narrative of architecture of Australia's Afghan Cameleers	How can the application of 4D modelling of the past of lost architectural heritage sites in remote central and Western Australia be applied along with Linked Open Data (LOD) to disseminate new knowledge through digital platforms and VR/AR experiences to audiences regarding Muslims in Australia?	Case study of the Afghan Cameleer	A prototype was created to facilitate meaningful and engaging easy-to-use VR/AR experiences to enable better appreciation of historic heritage assets of the Afghan Cameleer.
Succar, B. and Poirier, E. (2020)	Lifecycle information transformation and exchange for delivering and managing digital and physical assets	What are the foundational concepts for an open access digital platform for defining, managing, and integrating project and asset lifecycle information?	Design Science Research	The Lifecycle Information Transformation and Exchange (LITE) framework was developed. Rather than to focus on product or production, the LITE framework takes a lifecycle approach to information requirements, capturing information of physical and virtual assets, and of intent and delivered. This is to be validated in practice.

Beyond the tool: Broadening participation and involving the unfamiliar

When reviewing the 6 studies that are more generally connected with the built environment, the focus moves away from the usefulness of the tool to examining how platforms can be used to better engage with a broad range of users. These platforms either captures user experiences of the built environment (e.g. Chan and Cope, 2015; Abdelmonem *et al.*, 2017), or about capturing the requirements of users and citizens (e.g. de Waal *et al.*, 2017; Bakardjieva, 2019). Thus, while the focus of the 12 studies relating to the production of the built environment emphasised more the design and

construction aspects, 5 out of the 6 studies in this category emphasised the role platforms can play in enhancing the use and experience of the built environment.

Table 2: Summary of studies relating more generally to the built environment

Authors (Year)	Title	Research question	Method	Key finding
Chan, S. and Cope, A. (2015)	Strategies against architecture: Interactive media and transformative technology at the Cooper Hewitt, Smithsonian Design Museum	How does the introduction of digital platform help transform and reinvent the museum (and museum experience) itself?	Self-reflection by the Director of Digital and Emerging Media at the Cooper Hewitt Smithsonian Design Museum	Introducing new digital platforms is not just a technical proposition, but one that involves new organisational practices (e.g. of customer-facing and budgeting).
Shah, K. (2016)	Creation of cultural heritage inventories: case of the historic city of Ahmadabad	How can cultural heritage inventories and documentation act as critical tools for heritage conservation and management in historic cities?	Case study of historic city of Ahmadabad	Documentation should not be just about the physical artefact of heritage assets, but linked to contextual and cultural information about the urban environment.
de Waal, M., de Lange, M. and Bouw, M. (2017)	The hackable city: Citymaking in a platform society	To what extent can new platforms be opened up by citizens, who has access to the data they aggregate, under what conditions, and who governs these platforms and decides on the rules encoded in their algorithms?	Reflection on the 'Hackable City' project, in collaboration with Amsterdam and Utrecht	Seven steps were found: issue framed by an involved stakeholder, then visualised through online campaigns and by manifestations of public space, before engaging the public (often through social media), then tools are introduced through which publics can ideate, learn and exchange upon the issue, pool resources or act upon it, before attempting to institutionalise temporary interventions. Trust is built through social events, rather than through reviews of online platforms.
Abdelmonem, M. G., Selim, G., Mushatat, S. and Almogren, A. (2017)	Virtual platforms for heritage preservation in the Middle East: The case of Medieval Cairo	How can digital models pay attention to the human aspects of city life, the intangible heritage to which people can actually relate to?	Investigating how a cultural-feed can be built into digital platforms of Virtual Heritage in Medieval Cairo	Computer-generated visual interpretation of history and culture plays an increasingly influential role in shaping public perceptions of the past, are therefore subjective and in many instances inaccurate. Contours of historical understanding should be integrated within a generation's impressions of the past.
Bakardjieva, M. (2019)	A tale of three platforms: Collaboration, contestation, and degrees of audibility in a Bulgarian e-Municipality	What kinds of participation do digital platforms make possible, and what specific features proved instrumental in shaping participation and its effects?	Three digital platforms used to engage with civic society in the Bulgarian city of Stara Zagora were evaluated.	Where platforms are used in a collaborative manner, then there needs to be a link between citizens and those in power to make a difference. Where platforms are used in contestation, then it is important that legal arguments are made.
Honic, M., Kovacic, I., Sibenik, G. and Rechberger, H. (2019)	Data- and stakeholder management framework for the implementation of BIM-based material passports	How can a semi-automated BIM-based materials passport be developed, and what data- and stakeholder management framework can support this?	A BIM-based digital tool for capturing materials in existing buildings has been created and validated in a case of an office building.	There needs to be links made to eco-indicators, catalogues of building and construction elements, and product declarations, alongside a framework to connect AEC organizations, industry (product manufacturers) and regulative bodies.

Instead of affording production efficiencies, the focus of studies to date that are more generally related to the built environment has been geared towards extending the network of players and enabling knowledge co-production and sharing. Thus, these studies tend to be much closer to studies of platforms in management and organisational studies, where attention is paid to examine network-level effects as the platform is used by a growing number of users. Within this group of studies, dynamics of competition and collaboration also feature. For example, when comparing between different digital platforms used to shape citizen participation, Bakardjieva (2019) found that the effectiveness of platforms to engage is dependent on its legitimacy; in collaborative settings participants must feel that their voices matter to those with the power to make a difference in decision-making, whereas in contested settings platforms must demonstrate a legal basis for engagement. Platforms are thus not just digital instruments that broker relationships, but also an entity that dynamically evolves in an ecosystem - comprising both digital and physical elements - that shape and are shaped by user engagements (de Waal *et al.*, 2017).

FUTURE DIRECTIONS

While there have been a growing number of reviews on digital platforms in management and organisational studies (e.g. Gawer, 2014; Helfat and Raubitschek,

2018; Grabher and van Tuijl, 2020), far less has been done to review the concept of platforms in the AEC sector. The aim of this article has thus addressed this gap by presenting a systematic review of 18 studies relevant to the (production of the) built environment. The review found that studies on digital platforms in the AEC sector have mainly focussed on engineering better functionalities in platforms, often utilising BIM as the central basis for adding new technical features with the explicit or implicit intention of integrating multiple stakeholders across the whole life cycle of the built asset. This quest for integration is not new, and platforms are emerging as a new organising tool for facilitating better communication and coordination.

However, by treating platforms as a tool, current research in the AEC sector fails to consider the full potential for platforms to dynamically shape and be shaped by the market. It is here that previous reviews from management and organisational studies can provide some clues for possible future directions for construction management researchers interested in examining the workings of platforms to radically transform the AEC sector (see also Thomas *et al.*, 2014). Here, three possibilities are proposed. First, future research could shift the attention away from the constant drive to introduce, update and refine new features of enhancing platform functionality to examining how platforms (and especially platform leaders) create, sustain and grow the number and range of users engaging with the platforms and related innovation capabilities. In so doing, future research can find a balance between the current skewed focus on engineering more functional platforms and the currently-lacking analysis of the dynamics of platform ecosystems and the markets, thereby paying more attention to questions around the dynamic capabilities of platforms (Gawer, 2014; Helfat and Raubitschek, 2018) as they occupy a more strategic position in the ecosystem of incumbents and disruptors in the AEC sector.

Second, by moving towards a more strategic orientation, attention is also turned away from questions of production efficiency to the creation and curation of value. In a recent study of gaming platforms, Rietveld *et al.*, (2019) found that it is not always the 'best in class' that thrives in the platform ecosystem. Rather, it is about the kinds of value that sustains and grows complementary solutions for the users on all sides and the platform owners. Thus, the mindset needs to shift from finding the most technically optimal, to asking what kinds of (added) value platforms bring in engaging with different and novel players in the AEC sector, and to what (better) impacts.

Third, and finally, while platforms tend to be regarded as (more or less) stable entities in existing research in the AEC sector, there is a need to examine more processually what platforms do in everyday practices. Isind *et al.*, (2019) point to the idea of platformisation, as opposed to platforms, to stress the importance of understanding platform development as a process rather than an end-goal. In so doing, there is a need to examine the boundaries and boundary work involved within platforms, between platforms and users, and among users (Leong *et al.*, 2019) as the platform society orchestrates the AEC markets of/in the future.

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SCAFFOLDING IN THE UK AND IRELAND: A FRAMEWORK TO IMPROVE HEALTH AND SAFETY NEGLECT ON SMALL AND MEDIUM-SIZED CONSTRUCTION PROJECTS

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The health, safety and well-being of construction operatives is a fundamental aspect of the construction industry, and safety standards have improved greatly with the introduction of safety training initiatives and welfare facilities on-site. However, one area that often tends to be neglected is scaffolding safety, particularly on smaller construction sites. Therefore, this study aims to analyse current scaffolding safety systems for Kwikstage scaffolding in the UK and Ireland, identify any differences between the two regions, investigate current scaffold safety neglect, if any, and finally, create a framework to encourage operatives to be more aware of the dangers of working with scaffolding on construction sites. A detailed literature review and pilot study provided foundations for the research to lead to both qualitative and quantitative approaches, using a combination of interviews and questionnaire surveys with industry professionals. Results were analysed consistently to ensure comparability, linking key phrases and topics from each method of research undertaken. Findings identified that scaffolding safety is neglected more-so by SME's based on smaller scaled construction sites, who tend not to sub-contract scaffolding temporary works. This research led to the creation of a new 'INSPECT' framework, designed to be displayed at scaffolding access and egress points, along with the development of a 'traffic light system' for the inspection of erected scaffolding. The INSPECT framework, developed using keywords from the research undertaken, is an acronym for Inspect, Neat, Secure, PPE, Entry, Caution and Trips. Overall, the key contribution is the development of a framework, using key information to display to construction operatives on-site, to improve their overall health, safety and well-being on-site when entering a scaffolding structure.

Keywords: health and safety, Ireland, Kwikstage, scaffolding

INTRODUCTION

The dangerous nature of the construction industry has been well documented, where health and safety (H&S) can have a significant impact. If a construction site is not properly managed, it can either make or break a contractor (Ganah and John 2015).

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According to Lingard (2007), it is only in recent times that the safety of workers has begun to be treated as a serious concern. Overall construction standards have risen substantially regarding H&S, with various training initiatives and programmes being implemented on-site. In Ireland, the Health and Safety Authority (HSA 2019a) note that all construction contractors must comply with site rules and a H&S plan, whilst ensuring that all employees are also compliant throughout the construction process. It is illegal in Ireland to work on-site without holding a SOLAS Safe Pass Card (SOLAS 2015), and while not a legislative requirement, most contractors in the UK require their workforce to hold a CSCS Card (CSCS 2020) before stepping onto a site. However, one area that often tends to be neglected is scaffolding safety, particularly on smaller construction sites. The major application of scaffolding is to support building works at heights, as well as areas with poor access (Błazik-Borowa and Szer 2015). Nadhim *et al.* (2016) argue that scaffolding is one of the riskiest construction activities that leads to falls from heights (FFH), and scaffolds can be very dangerous when they are improperly used or erected (Wong *et al.*, 2009). Thus, FFH are at the forefront of construction industry incidents compared with other industries (Hanapi *et al.*, 2013), and prolonged construction activities on poorly used or erected scaffolds contributes to higher rates of FFH (Rubio-Romero *et al.*, 2013).

On review, previous research fails to acknowledge and highlight the issue of scaffolding neglect and misuse within a UK and Irish context, while a lot of industry reports and surveys appear vague in comparison. Therefore, in the context of small and medium sized (SMEs) construction contractors, it is necessary to identify the reasons for scaffolding neglect and establish appropriate safety measures for operatives to adhere to on-site. In addressing these issues and answering a gap in knowledge, it is paramount to develop results based on actual events that emerge, when studying implicitly complex environments such as the UK and Irish construction industries. Focusing on a very important area of interest, this study aims to analyse current scaffolding safety systems for scaffolding in the UK and Ireland, identify any differences between the two regions, investigate current neglect of scaffold safety, if any, and finally, create a framework to encourage operatives to be more aware of the dangers of working with scaffolding on construction sites. This is achieved by incorporating a mixed methods research approach, encompassing a literature review and semi-structured interviews (qualitative), and a questionnaire survey (quantitative). Many different types of scaffolding exist; however, this study concentrates on the Kwikstage scaffolding system, as it is the most popular scaffolding system used in the UK and Ireland (ESL 2020; MJR 2020). SMEs are considered as they are very dominant in the sector, and furthermore, nearly a fifth of all SMEs covering all industry sectors in the UK and Ireland operate in construction (CSO 2014; Barton 2020). Thus, it is anticipated that in challenging this aim, this study will assist and aid construction contractors and operatives in identifying risks and issues regarding scaffolding neglect, and adopting strategies considering scaffolding safety, to improve H&S on construction sites in the UK and Ireland.

Despite construction environments becoming dramatically safer over the past several decades (Shin *et al.*, 2014), the industry remains 'high risk' (HSE 2013). Man *et al.* (2017) support that the construction industry has the highest number of fatalities and accidents among all sectors. Furthermore, the Centre for Construction Research and Training (CPWR 2013) validate that 56.3% of construction deaths occurred in companies with fewer than twenty employees. Chi *et al.* (2014) argue that FFH are the leading cause of fatalities in the industry, and Saurin and de Macedo Guimarães

(2006) concur that work on scaffolds, whatever the type, is usually associated with fall hazards. Hoła *et al.* (2017) identify that the causes of falls from scaffolds are of a technical, organisational and human nature, such as the lack of or inadequate equipment, inadequate professional preparation and a tolerance by management to deviate from H&S regulations. Lij *et al.* (2016) corroborate that a lack of guard rails on scaffolds is the main cause of falls, and Dodge (2012) furthers the argument that partially dismantled scaffolds leads to FFH. Considering regulations, Ismail and Ab Ghani (2012) state that the main factor contributing to accidents involving scaffolding is the lack of compliance. Moreover, findings from a Health and Safety Executive (HSE) report in the UK substantiate that complacency exists surrounding legislation, as 20% of scaffolds on construction sites failed to address working at height regulations (Hughes and Ferrett 2011).

Research in the areas of scaffold safety and neglect in the UK and Ireland is scant, however, studies have been undertaken elsewhere. When evaluating scaffold safety on construction sites in the USA, Halperin and McCann (2004) establish that on small sites with fewer than ten workers, only 48% of the scaffolds received an acceptable scaffold rating. Rubio-Romero *et al.* (2013) argue that the safety of scaffold supports on construction sites in Spain is a concern due to ignorance on the part of building contractors. In Malaysia, Hamdan and Awang (2015) observe that unskilled workers contribute to scaffolding accidents, and Pieńko *et al.* (2018) strengthen that in Poland, scaffolds used for small investments are in the worst technical condition, because they are most often assembled by contractor's employees rather than by professional companies. In the UK, Whitaker *et al.* (2003) outline the development of a prototype decision aid to promote access scaffold safety. Concentrating on contributing factors in UK construction accidents, Haslam *et al.* (2005) argue the ergonomics of traditional scaffolding has not been examined, and there is opportunity for modest innovation.

Kwikstage scaffolding is contrived from hardwearing galvanised steel and it is admired for its easy installation (Adhikari *et al.*, 2019). Compared to traditional tube and fitting scaffolding systems, Hou *et al.* (2017) affirm that the Kwikstage system is easy to handle on-site, sparing workforce, resource and effort. Furthermore, it is popular in the UK and Ireland as it is cost effective, which is attractive to smaller construction contractors. Regardless of which scaffolding system is used, both the UK and Ireland are bound by stringent regulations and legislation. Howarth and Watson (2009) note that safety requirements for UK construction sites are controlled by a hierarchy of legislative elements, and some scaffolding regulatory bodies include the National Access and Scaffolding Confederation (NASC) and the Construction Industry Scaffolders Record Scheme (CISRS) (Scaffolding Costs 2019). In Ireland, the HSA (2019b) have published a Code of Practice for Access and Working Scaffolds, and they comply with normal European Union (EU) legislation EN12810 and EN12811, which provide some recommendations on the manufacturing and assembly of scaffolding (Rubio-Romero *et al.*, 2013). However, even with such legal requirements, issues with scaffolding continues to occur. Błazik-Borowa and Szer (2015) argue that because of the temporary nature of scaffolds on a building site, their construction is regarded with little significance, and minor importance is attached to their proper assembly and exploitation. Kumar *et al.* (2013) support that the scaffolding process is less significant against the overall construction project, even though it involves a considerable amount of resource input and effort. The construction industry is classed as 'fragile' with low profit margins and high risks (Hawker 2019), thus attributing to smaller construction contractors not complying

with legislation and implementing cost-cutting measures. Therefore, Kim and Teizer (2013) postulate that scaffolding systems deserve more attention due to the impact they have on costs, schedules, and the H&S of the overall construction site.

RESEARCH METHOD

This study is part of an initial exploratory investigation which aims to contribute to both industry and academia. Considering the theoretical stance and reasoning this research is founded on, a critical realism approach is adopted. Also, the ontological approach is that of a subjectivist, as the nature of the study mainly concerns the opinions of human participants. An abductive logic is selected as it breaks down our understanding of something and is oriented towards making the indeterminate more determinate to facilitate action (Alvesson and Kärreman 2011). A mixed methods research approach is utilised, encompassing both qualitative and quantitative techniques including a pilot study, informative literature review, five exploratory individual interviews and a questionnaire survey. Leon *et al.* (2011) suggest that pilot studies play a key role in the creation or implementation of new approaches, assessments and other methods of research. The pilot study consisted of a short questionnaire on general H&S practices and distributed to six construction industry professionals. These participants, along with the five individual interviewees, were selected based on criterion and convenience sampling strategies; firstly, by identifying their credentials and experiences with scaffolding systems in the UK and Ireland, and secondly, by arranging interviews depending on the participants availability at a suitable time. For the individual interviews, a semi-structured interview format is chosen, as it determines people's subjective reactions to situations, thus, extending the researcher's knowledge on the topic (McIntosh and Morse 2015).

From an ethical perspective, the participants are informed of the nature of the research, its purpose and what the resultant data will be used for, prior to commencement of interviews. Also, the identities of those involved remain anonymous and confidential information is not disclosed. All five interviewees are currently based in Ireland; however, they all have industry experience in the UK. Interviewee 1 is a Site Engineer working in the greater Dublin area; Interviewee 2 is a H&S Officer working across the Leinster region; Interviewee 3 is a H&S Consultant working nationwide; Interviewee 4 is a Director of a Scaffolding Company working nationwide; and Interviewee 5 is a Project Manager working in the greater Dublin area. Following the interviews, a questionnaire survey was distributed to various construction professionals ranging from Site Operatives, Contractors, Project Manager's and H&S Officers, to further consolidate the findings. Questionnaires are a widely used means of collecting data, and it is an easy way to get responses from many people (Rowley 2014). One hundred and fifty questionnaires were distributed, and forty-one people responded, resulting in a 27% response rate.

RESULTS

The interviews began by gaining general background information from each participant, followed by a discussion on scaffolding systems, safety and neglect in the UK and Ireland. Findings from both the interviews and literature review were then combined to generate the questionnaire survey, and this was circulated out to industry. All the resultant data from each research method was amalgamated and thematically analysed, identifying key words, topics and themes for discussion. A summary of the key findings is illustrated in Figure 1. Links are established between all the key points

and phrases, which forms the basis for creation of the framework, as a result of the research undertaken. It is worth documenting that the findings from the individual interviews and questionnaire surveys are specific to this research; thus, not a generalised view. Nevertheless, this study provides a foundation to advance and expand further, supporting continuous research into scaffolding systems on construction sites in the UK and Ireland.

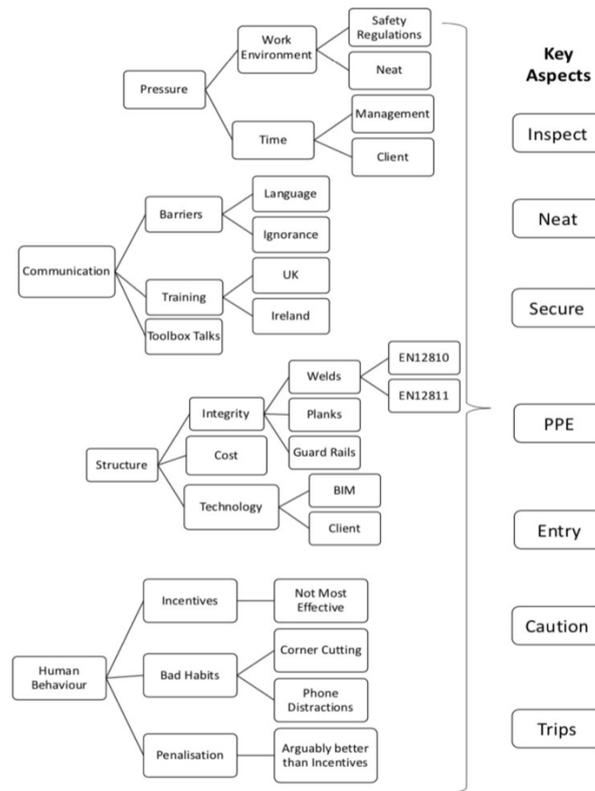


Figure 1: Summary of Key Findings

DISCUSSION

Theme 1 - H&S Compliance and Human Behaviour

Four out of five interviewees agreed that current scaffolding safety compliance is of an acceptable standard, supporting Zin and Ismail (2012) who view that good safety behaviour results in the achievement of good safety compliance. However, the H&S Officer argued that 'corner cutting' is still a huge factor, particularly on smaller sites. There is a direct correlation with contractor size and scaffolding safety, where SME's tend to erect their own scaffolding without trained personnel, and not sub-contract out to a professional company, substantiating with the findings of Pieńko *et al.* (2018). Human behaviour is also a huge factor, and the Director of the Scaffolding Company discussed how bad habits are rife among operatives on-site. Li *et al.* (2018) agrees that construction workers are renowned for getting into bad habits and taking the easy way out without respect for safety. Phone usage on-site, particularly among younger site workers was also highlighted by the H&S consultant, corroborating with Westaby and Lowe (2005) who argue that young people are more likely to partake in risk-taking behaviour on-site. Liang *et al.* (2018) confirm the findings and encourage further elimination of unsafe behaviours of construction workers.

Theme 2 - Incentives

80% of interviewees and 60% of questionnaire respondents verify that incentives are beneficial, confirming Kim's (2018) view that accident prevention on construction sites is improved when an incentive system is introduced. However, all five of the interviewees spoke about a penalty system instead. The Site Engineer summarised that the penalisation system rates each worker, and the more points against that worker, the greater severity of consequence. For example, for not using safety goggles, they are penalised one point, and if they were caught altering scaffolding without the relevant training, they are penalised ten points, and the culmination of points may result in a wage reduction. Other non-monetary incentives might include free company merchandise. Zulkefli *et al.* (2014) conclude that offering rewards, either monetary or non-monetary, is an important part of improving overall safety on construction sites.

Theme 3 - Technology

All interview participants noted the importance of technology and particularly Building Information Modelling (BIM). The general belief is that BIM can very much improve scaffolding safety, with the Project Manager stating that 'BIM is the future'. Zhang *et al.* (2013) argue that the use of virtual reality-based tools such as BIM can improve safety standards in construction, and Collins *et al.* (2014) support that safety risk factors for scaffolding construction can be integrated in BIM. However, 80% of the questionnaire respondents believe that BIM will not be implemented in SME's in this way due to the high costs involved. The interviewees also discussed the potential use of a 'Traffic Light System', where instead of signing off scaffold tags after each inspection, card tapping could be introduced, which would display a green light enabling access to the scaffold. However, on smaller sites, the interviewees agreed that cost would again be the main issue, and it would be hard to implement.

Theme 4 - Communication

Four of the interviewees agreed that toolbox talks are an effective way of communicating with site operatives. However, the Site Engineer remarked that toolbox talks concerning scaffolding safety or working at height are not given regularly unless it is relevant to the activity on-site at that time. Ganah and John (2015) encourage the use of BIM in toolbox talks, as the personnel can visually understand H&S issues as work progresses. Due to the diversity of the site operatives, language barriers are also prevalent. The Project Manager felt that toolbox talks, and daily meetings should contain more detailed information regarding scaffolding safety, supporting Eggerth *et al.* (2018) who claim that a narrative and informed discussions increase toolbox talk effectiveness. 40% of the questionnaire responses identified daily meetings to be more effective than toolbox talks, validating Kines *et al.* (2010) who state that coaching construction site foremen to include safety in their daily verbal exchanges with workers has a positive effect on the overall level of safety.

Theme 5 - Training

The H&S Officer and Consultant have a wealth of experience in both jurisdictions, and in their respective interviews, they both strongly argued that the standard of scaffolding safety training in Ireland is unacceptable and insufficient, compared to the UK. The UK has a well-structured scaffolding training procedure, with different tiers for different roles (HSE 2019). All the interviewees believed that all site operatives should have basic scaffolding training, particularly in housekeeping and general maintenance. However, the Project Manager suggested that there is a lack of interest due to the temporary nature of scaffolding on site, which supports the findings of

Błazik-Borowa and Szer (2015). The H&S Officer further acknowledged that construction SME's are taking advantage of the Irish system, where only one person is required to complete the relevant scaffolding safety training. Thus, they can then sign off inspections on all company sites, sometimes without even being present on-site. Moreover, only two of the interviewees claimed that the new scaffolding Code of Practice in Ireland (HSA 2019b) was effective, and not strict enough regarding safety.

Theme 6 - INSPECT Framework

The initial ideas for a scaffolding safety framework were discussed with the interviewees, and it received an overwhelmingly positive response. The design was finalised following data analysis of both the interviews and questionnaire responses, leading to the creation of the INSPECT Framework. It was developed using keywords from the research undertaken and is an acronym for Inspect (Has the scaffold been inspected in the last seven days?); Neat (Ensure housekeeping is in place); Secure (Is the structure secure - guardrails, bracings etc.); PPE (Have you got the correct Personal Protective Equipment before entry?); Entry (Access and egress - are ladders intact and tagged?); Caution (Take caution - risk of falling from height); and Trips (Be aware of slips, trips and falls). The framework has been designed to be displayed at scaffolding access and egress points on-site, with the anticipation of creating awareness and encouraging safe practices when using scaffolds on construction sites.

CONCLUSION

Essentially, this study focuses on scaffolding safety on small and medium sized construction sites in the UK and Ireland. The construction industry is one of the most dangerous industries in the world in terms of H&S, and scaffolding is one of the riskiest construction activities that leads to FFH. Therefore, construction site managers and contractors are tasked with ensuring that all workers on-site are sufficiently trained in the operation and maintenance of scaffolds, the equipment and tools used are adequate, and that all processes are compliant with the appropriate legislation and regulations. Considering the results captured from the individual interviews and questionnaire survey, key themes emerged including H&S Compliance and Human Behaviour, Incentives, Technology, Communication and Training. These themes culminated into the creation of the INSPECT Framework, designed to be displayed at scaffolding access and egress points on-site to encourage scaffolding safety. The framework was developed using keywords from the research undertaken and is an acronym for Inspect, Neat, Secure, PPE, Entry, Caution and Trips.

However, the findings established from the interviews and questionnaire surveys are specific to this research, and only a concise, subjective view of the topic is produced; not a generalised one. Nevertheless, this study provides a foundation to advance and expand further, supporting continuous research into scaffolding systems on construction sites in the UK and Ireland. There is potential to further develop the findings in this paper, and it is anticipated that a broader analytical context will be addressed in a future publication, where additional theoretical points of departure, coupled with the initial findings of this research, can be articulated. It is recommended that further individual interviews and focus group seminars for qualitative analysis are introduced, using sequential selection strategies incorporating quota and random sampling methods. To gain a richer understanding of scaffolding use in these environments, alternative research methods can be implemented such as action research and ethnographic studies. There is also an opportunity to further develop the 'Traffic Light System' concept that was previously discussed.

Nonetheless, this study provides a foundation for informing and confirming the validity and necessity of the research and ensuing investigation going forward. Going forward, large custom-made signs of the INSPECT Framework have been produced and are being deployed and piloted on a number of SMEs located in the Leinster region of Ireland. These will be displayed at scaffolding access and egress points on-site to promote safe scaffolding use, and any feedback and recommendations received will be utilised to support further research. Overall, the key contribution of this study illustrates the development of the INSPECT Framework to construction contractors and site management, using key information to display on-site, to improve the overall H&S of operatives when entering a scaffolding structure.

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APPLYING LCA-BIM INTEGRATION FOR A SUSTAINABLE MANAGEMENT PROCESS

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This work investigates the benefits of performing Life Cycle Assessment (LCA) using Building Information Modelling (BIM) techniques on a case study management process. This provides insights for reducing the environmental impacts of building materials and elements along the life cycle of a concrete residential project in Egypt. The study follows the LCA ISO 14040 and 14044 guidelines, local materials database, Revit modelling and One-Click LCA plugin. The result outlines that most of the environmental impacts occur during the operation and manufacturing phase. It also shows that slabs and beams result in most of the environmental loads. In terms of the material analysis, it was found the steel reinforcement had the largest impact. This study indicates the potentials and challenges of applying an LCA-BIM integration procedure towards achieving a sustainable management process in middle and low-income countries. This helps project team members to consider the use of different construction materials, elements and building life cycle phases that contribute fewer impacts.

Keywords: environmental impact assessment, Life Cycle Assessment (LCA)

INTRODUCTION

In 2018, the Global Status Report for Buildings and Construction reported that construction buildings alone were responsible for approximately 36% of the global energy and resource consumption, and around 39% of the global greenhouse gas emissions (GlobalABC, IEA and UNEP, 2019). It is noted that 60% of buildings in Egypt are residential and that makes the residential sector the main energy consumer, accounting for 42% of the total consumption (ElGohary and Khashaba, 2018). In this regard, the consumption of the residential sector has been increasing in the past few years; in 2016 and 2017, it reached 5514 and 5744 (ktoe), respectively. Moreover, carbon dioxide emissions were increasing (6% every two years) and expected to continue growing. In 2013, 2015, and 2017 the residential sector presented 15, 16, and 17 Metric tons of carbon dioxide equivalent (MTCO₂eq), respectively (US EIA, 2018).

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Any project can be seen as an input-output process; consuming raw materials, water and energy and emitting waste. Soust-Verdaguer, Llatas, and García-Martínez (2017) argued that there is a growing attention to adopt sustainable design approaches to reduce buildings environmental impacts. The term “Green BIM” has also emerged denoting the use of BIM techniques to account for buildings environmental loads. It may also enable better collaboration between project team members at various project stages and achieve interoperability and consistent standards in the construction industry. This allows systems and individuals to exchange information which is a pivotal concern for the construction industry in middle- and low-income countries. The underlying interoperability framework converts a software-specific data format into a global data format; thus, the tools enable the exchange, transfer, and process of data (Grilo and Jardim-Goncalves, 2010). The BIM currently provides project team members with required data to assess the building performance throughout its life-cycle (Najjar *et al.*, 2017; Santos *et al.*, 2019).

Life Cycle Assessment (LCA) encompasses for all physical exchanges with the environment through various phases of the building process, nevertheless, it cannot be considered a common process in middle and low-income countries due to several challenges associated with data availability, specialized software and practitioners competencies (Ismaeel and Elsayed, 2018). Hence, Anand and Amor (2017) argued that both the information for building materials and their environmental impacts assessment are harmonized by BIM. This facilitates the application of LCA in the building industry and considers the environment as one of the criteria for design decision-making. Hence, this study emphasizes the interoperability between LCA and BIM to allow the exchange of data and interaction between BIM Model, Revit Structure 2020, and One-Click LCA plugin as shown in Figure 1. This aims at evaluating the environmental impacts of building materials and elements for a residential building in Egypt during its life-cycle.

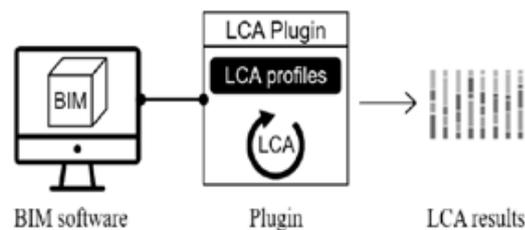


Figure 1: Workflow based on use of an LCA plugin for the BIM software source (Wastiels and Decuyper, 2019)

LITERATURE REVIEW

LCA is defined as “the compilation and evaluation of the inputs, outputs and potential environmental impacts of a product or system throughout its life cycle” (ISO, 2006). It is the most universally type of validation used for environmental impact with broad international acceptance. Through LCA, The life cycle inventory (LCI) is an essential step, adding basic flows over time and space (Hauschild *et al.*, 2013). The functional unit is used to assure a comparable level of function or service. Moreover, the selection of impact categories is the main obligatory components of Life Cycle Impact Assessment (LCIA).

The framework for LCA according to ISO 14040:2006 consists of four iterative steps: Goal and Scope Definition, Inventory Analysis, Impact Assessment and Interpretation (ISO, 2006). There are three LCI methods with significant differences, pros and cons;

the Process Analysis shall be used in this study which operates according to a bottom-up approach starting from the small material scale to the whole building.

It is noted that the Ecoinvent database is the world's leading LCI database which convey both in terms of transparency and consistency (Anand and Amor, 2017; Azari and Abbasabadi, 2018).

Bionova Ltd. developed One-Click LCA as an automated tool in Helsinki, 2011. It operates based on a web-based interface, which can be incorporated into compatible open standard software, and as a plug-in tool in the Revit software. This tool complies with the international standards for the LCA study. One-Click LCA is independently approved for EN 15978, EN 15804, ISO 21931-1, ISO 21929-1 and ISO 14040. Furthermore, it has been created over an international Environmental Product Declarations database which addressed the European market (Bionova, 2015). Also, it makes it possible to select, change and simulate the performance of building materials. It has been used by scholars who studied the integration of LCA and BIM by using different tools such as the One-Click LCA and Tally. The results for both tools were compatible and showed that the manufacturing phase had the highest environmental impact and that the concrete slabs had the major contribution to CO₂ emissions (Petrovic *et al.*, 2019). Table (1) shows the life cycle stages as defined by EN 15978 divided into pre- operational phases, operational phase and post-operational phase (Bionova, 2015).

Table 1: Life-Cycle Stages as defined by EN 15978, elaborated after (Bionova, 2015)

Module A					Building life cycle							Module C				Module D
Product / Manufacture Stage [A1-A3]			Construction Process Stage [A4-A5]		Use stage [B1-B7]					End-of-life Stage						
A1	A2	A3	A4	A5	B ₁	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Raw materials supply	Transport	Manufacturing	Transport	Construction	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Demolition	Transport (to disposal)	Waste processing	Disposal	Reuse Recycling Energy recovery
Pre-Operational phases					Operational phase							Post operational phase				

RESEARCH METHOD

Figure 2 shows a flowchart for a LCA-BIM based decision support analysis for a residential building in Egypt composed of a ground floor and 5 upper floors, 8 apartments with a total floor area of 1446 m². The case study was selected because it represents the best practices in designing and constructing a residential building in Egypt; the floor plans and 3D model are shown in Figure 3. The case study is a reinforced concrete (RC) solid slab system consisting of cast-in-place RC slabs with various thickness (12-25) cm and several cross-sections for the beams and columns as well as combined and isolated footings.

The LCA framework follows ISO 14040 and 14044. The steps can be described as follows;

- Goal and scope definition: investigating the environmental impact of different building materials, elements and construction phases.

- Scope: covering six impact categories along the building life cycle.
- Functional unit: square meters of building floor plan
- Service life: The average life of most structural buildings is 50 years.
- System boundary: cradle to cradle covering the projects life cycle stages; extraction of raw materials, manufacturing, transportation, operation as well as end-of-life scenarios (reuse, recover and recycle) of the building
- Impact categories: this covers midpoint impact categories as shown in Table (2) (Hauschild *et al.*, 2013).
- Life cycle inventory (LCI): this accounts for all the inputs and outputs for the three defined phases of the projects life cycle according to (Bionova, 2015). This includes Pre- Operational phases: [A1-A5], Operational phase: [B6 and B7], it is noted that [B1- B5] are excluded from the scope of this study and Post operational phase: [C1- C4] and [D] module.

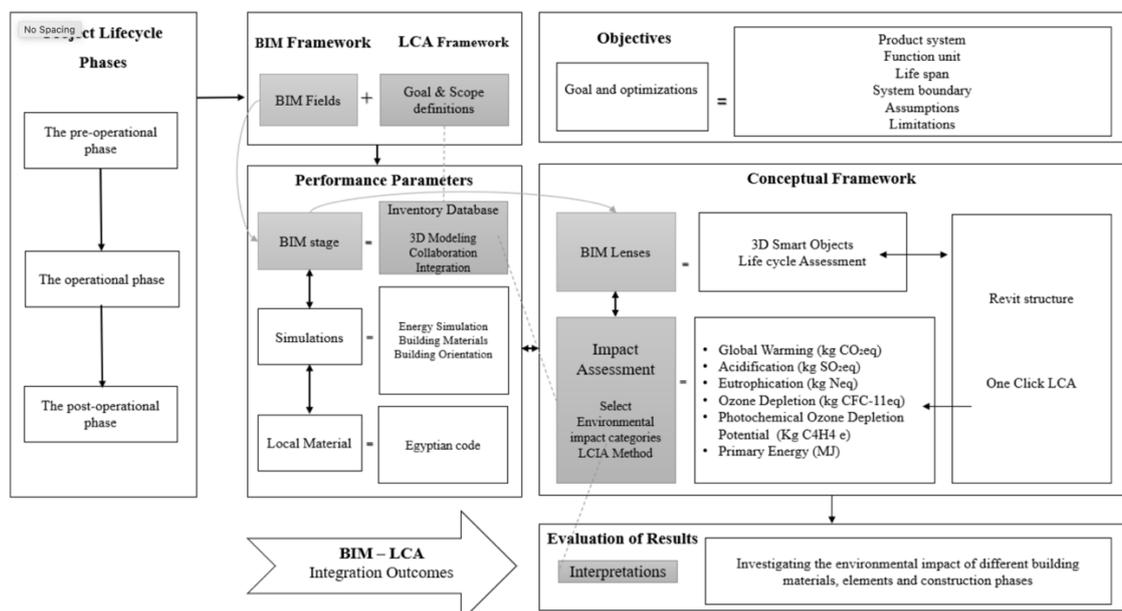


Figure 2: Detailed BIM and LCA integration flowchart for a residential building in Egypt

Table 2: Selected impact categories

Impact category	Abbreviation	Measurement unit
Global warming potential	GWP	kg CO ₂ eq
Acidification potential	AP	kg SO ₂ eq
Eutrophication potential	EP	kg PO ₄ eq
Ozone depletion potential	ODP	kg CFC-11eq
Photochemical ozone creation potential	POCP	kgC ₂ H ₄ eq
Primary energy demand	PED	MJ

The initial plans and modelling of the solid slab concrete structural systems are modelled using the Autodesk Revit software, nevertheless, it is noted that some material environmental properties are not specified and needed to be manually entered.

The Pre-Operational Phase

This phase accounts for the total mass of the main building materials, electricity consumption and water use. The direct material losses (solid waste) and material transportation are also considered.

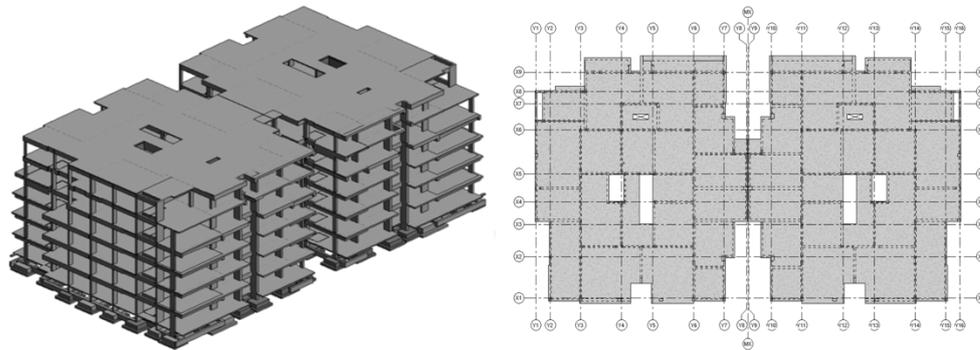


Figure 3: The residential case study building (3D model and structural floor plan)

In this regard, it is noted that the transportation of waste from the supplier to the construction site was reported. The material flows and the unit processes chosen by the Ecoinvent database were determined. During the construction period, the consumption of water and electricity was obtained from the supplier bills and provided by the construction companies. Concerning the solid waste, the usual theoretical loss was estimated as 2-5% for RC, 6% for RC rebar and 8% for Soil waste (sand) (El-Desouky, Ibrahim and ElDieb, 2018). The overall values of inventoried construction materials for the quantification of construction waste are applied. Table (3) shows authors estimation to the consolidated transportation distance using Google maps as a result of the lack of supplier data in this regard. This was done for 1) transporting building materials to the building sites and 2) transporting solid waste to the destination. Then the distance was doubled to account for the empty trucks arrival distance to the construction site and its return to the building site.

Table 3: Transportation calculations

Life cycle phase	Material	Distance supplier/ Construction site	Distance construction site/ landfill
Construction	Cast-in-place concrete, structural concrete	29 km	7km*2=14km
Construction	The sand soil	--	7km*2=14km
Construction	Steel reinforcing rod, galvanized steel and rolled section	31 km	31km*2=62km

The Operational Phase

This phase includes the domestic water and electricity use, artificial lighting, energy used for cooking, as well as building maintenance requirements. The solid waste generated during the maintenance process and its transportation are also included. The consumption of electricity and water was calculated according to the average use and number of occupants. For the annual electric energy consumption, it was estimated as 387,072 kWh /building/year- according to the Egyptian Electricity Holding Company (Desoki, 2018). Also, the energy use was calculated according to Egypt's mean voltage matrix available in the Ecoinvent database. Similarly, the values used by the Central Agency for Public Mobilization and Statistics state that water use is 328 m³/building /year. Nevertheless, the impact resulting from the maintenance

stage was excluded because the assumed lifespans of the used materials were equal to or greater than 50 years.

The Post-Operational Phase

In this phase, reusing, recovering energy, and recycling materials were considered as end of life scenarios. Table (4) shows the inventory data for the project case study.

Table 4: The inventory data for the solid slab concrete structural system

Description	Solid slab structural system	
	Input materials	Output (waste)
I-Pre-operational phase		
Construction process		
Foundation and sub structures	614 m ³	27016 kg
Steel rebar for foundation and sub structures	35,948 kg	2157 kg
RC-Columns	308 m ³	13552 kg
Steel rebar for columns	32340 kg	1940 kg
Shear walls	137 m ³	6028 kg
Steel rebar for shear walls	16440 kg	986 kg
Solid slab with beams	2003 m ³	88132 kg
Steel rebar for solid slab and beams	159460 kg	9568 kg
Soil waste	-	1,289,232 Kg
Consumption during the construction phase		
Water (m ³)	100 m ³	-
Electricity, 2 Generator, diesel-driven (100 Kilo-volt-amperes), (operation per hour)	1320 h	-
Equipment used during the construction phase		
Crane, diesel-driven, (operation per hour)	800 h	-
Vibrators operation, diesel-driven, (operation per hour)	120 h	-
Excavator, crawler and wheel loaders diesel-driven, (operation per hour)	48 h	-
Compactors, diesel-driven (operation per hour)	8 h	-
II- Operational phase		
Electric energy	387,072 kWh/ building /year	
Water	328 m ³ / building /year	
III- Post operational phase		
Total incorporated mass (kg)	-	1,438,083 kg

Then the LCIA was carried out on the following levels to pinpoint the highest contribution of environmental impact:

- Materials: steel reinforcement and RC
- Construction elements: foundation and substructures, columns, shear walls, as well as slabs and beams
- Life cycle phases of the whole building: pre-operational, operational and post-operational).

RESULTS

This paper presents a LCA-BIM based decision support analysis for a residential building in Egypt that tackles the material, construction element and life cycle stage.

For different impact categories, the Primary energy demand (PED) is the highest environmental impacts during the building's life cycle. It is followed with the GWP with value 1.57E7 kg CO₂eq then AP with value 4.40E4 kg SO₂eq, EP, POCP and the least value was for ODP.

For life cycle phase: Figure 4 shows that the largest part of the environmental impacts occurs during the operational phase. The energy consumption during the operation phase was approximately (78.4%-90.2), while the manufacturing stage was approximately (3.6%-18.7%), the transportation stage accounted for approximately (2.1%-4.4), the construction stage represented about (0.6%-1.2%) and the end of life

was about (0.3%-1.2%). Nevertheless, the water consumption during the operation phase had a less impact of (0.1%-0.3%).

For the construction materials: Figure 5 shows that the reinforcement steel rebar dominates four out of six impact categories: AP, EP, POCP, and PED but otherwise, the reinforcement concrete dominates two out of the six impacts. This is due to the large amount of energy required for manufacturing the steel elements and transporting the steel waste to the landfill area.

For the construction elements: Figure 6 shows that the slabs and beams had a higher value than the other construction elements followed by the foundations and substructures, columns, and shear walls. This is due to the large material quantities (RC and Reinforcement rebar of 2,003 m³ and 154,460kg, respectively) included in their manufacturing process which required more energy input and lead to more output emissions. Similarly, for the transportation to the site stage (the steel reinforcement for slabs required 4 trailers/ 40-ton capacity). The RC is delivered to the site by a pump with capacity of 140 m³/hour, hence, for the slabs, 2 pumps working 8 hours/day are needed. Thirdly, during construction stage, it depends on the required equipment and operational hours as well as the buildings floor number. The construction waste included concrete and steel, as well as soil waste (resulting from cut and fill)- noting that the soils swell factor is equivalent to 1,289,232 kg. Finally, the end of life scenarios (reuse, recycle and energy recovery), are the highest for slabs and beam according to EN-15978. This is because the RC in this stage are 55% recycled into coarse aggregate and 45% landfilled, but the reinforcement steel rebars are 95% recovered and 5% landfilled.

DISCUSSION

The results of the current study (in Egypt) correspond to international findings in terms of the impact of concrete structures, building elements and materials (Anand and Amor, 2017; Azari and Abbasabadi, 2018; Petrovic *et al.*, 2019). Furthermore, the study shows that applying LCA in a developing country like Egypt includes several challenges. This includes data availability, time limitations, users' skills and guiding principles, this is in addition to considering the variations arising from building types. This calls for the need to integrate it with BIM techniques to ensure transparency, coherency and consistency of the assessment and promote its endorsement in the building industry (Najjar *et al.*, 2017; Soust-Verdaguer, Llatas and García-Martínez, 2017; Wastiels and Decuypere, 2019). On the other hand, some challenges exist for the use of the software itself and the comprehensiveness of imbedded database and its compatibility with the project type and local context. Hence, in this study, practitioners had to perform manual entry for some materials according to the Egyptian code of practice.

CONCLUSION

The study presents a LCA-BIM based decision support analysis for a residential building in Egypt that tackles the material, construction element and life cycle stage. This guides practitioners for a sustainable management process along the full building life cycle. The results show that the operational phase has the greatest environmental impact (76% in many impact categories); the pre-operational phase contributes to less than 23% while the post-operational phase has the least impact, with contributions of less than 1%.

On the construction element-level, the floors and beams as well as the foundation and substructures have the highest environmental impact.

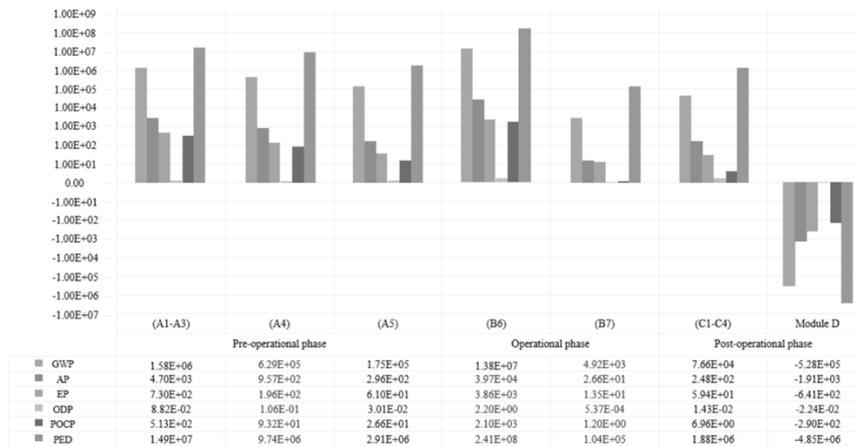


Figure 4: The environmental impacts of the three defined life cycle phases

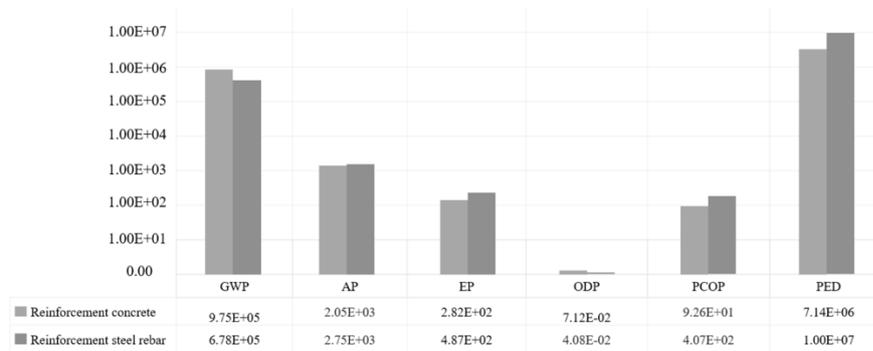


Figure 5: The environmental impacts for building materials

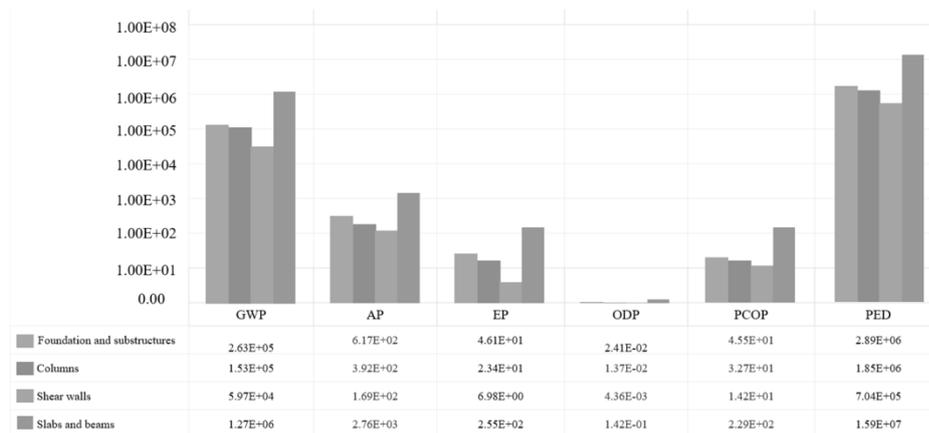


Figure 6: The environmental impact of different building elements

While, on the material-level, the steel reinforcement dominates 4 out of 6 environmental impacts more than the RC. Hence, it is noted that the more construction materials used, the greatest impact therein, hence, the primary recommendations for team members is to reduce material quantities through adopting a material and resources efficiency approach and consider end of life scenarios during material selection; prioritising reuse and recycling materials.

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SCENARIOS FOR THE DIGITALISATION OF THE CONSTRUCTION INDUSTRY

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Digital technologies have the potential to help address some of the key challenges facing construction. Thinking and planning for the future, including unexpected events, is vital if the implementation of digital technologies is to realise their benefits. Four plausible future scenarios for an industry transformation enabled by digital technologies were developed using scenario-axes approach. The underpinning empirical work involved a review of literature, 20 semi-structured interviews and five focus groups/ workshops with industry practitioners. Qualitative data were analysed to identify emerging themes, which were subsequently conflated to determine the two main driving forces/ uncertainties underpinning the digitalisation in the industry: the extent of Innovation, Research and Development (IR&D), and the extent of integration/ collaboration. They were adopted as two axes to provide a framework to develop four plausible scenarios, named as 'bleak segregation', 'utopia transformation', 'lonely investment', and 'cheap combination'. Feedback from industry practitioners was generally supportive to the scenarios. The scenarios do not only describe how external factors impact on digitalisation, but they also raise many questions on what the industry stakeholders could do to influence the outcomes, particularly on those related to collaboration and investment. These will determine the pathways and the level of competitiveness of the industry, the companies and the individual stakeholders. Based on this, it could be argued that appropriate strategies and actions of the construction stakeholders themselves can, to a great extent, shape the future outcomes. Apart from the resulting scenarios, the research highlights the benefits which could be derived from the process of developing scenarios for the participants.

Keywords: digitalisation, future studies, Industry 4.0, scenarios

INTRODUCTION

The construction industry is faced with fundamental challenges of low labour productivity and low-profit margins (Turner and Townsend 2018, EY 2018). Globally, over the last 20 years, the growth of labour productivity in the construction industry has been only 1% compared to 2.8% in the wider world economy (McKinsey and Company 2017). Furthermore, profit margins are the lowest of all sectors apart from retail (EY 2018). These issues have hampered project performance and quality of the built environment, resulting in high profile and very public cases, such as Cross

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Rail and Grenfell Tower in the UK. In order to address these considerable and persistent problems, there is a need for radical solutions to transform the production and delivery process in the construction industry. Digital technology, the move to Industry 4.0 and related business model innovations offer an opportunity for radical transformation. The UK Government attempted to facilitate a transformation of the construction industry through the launched of Industry Strategy Challenge Fund (UKRI 2016), with an inspiration of faster and cheaper construction, and reduced carbon emissions. Specifically, the Transforming Construction Challenge (TCC) initiative promotes exploration and development of digital manufacturing in construction, amongst other initiatives. Given the many previous initiatives and current impetus for change in the digitalisation of construction, it is critical that possible pathways to move from the current state to transformed futures are explored, determined and examined, so that appropriate strategies can be devised.

There are several recognised approaches to formulate and examine possible pathways to the future. There are three reasons for selecting scenario planning approach. Firstly, by nature, the future is very uncertain. Schoemaker (1995) argues that scenario planning is one the most effective tools to deal with uncertain events and to plan for 'a range of possibilities in rich detail'. Secondly, it can reduce errors in the analysis, in particular the treatment of exogenous and endogenous variables. Chermack (2004) highlights that scenario planning can mitigate this problem, but also address many other decision errors including the ingrained mental models. Thirdly, the end goal is to ensure appropriate strategies can be developed. Schoemaker (1995) and van Notten *et al.*, (2003) argues that scenario planning is very useful for strategy development at the national, firm and even project level. Scenario planning has also been applied in the construction industry (Goodier *et al.*, 2010). Although with a long history, there are limitations of previous applications of scenario planning. For instance, Harty *et al.*, (2007) critically examined 13 construction-related futures scenario studies and concluded that these studies did not provide anything substantially different than studies related to the present due to a lack of attention to uncertainties and the failure to connect the present and the futures. Given the general low take-up of innovation in construction (Gruneberg and Francis 2019), and uncertainties posed by the adoption of digital technology, scenario planning could be applied to enhance understanding of the required changes for a more digitalised industry (Lavikka *et al.*, 2018), and to develop appropriate strategies in a more proactive and holistic manner. The strategies should address all elements in the ecosystem, hence promoting a radical change in the production and resultant quality of the built environment.

DIGITALISATION OF THE CONSTRUCTION INDUSTRY

Digitalisation is the use of digital technologies, particularly technologies that use digital data, to generate insights into new business models and processes such as supply chain management, e-governance, smart transport, etc. (Boulton and Lamb 2019). The UK's Centre for Digital Built Britain (CDBB) proposes a data-centred digital landscape for the construction sector. Data-driven decision making is thought to bring efficiencies in design, construction, operation, and integration of the built environment with the services they deliver. A well-managed digitalisation of the construction industry could improve building performance, reduce impact on the environment, and deliver better public and social services (Neely *et al.*, 2019). Building information modelling (BIM) is a key driver and enabler of the digitalisation of the sector. However, there are other technologies that have a role in further

digitalisation of the sector, such as the Internet of Things (IoT), big data analytics, and machine learning. Neely *et al.*, (2019) argued that more research is needed to exploit the role of digitalisation in improving the design and development of services that are linked with assets and the interplay of costs and returns. Business models research addresses the ways in which investments could be integrated to develop new design and construction services in the built environment. Despite this potential, the ‘environment’ in which this digitalisation (and its new business models) could be nurtured and stimulated needs to be identified and understood; future scenarios are one way of doing this. These scenarios provide critical links between digitalisation and socio-economic, structural and cultural context of construction; thus, allowing grounded and realistic (adoption) strategies to be developed.

Scenario Building Approach

There is a general lack of consensus on the most appropriate approach to scenario building. Instead, literature suggests several techniques and methodologies for generating scenarios with common characteristics (Amer *et al.*, 2013). Scenario-axes is a common approach to structure thinking and discussion about future scenarios and recommended as a useful tool to construct images of the future in a coherent and systematic manner (van ‘t Klooster and van Asselt 2016). It has been used in a number of studies (e.g. Arup 2019). In this research, the approach was adopted because it allowed development of explorative scenarios to respond to what can happen to the development of external factors (which are beyond the control of the users/ actors) and how strategies (and other internal factors) could be devised/ considered by the users to cope with the issue(s) at stake (Börjeson *et al.*, 2006). The approach identifies the two most important driving forces/ uncertainties that could have a decisive impact on the digitalisation (adoption of digital technologies) in the construction industry, applies them as axes, and then generates scenarios that represent combinations of extreme, but plausible situations from the axes (van ‘t Klooster and van Asselt 2016). There are competing approaches to determine the axes, but the most common approach is to identify the two most important uncertainties (*ibid.*). Plotted on a Cartesian graph, there are four plausible scenarios with each scenario representing one quadrant. Based on an extensive review of literature, Amer *et al.*, (2013) suggest that three to five scenarios are considered appropriate by most researchers. Further, the number of scenarios (four) produced in the research here was considered optimum to aid the practical administration of the scenario building process and the communication of the results to industry practitioners. Less scenarios begin to limit variety, and more become difficult to communicate. To identify the two axes, a series of semi-structured interviews and focus groups/ workshops were conducted to identify the two axes (Börjeson *et al.*, 2006) and generate the scenarios, explained in the following section.

METHODS

The research adopted qualitative research methods. Data were collected through 20 semi-structured interviews and five focus groups/ workshops with both construction and non-construction stakeholders. The interviewees were from a range of disciplines (e.g. engineering, IT, economic) and roles (CEO, management, technical, sales). Two key questions for the interviews are: (i) What do you think are the key (social, environmental, political, legal, economic, technological) factors that could impact the future adoption of the digital technologies in construction? (ii) What are the barriers that might limit the adoption of these digital technologies? The questions were meant

to initiate discussion and generate ideas, with follow-on questions to prompt and pursue any interesting ideas and clarify the discussion. The aim was to identify uncertainties, trends and barriers to the adoption of digital technologies (Lavikka *et al.*, 2018). Each interview lasted for about 30 minutes. All interviews were conducted face to face, in-person, and the majority being audio recorded and then transcribed (few were not willing to be recorded, but responses were note-taken).

Five focus groups and workshops were conducted to populate the content/narrative of the scenarios, refine and validate the scenarios. Table 1 describes the main expertise of participants, the number of participants, and the objective. The focus groups/workshops represented a progression of the research to substantiate the findings from the interviews. One focus group/workshop was informed by the previous and inform the subsequent focus group/workshop. The main difference between focus group and workshop was the number of participants and their grouping. Focus groups were attended by fewer participants who were engaged in a single group discussion, whilst workshops were attended by more participants who were divided into groups of 4 or 5 participants (except the online workshop where participation was facilitated interactively). In the last two workshops, feedback on the scenarios were sought and presented in this paper.

Table 1: Focus groups/ workshops (in chronological order), main expertise, number of participants, and objective

Focus group/ Workshop	Main expertise	Number of participants	Objective
Workshop 1	Project management from construction and non-construction, digital technologies, AI	22	To identify emerging themes and narrative for input to scenario development
Focus group 1	Digital technologies across different industries	3	To identify emerging themes and narrative for input to scenario development
Focus group 2	Housebuilding, manufacturing, project management, digital technologies, AI, robotics	5	To identify emerging themes and narrative for input to scenario development
Workshop 2	Construction	23	To generate feedback and response strategies on the scenarios
Workshop 3 (online)	Construction, digital technologies	18	To generate feedback and response strategies on the scenarios

RESULTS

The uncertainties, trends and barriers to digital technology adoption were classified into emerging themes. Figure 1 shows the arbitrary grouping of the emerging themes into driving forces, barriers, policies, and business models. The next step was to conflate these themes into two intersecting axes. The emerging themes were subsequently grouped into two key uncertainties, ‘integration/ collaboration’ and ‘innovation, research and development’ (IR&D), as depicted in Figure 2. The inclusion of the themes in the two groups was determined based on evidence obtained from the interviews that suggested association with the group in which the themes belonged. To determine the appropriate axes, our approach was to uncover connections between themes and determine what axes would best represent them. We undertook a thematic categorisation to identify key themes which represented the data. The analysis then involved compiling numerous potential names of the axes and

analysing whether they were appropriate to capture the themes identified. The themes were then mapped into four different quadrants (shown in Figure 3). Every theme was used in at least one of our four scenarios. The themes are the explicit link between the findings in the interview data and the scenarios and the axes. Most emerging themes were best represented and related inclusively to one uncertainty.

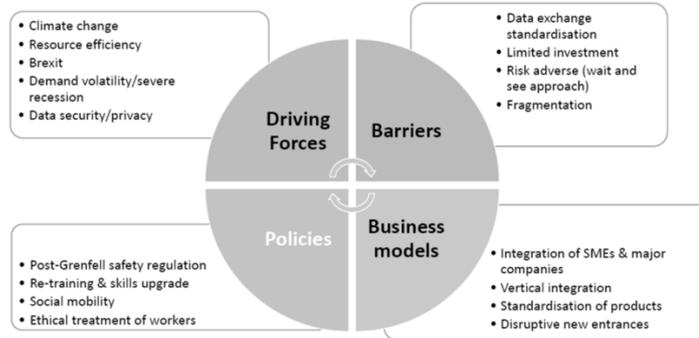


Figure 1: Emerging themes from the interviews

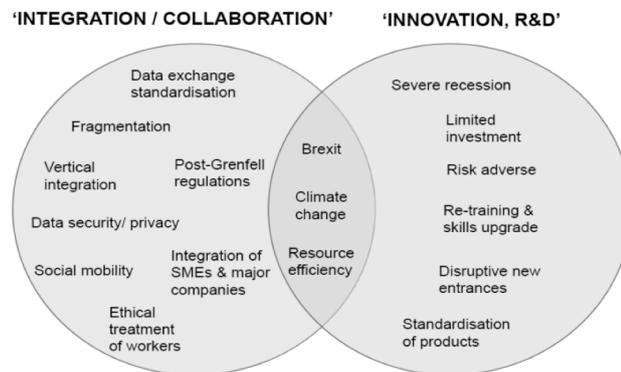


Figure 2: Grouping of emerging themes into two key uncertainties

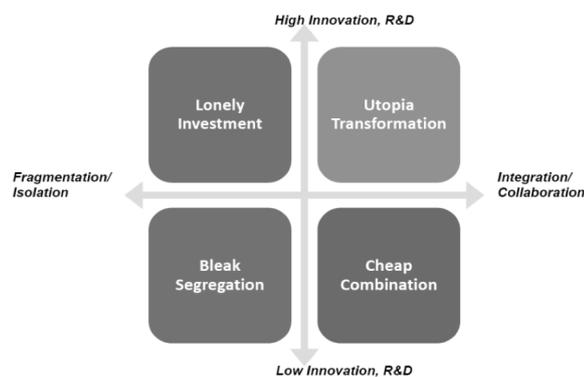


Figure 3: Four scenarios based on two key uncertainties

Several key themes, including 'Brexit', 'climate change', 'resource efficiency' were considered to fall into both groups. For example, poor trading deals with Europe resulting from 'Brexit' hits profit margins and hence impacts upon IR&D. In addition, Brexit impacts the extent (and nature) of collaboration with Europe and elsewhere.

The scenarios were named to reflect the content, 'bleak segregation', 'utopia transformation', 'lonely investment', 'cheap combination' (Figure 3). Each scenario's narrative was then developed from the data. Due to space constraint, the full narrative

is not included in this paper. Instead, a summary of each scenario with its dominant drivers and outcomes is presented in Table 2.

Dominant drivers include ‘self-interest/ isolationism’, ‘global concern’, ‘investment’, and ‘corporate movement’, which represent synthesis of the scenario narrative. In the ‘outcomes’ row, we can see how the scenarios produce different outcomes.

Table 2: Four scenarios with their dominant drivers and outcomes

Dominant drivers	Scenarios			
	‘Bleak Segregation’	‘Utopia Transformation’	‘Lonely Investment’	‘Cheap Combination’
Self-interest/ Isolationism	Increased isolation, started by Trump’s foreign policies. No deal Brexit restricts labour movement.		Self-preservation drives competition at corporate level.	
Global concerns	Trade war leads to collapse of housing market and global recession.	Australian bushfires trigger climate change rallies; increasing environmental concern.		Coronavirus provides impetus for collaboration. Coronavirus leads to recession.
Investment		Synergy between private ‘bottom-up’ investments (including merger & acquisition, such as Google, Goldman Sachs) and public ‘top-down’ investments (such as ISCF, Innovate UK).	China and India invest heavily in R&D and become hubs for the development of new digital technology. ‘Top-down’ UK government interventions and investments and subsidies, but lack ‘bottom-up’ initiatives from private sectors.	Stagnant IR&D investment due to global recession. General reluctance to invest in IR&D (particularly by private sector). Investments are driven to obtain competitive advantage in the open market.
Corporate movement	Large firms maintain status quo to dominate small firms.	Increased collaboration between construction and technology (such as Google); disruptive new entrants.	Lack collaboration at corporate level.	SMEs suffer from recession, and are taken over by big players.
Outcomes	Limited investment in innovation, R&D; increase fragmentation and distrust.	Open source technologies/ communities, and Industry 4.0 revolution. Combined ‘top-down’ interventions and ‘bottom-up’ efforts, yield optimum outcomes i.e. competitive construction industry, able to compete in international market.	Large government investment in IR&D does not really match ‘isolated’ investments by private sectors (mainly major companies, such as Google, Goldman Sachs), hence creating ‘hot spot’ success stories of best practice. Wide-spread take-up of innovative approaches is still a way to go.	Industry becomes more integrated. Investments are to obtain competitive advantage, with little regard to common good and sustainability for the majority of public.

PRACTITIONER FEEDBACK ON THE SCENARIOS

Feedback on the scenarios from industry practitioners was ascertained in the last two workshops (see Table 1), across three questions, as follows.

Question 1: Do the scenarios make sense to you? Are they logical and plausible?

Workshop participants were generally in agreement that the scenarios presented to them make sense and were logical and plausible. One participant mentioned that the scenarios would likely to be very different post-Coronavirus pandemic. This pandemic could be considered a ‘wildcard’ in the development scenario. The impacts may be long-lasting in most aspects of life but are difficult to predict with a high degree of certainty. One feedback considered that three scenarios are sufficient with two extremes, i.e., ‘bleak segregation’ and ‘utopia transformation’, and ‘cheap combination’ in the middle, driven by difficult economic circumstance in the post-pandemic context. Another participant mentioned that ‘lack of internal investment due to poor profitability’ gives support to scenarios with low IR&D (i.e. ‘bleak segregation’ and ‘cheap combination’).

Question 2: What are other potential dominant drivers that need to be considered?

One participant drew attention to the ‘bigger picture’ in relation to ‘circular economy thinking’ and ‘doughnut economics’. The latter highlights the need to bring social and environmental considerations in pursuing economic efficiency imperative in construction. The issue of ‘leadership’ was also coined as a potential dominant driver. This is related to investment, highlighting ‘Government capacity for investment’ and ‘the willingness to share between companies and governments’. Investment was considered a dominant driver in Table 2. It could be most effective when there is a synergy between ‘top-down’ government and ‘bottom-up’ private sector initiatives. A couple of participants highlighted the need for thinking new business models, based on data centric works on standardised platforms, and the potential of Artificial Intelligent (AI) and robots taking over the workforce in digitalised construction. The

issue of ‘availability, adoption and acceptance of new technology e.g., drones and data analytics’ were also proposed.

Question 3: What changes of current practices and strategies are needed in order to respond to the scenarios?

Some participants considered re-orientation of current business model from short-term outputs to solutions that bring long-term benefits and values for the customers and wider society. Few issues came up within this new business model, including the provision of rewards, supply chain practices and strategies, risk allocation and collaboration, contractual, intellectual property and insurance issues that inhibit digital collaboration. One participant suggested the need for more collaboration, open source working and trust, with more active benchmarking. Another participant highlighted the need for an improved climate/ carbon literacy, and to consider nature and complexity of supply chains in the new strategies. The need to adopt strategies that look at other industries outside the construction industry, e.g., automotive industry, was also suggested.

Specific feedback on each scenario

Participants also gave specific feedback on each scenario. One group argued that rather than having firms become less efficient in 'Bleak Segregation', firms and people may create innovative ways to work more efficiently. The group also suggested that, during difficult business environment, firms have always found IR&D investments in the core of their business (e.g. labour and energy efficiency).

One group argued that ‘Utopian transformation’ should be viewed on a moving timescale with continuous revision of the target. This scenario is the ideal for nurturing ‘circular economy’ and ‘doughnut economic thinking’.

A criticism of ‘Lonely investment’ was distinguishing between geographic fragmentation and sector-specific fragmentation. The participants argued that, in the industry, fragmentation refers to the lack of continuity between asset owner, designer and builder in the procurement method, not to geographic fragmentation. This group also mentioned that fragmentation could lead to builders using the best technologies to build at the lowest cost. The group pointed out that the scenarios should consider the data exchange problem. They argue that firms are reluctant to share information to avoid other companies taking advantage of their knowledge.

Regarding, ‘Cheap combination’ a group pointed out that limited investment would challenge the achievement of TCC target via digital manufacturing. Nonetheless, the new global compassion to collaborate may bring new opportunities for targeted global cooperation to tackle global challenges.

DISCUSSION

The scenarios have been developed to portray plausible future environments which may have implications for the development and take up of digital innovations, business models and corporate strategies within the construction industry. They are also aligned with TCC agenda, particularly contribution to faster and cheaper construction, and importantly facilitating digital manufacturing in construction.

The scenarios presented reflect different environments in which companies and sectors of the industry could respond to facilitate adoption and implementation of digital technologies. If ‘utopia transformation’ represents an ideal scenario for successful implementation, then it would be logical if strategies should be devised to

shift the other three scenarios closer to 'utopia transformation'. The strategies/ actions for this beneficial shifting could be explored through several key differences between the scenarios, explained as follows. Considering dominant driver 'investment' in Table 2, in the 'utopia transformation', there is a synergy between public and private investments, whereas in the 'lonely investment', the investment is predominantly public, with little private sector contribution. This suggests that shifting from 'lonely investment' to 'utopia transformation' would require a more significant level of investment/ effort from the private sector. It is important to encourage private investment in IR&D, which is historically low in the current (contracting) business model (Gruneberg and Francis 2019). In the 'lonely investment' in contrast to 'utopian transformation, we foresee little collaboration. Nonetheless, we foresee UK unilateral policies driving digitalisation in the UK and in the construction sector. These policies can include (i) environmental standards, (ii) regulations to ensure safety, transparency, quality and accountability, and (iii) IR&D subsidies.

Considering dominant drivers of 'corporate movement' and 'outcomes' in Table 2, in 'utopia transformation', integration means collaborations amongst construction and other disciplines (which are external to construction, such as technology and investment companies), whereas in 'cheap combination', integration occurs internally within the construction industry to obtain competitive advantage with little regard to a wider public common good and sustainability. This suggests that 'utopia transformation' requires a shift in modus operandi that encourages more multi-disciplinary working, open innovation, and cross-sector participation. Digitalisation also means that we should consider training existing workforce with digital skills, and employing staff with different skill sets, such as data analytic skills. The industry would also need to be open to inputs from the manufacturing and digital sectors. Construction industry stakeholders should not feel threatened by investment made by other sectors, such as IT companies and investment banks, and instead, learn and adopt these innovations. Disruptive new entrants such as Google, leads to a significant amount of digitalisation in the sector. In the 'cheap combination', the Coronavirus pandemic leads to collaboration between WHO workers, global experts, governments and partners to rapidly expand scientific knowledge to protect health and prevent the spread of the virus. However, despite increased collaboration, recession leads to little money available for digitalisation. Consequently, there is a lack of technology adoption in the construction sector.

Despite a preference towards ideal scenario of 'utopia transformation', the other three scenarios have their own merit in bringing or providing environment for digitalisation. For example, 'bleak segregation' scenario may be the key to uncovering business opportunities and becoming more efficient out of necessity. We found in the focus groups/workshops that our scenarios provoked optimistic insights and imagination. The participants were optimistic with relative consensus regardless of the scenario. We also discovered imaginative/ creative ideas from the discussions including the development of modular building for electric vehicle parking that actively generates its own energy for battery charging in the discussion on 'utopia transformation'.

Feedback from the participants was generally supportive towards the scenarios. Participants of the workshop emphasised the need to depart from the current (contracting) business models to more long-term solutions that bring wider benefits and values to customers and society. To facilitate this, construction stakeholders should consider the provision of reward systems, active benchmarking, allocation of risk, contractual, intellectual property and insurance issues. The strategies should also

consider complexity of the currently fragmented supply chain. It is imperative that successful digitalisation for industry transformation would require radical change in the structure and culture of the industry to provide fertile ground for new business models to flourish. Here, the essential role of leadership and collaboration cannot be overemphasised.

CONCLUSION

Based on interviews and focus groups/workshops with industry practitioners, four scenarios for digitalisation of construction have been developed using scenario axes approach. Not only the scenarios describe how external factors provide environment for and impact on digitalisation, but they also raise many questions on what the industry stakeholders could do to influence the outcomes, particularly on important issues in relation to collaboration and investment. These factors are within the control of stakeholders, and to a large extent, will determine the pathways and the level of competitiveness of the industry, the companies and the individual stakeholders, derived from digitalisation. Based on this premise and the absence of ideal ‘utopia transformation’ scenario, appropriate strategies and actions of the construction stakeholders themselves can, to a great extent, shape the future outcomes. For instance, ‘bleak segregation’ scenario could lead to firms collaborating, investing in digital technology and becoming more efficient in order to survive. Alternatively, it could lead to firms being too apprehensive about the future and limiting investment.

The research has a few limitations. More data from wider participants may bring nuances to the scenario. However, careful analysis was undertaken to ensure that the scenarios reflect the opinions of the participants. Towards the end of the research, the Coronavirus pandemic struck, and the last workshop was organised via online mode. Participation during the workshop may have been impacted, but arguably, the online mode may also bring benefits, particularly, in terms of ability to solicit succinct and ‘to-the-point’ responses. Although the Coronavirus has been incorporated in the scenarios, its impacts on the industry are likely to be wider and more significant than what was originally thought. There are considerable uncertainties on this.

During the progressive development of the scenarios, the engagement with participants has provoked questions, stimulate discussions and debate on topics related to digitalisation. This is useful to identify and enhance understanding of problems and knowledge gaps in the journey of transforming construction. Apart from the resulting scenarios, the research highlights the benefits which could be derived from the process of developing scenarios for the participants (Soetanto *et al.*, 2011).

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SWEDISH LEAN CONSTRUCTION PRACTICES IDENTIFIED IN THE LAST DECADE OF RESEARCH

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Studies on lean construction (LC) can possibly point to differences in its practical realization (i.e. different coverage of construction processes), in order to fit certain purposes. Different LC practices may entail the implementation of parts of the bundle of concepts that constitute LC (e.g. Last Planner), or the integration of LC with other frameworks and tools (like BIM). The identification of such practices may lead to the emergence of certain positive outcomes, like initiating a discussion on suggesting new and/or updated LC tenets. Here, the contextual characteristics of different construction sectors are appreciated by focusing on the Swedish national context. We explore the last decade of research output documenting cases of LC practices in Sweden, and then we critically analyse this output to categorise these practices according to the construction processes they cover. Methodologically, a systematic literature review utilising the augmented concept-centric framework was conducted, and the abductive method was utilised to analyse the review outcomes. The main LC practices in Sweden are found to pertain heavily to production and strategy, while covering partnering, stakeholder collaboration, design, planning, and supply chains to a lesser extent. However, the knowledge of these practices is scattered, which precludes a more advanced adoption of LC in Sweden and prevents it from fully countering issues it is supposed to tackle - as shown in a recent report on the productivity in the Swedish construction sector. Moreover, through the years, there has been a heavy focus on industrialised, rather than “conventional”, construction. However, while the study of the former - which has a well-defined, but also modest market share in Sweden - has been precise and extensive, the needs of the latter have yet to be adequately addressed. These findings may entail that more work is needed for a stronger requirements-driven adoption of LC in Sweden.

Keywords: Lean Construction, industrialised construction, practice, Sweden

INTRODUCTION

Over the years, there has been increasing research and practical interest in lean construction (LC). LC is considered to have caused a paradigm shift in the industry (Tommelein 2015) and has been the focus of several contexts - e.g., Lean Forum Bygg in Sweden, which features several industrial partners (Lidelöw *et al.*, 2019). This growing body of knowledge can possibly point to variations in the way LC is practically implemented to address different practical purposes, as in e.g., Meng’s (2019) research on different building types in the UK. Different LC practices - understood as different ways in which LC tenets are used to cover various building

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processes - may entail, among other things: (a) the implementation of only certain LC processes and tools, like Last Planner (Neve and Wandahl 2018) and target value delivery (Ballard 2020), and/or (b) different levels of integration between aspects of LC and other frameworks and tools, like e.g., Building Information Models (BIM) (Dave and Sacks 2020) and integrated project delivery (Alves and Lichtig 2020).

Despite such attention on the differences in the practical adoption of LC, there have scarcely been studies on actually identifying the respective practices. The benefits of such identification, as can be envisioned through the insights of such efforts as Tzortzopoulos *et al.* (2020), may include: (a) providing a clearer image of the state-of-art, (b) facilitating the adoption of LC, (c) initiating a practical benchmarking, and (d) leading into the suggestion of new and/or updated LC principles and tools, specifically tailored to fit certain needs. Here we focus on a national context, Sweden, in order to appreciate that the diffusion of concepts (like LC) might be impacted by national institutional forces, and because it constitutes a researchable body of knowledge. In Sweden, there has been a growing research interest on LC, which in the middle of 2020 has culminated into more than 330 publications. Among them, a number of studies investigated actual examples of practical LC implementation. However, this number is relatively small, and the respective studies lack a specific direction on identifying distinct LC practices according to the construction processes they cover.

Given the aforementioned motivations, the aim of the current effort is twofold: (a) explore the research output regarding practical LC implementation in Sweden; and (b) attempt a construction process-driven identification of LC practices in the Swedish context, by critically analysing the aforementioned output. For the first aim, a systematic literature review covering the last decade (2011-2020), was performed. For the second aim, the studies found during the review were qualitatively discretised.

Following this introduction, the paper's theoretical basis and research method will be described. Afterwards, the content, analysis and results of the literature review, will be elaborated on and followed by a critical discussion. Finally, the current study will conclude with its final remarks and recommendations for future work.

THEORY

To identify LC practices in Sweden, it might be beneficial to first define LC itself. However, there is not a single and universally referable definition, but rather a bundle of relevant interrelated themes (Koskela 2020). Therefore, a systems theory approach (Arbner and Bjerke 2009) was adopted to synthesise a collection of fundamental LC aspects, in order to offer an overarching understanding (without claiming that it is exhaustive) and prepare for the analysis of the literature review.

Initially, lean manufacturing (LM) was utilised within the Toyota production system to streamline and internally improve production processes and product quality (Gao and Low 2014). LM focuses mainly on eliminating waste, i.e., activities not creating value for the customer (Koskela 2020). This can be critically facilitated through continuous production flow, with just-in-time product manufacturing (Liker 2004).

LC emerged as a particularisation of LM for construction (Koskela 1992). LC aims at waste elimination, efficient resource use, optimisation of workflow, on-time delivery of information and materials to project sites, minimisation of cost, and maximisation of customer value (Tzortzopoulos *et al.*, 2020). Koskela (1992) proposed 11 LC principles of flow process design and improvement: (1) reducing the share of non-value-adding activities, (2) increasing output value through systematic consideration

of customer requirements, (3) reducing variability, (4) reducing cycle times, (5) minimising the number of steps, parts, and linkages, (6) increasing output flexibility, (7) increasing process transparency, (8) focusing control on the complete process, (9) building continuous improvement into the process, (10) balancing flow improvement, and (11) benchmarking. Moreover, Koskela (2000) defined the transformation-flow-value (TFV) framework of production, which allowed these principles to be applied to construction management. According to TFV, inputs are transformed into outputs while materials (and information) flow through value-adding activities and waste, with end-customer value as the goal (Koskela 2000). As in LM, just-in-time can eliminate lead time and waste in LC, making products to-order (Koskela 2020). Moreover, on-site logistics and construction supply chains can be optimised by using prefabrication (Vrijhoef 2020).

In terms of LC foci, five areas have been highlighted: lean project management, lean supply, lean design, lean partnering, and cooperative supply chain management (London 2008). Regarding LC implementation, Green and May (2005) have identified three increasingly mature levels: (1) waste elimination from a technical and operational perspective, (2) elimination of adversarial relationships and enhancing cooperation and teamwork, and (3) fundamentally changing the project delivery.

METHOD

In order to identify the core literature central to the research question, a systematic review was conducted, for which the concept-centric framework augmented by units of analysis (Webster and Watson 2002) was used. By using this framework, the review could be gauged to approach completion when no new relevant concepts could be found (Webster and Watson 2002). The main concept was “LC practices in Sweden”. The emerged units of analysis included, indicatively, “lean thinking”, and “prefabrication”. This framework was enhanced by using the “snowballing” and references-of-references techniques (Greenhalgh and Peacock 2005), while conducting a targeted but comprehensive search (MacLure 2005). A relatively complete body of literature was initially accumulated (n=237).

In order to be more relevant to the current Swedish construction context, we focused on publications within the last decade. Hence, the start for the literature search was set to 2011, and the end to June 2020 (i.e. the submission date of this paper). 37 search engines featuring engineering and/or managerial content were initially tested. After omitting 27 engines that returned no results or results already included in other engines, the remaining 10 (each returning at least one unique result) were utilised: Chalmers Library, Chalmers Open Digital Repository, Taylor and Francis Online, Google Scholar, BASE, Semantic Scholar, WorldWideScience, Baidu Scholar, Mendeley, and Scopus. Operators were applied to seek the searched terms in the title, abstract, keywords, text, author affiliations, and references of each publication.

The review was conducted in iterations and resulted in a large number of aggregated hits per research engine and per year. Refining the initial results led to finding the unique studies pertaining to the aforementioned criteria. In case entire papers were featured in collective works by the respective authors (e.g. “umbrella” theses), only the collective works were included here. Moreover, due to space constraints, no conference papers were considered, which reduced n to 27. Exploring these unique studies to find the ones featuring empirical material on Swedish LC practices, resulted in the final selection of the 16 publications featured in the following section. A simple visualisation of the systematic review process is shown in Fig. 1 (next page).

The review iterations followed the abductive reasoning of qualitative research, where observations and explanations are developed by working iteratively between concepts and data (Bell *et al.*, 2019) - in this case, data as research content. The themes of conventional and industrialised construction became the prevalent distinguisher, and the differentiated coverage of construction process became the second distinguisher.

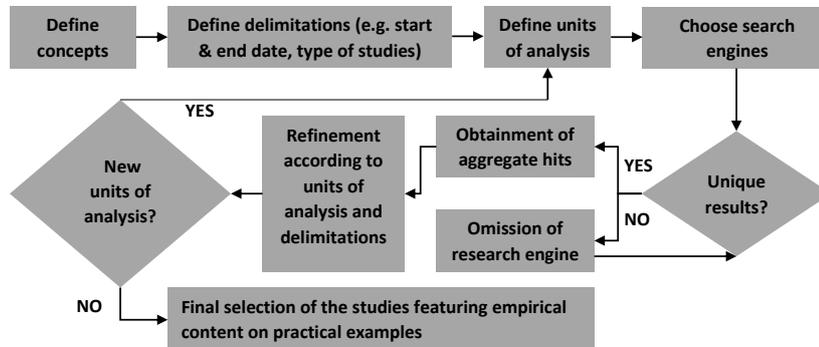


Figure 1: Flowchart depicting the systematic literature review process

RESULTS

Table 1 summarises the analysis of the 16 studies featuring empirical data on the practical implementation of LC in Sweden.

Table 1: Identified themes and LC-covered construction processes in the selected publications

References	Themes		Construction processes covered by LC practices					
	IND	CON	PROD	STRAT	DES	PLAN	SUP	PR/ST
Bildsten <i>et al.</i> , (2011)	x			x				x
Brege <i>et al.</i> , (2014)	x		x	x				
Gerth <i>et al.</i> , (2013)	x		x	x	x			
Haller (2012)	x				x x			
Jansson (2013)	x		x		x		x	
Jansson <i>et al.</i> , (2016)	x		x		x x			
Jonsson and Rudberg (2014)	x		x	x				
Lennartsson and Björnfot	x		x			x		x
Lessing and Brege (2018)	x			x				
Lessing <i>et al.</i> , (2015)	x		x	x				
Malmgren (2014)	x		x					x
Meiling <i>et al.</i> , (2012)	x		x					
Polesie (2012)		x	x					x
Psilander (2012)	x	x	x					
Simu and Lidelöw (2019)	x	x	x	x				
Tjell (2016)		x		x	x x			x
SUMS	16	15	4	12	8	5	4	2

Firstly, Table 1 features the themes of studies, by discretising them into the ones focusing on industrialised construction (IND), and the ones focusing on conventional construction (CON). It is shown that 13 studies focus exclusively on IND, two exclusively on CON, and two on both. Secondly, Table 1 features the construction processes that were reported in the respective studies as covered (sometimes overlappingly) by LC practices. These are described in more detail below.

Production (PROD) is the construction process covered in most studies, both IND- and CON-related (exclusively or overlappingly). It is mainly expressed through practical LC approaches to prefabrication and module and component construction (e.g. in Meiling *et al.*, 2012), technical analyses on performed production processes utilising LC (e.g. in Malmgren 2014), and the effect of practically implemented LC principles on production performance indicators, e.g., quality, delivery speed and

dependability, cost level and dependability, production flexibility (Johnsson and Rudberg 2014), and resource efficiency (Simu and Lidelöw 2019).

Strategy (STRAT) is mainly covered with regard to: (a) organisational practices and changes to accommodate LC principles, processes, tools, and product platforming (e.g. Lessing *et al.*, 2015), and (b) business models featuring practical LC (e.g. Brege *et al.*, 2014, Lessing and Brege 2018). While not being on the foremost concern of the respective studies, thus confirming Lessing's and Brege's (2018) observation mentioned earlier, STRAT is indeed the second most present process after PROD. It is applied exclusively for CON only in Tjell (2016).

The studies featuring the process of design (DES), express the practical interconnection of LC with frameworks like constructability (Gerth *et al.*, 2013), design-for-manufacturing-and-assembly (DFMA) (Gerth *et al.*, 2013), and product platform development (Jansson 2013). The practical integration of lean with tools such as digraphs for design process modelling (Haller 2012), visual management (Tjell 2016), and design breakdown structures (Jansson *et al.*, 2016), is also featured prominently. DES is explored mainly in IND studies, except Tjell (2016).

Planning (PLAN) often overlaps heavily with DES and PROD, and is featured almost exclusively in IND studies, apart from Tjell (2016). The practical implementation of Last Planner is exemplified (e.g. Haller 2012). Moreover, practically integrating other frameworks with lean planning, such as BIM (Jansson 2013), Knowledge Innovation/Visual Planning (KI/VP), and Obeya (Jansson *et al.*, 2016), is discussed.

Supply chains processes (SUP) are featured almost exclusively in IND studies. Different studies focus on practical LC implementation at different points across the supply chain; for example, Jansson (2013) investigated the transformation of the engineer-to-order approach to the make-to-order one, and Bildsten *et al.* (2011) argued for value-driven purchasing.

Partnering and stakeholder collaboration (PR/ST) is featured in one IND (Malmgren 2014) and one CON (Tjell 2016) study. In both studies, LC is identified as a facilitator for increased stakeholder collaboration. Malmgren *et al.* (2014) indicates that such a LC-facilitated collaboration can promote long-term commitments between clients and other stakeholders, rather than short-term relationships and opportunistic thinking. Tjell (2016) argues that LC-facilitated collaboration between the professionals in the design phase is crucial for increasing customer value.

The combination of the identified themes and the construction processes covered in the selected studies, indicates that within the last decade in Sweden, research has mostly reported on the LC practices pertaining to the production and strategy processes within industrialised construction. The focus on design, planning, supply chain management, and partnering and stakeholder collaboration has been smaller and scattered; whenever there was such a focus, it mostly regarded, again, industrialised construction. LC practices for conventional construction were investigated in only a few studies, where production was once more the main process covered. Figure 2 summarises the results of the analysis.

In Figure 1, the numbers in the bars indicate the amount of the selected papers that elaborate on the respective practice. There is an agreement between the results of our analysis and Lessing's and Brege's (2018) observation that research on industrialised construction has, historically, focused more on production and technical aspects, rather than organisational strategy and business models.

The focus on industrialised construction can be considered imbalanced in terms of its relatively modest market share in Sweden, which according to Brege *et al.* (2014), has recently been at 15% in the central case of multi-storey house apartments.

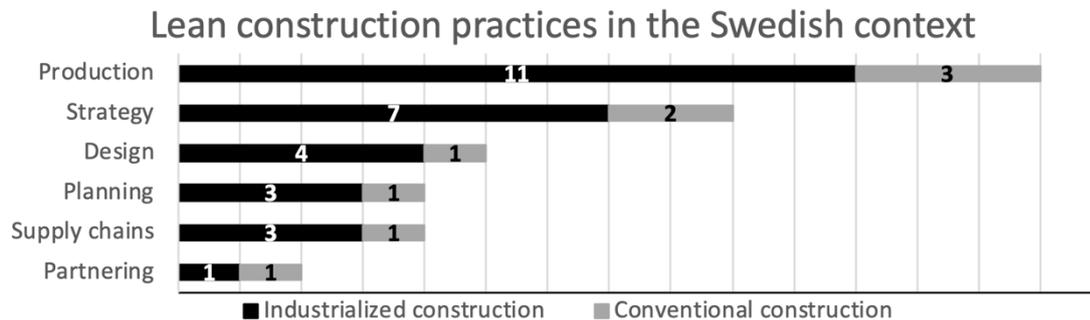


Figure 2: Summary of the results of the literature review

Moreover, apart from the end product itself (i.e. buildings and building modules), industrialised construction embodies a business approach that has been considered to diverge from conventional construction, and instead approach manufacturing (Malmgren 2014). This can mean that the practices explored in the respective studies, although designated as LC, might actually align better with LM. Indeed, Simu and Lidelöw (2019) note that in flow-oriented operation strategy companies (such as industrialised building firms), an ongoing empirical result is that they adopt LM rather than LC.

DISCUSSION

The material investigated in the present study clearly shows differences in the coverage of construction processes, but also large overlaps. Within the reviewed studies, an incomplete understanding of value from a LC lens, and a partial implementation of LC across the value stream, are prevalent. There is also a tendency to exemplify certain LC practices, but not elaborate on their actual positive or negative outcomes. Moreover, regarding the organisational context in most reviewed practical cases, there is largely an effort to tailor the organisation within lean, rather than the opposite. This has been posing, and continues to pose, a challenge in the adoption of LC tenets within construction management in Sweden, as there can be a dissonance between what is implemented and what is actually needed. This situation is accentuated due to the overt focus on technical aspects of production, which corresponds to the lowest level of LC implementation maturity in Green and May (2005). Indeed, the following two maturity levels, which could be considered as high-end goals for successful construction management, can potentially fall out when focusing only on waste elimination from a technical and operational perspective.

The present multiplicity of practices and their performance is sharply showcased in a recent industry-wide research report on the state of productivity in Swedish construction (Koch *et al.*, 2020), where, according to site managers, only around a third of projects actually feature LC - and there, the production costs are evaluated as higher (!) in all price ranges compared to the average of the other projects in the study. However, according to the respondents using LC, process parameters such as disturbance mitigation and schedule punctuality are improved. This indicates that there is a need for more LC competence in the industry, and a push towards requirements-driven LC adoption by focusing on its practical implementation and

understanding the way it affects not only project processes, but also organisational needs, culture, value streams, development, growth, and human interaction.

Considering industrialised construction specifically, current observations on the Swedish construction sector show that there is a concentration tendency; while the market share has not altered significantly in size over the years, there are presently fewer firms sharing it (Steinhardt *et al.*, 2020). Thus, a persistent research focus on the same, already significantly investigated companies, having a more or less solidified business model leaning heavily on manufacturing, may develop into giving somewhat less interesting and utilisable observations. Indeed, further research on the LC practices in the so-called conventional construction sector, may yield richer results.

Attention should also be drawn to the connection of the practices identified in research, compared to what is actually happening in the construction praxis itself. While some of the latest studies succeed in capturing facets of the current state-of-art (e.g. Simu and Lidelöw 2019), it is recurrent that research may lag behind practical LC developments, in subject areas like professional education and standardisation, digitalisation, project planning, logistics, stakeholder cooperation, and leadership (Lidelöw *et al.*, 2019). Resolving this tension would be beneficial for the Swedish construction sector and could simultaneously serve as a benchmark for other contexts facing similar issues. The kick-off for such a resolution could be the conduct of extensive empirical studies to update and deepen the knowledge on current LC practices, which could mark the boundaries of the state-of-art.

Questions about the generalisability of the present study beyond the national context can be raised. Construction sectors in different national contexts vary significantly (there can even be remarkable variations even within the same country or region), which would impede attempts of generalisation. Such variations obviously extend to the relevant praxis, including LC practices. Acknowledging these variations and trying to capture the specificities of a certain context can be considered a methodological strength, since research delimitations are more specifically defined and thin claims of universality are avoided. As such, the results of the current study, emanating from only Swedish context, are not considered generalisable. However, the reasoning behind the identification and reporting of LC practices, as well as the envisioned benefits from such an identification, have been recently noted in more generalised studies, e.g., Tzortzopoulos *et al.* (2020), as mentioned in the Introduction.

A last point in this discussion is the journey of the particular Swedish adoption of LC, something which is outside the direct focus of the current study, yet surfaces as an interesting set of reflections. The Swedish construction industry was not among the early adopters of LC, and when diffusion began, central LC elements were developed internationally. Nevertheless, the challenges Swedish construction management faced in adopting LC tenets over the last 10 years appear to be broadly the same as elsewhere - such as the lack of support to site managers' LC implementation, and/or the resistance to top down initiated change (Koch *et al.*, 2015). Training offers and other institutional support was established around 2009, shortly after the dominance of the interpretation of LC as factory production was established. It is likely that this even drew on and borrowed legitimation from the Swedish manufacturing industry, which had been actively adopting lean, drawing on the Toyota production system (Liker 2004). Apart from this characteristic early dominance of factory production and its split between with conventional production, it is likely that the adoption of the

LC concept follows patterns of many other management concepts - i.e., picking parts of the full concept and shaping it to local needs, thus giving the adoption different scopes in the building processes and firms (Kamp *et al.*, 2005). A particular example of this is the presence of a design variant, which largely can be ascribed to one large Swedish contractor with a practice of doing design-build contracts.

CONCLUSION

The research of the last decade which features empirical material on the practical implementation of lean construction (LC) tenets in the Swedish construction sector, can facilitate the possible understanding of relevant specific practices. Current research on such practices is far more focused on industrialised rather than conventional construction. Moreover, it primarily focuses on production and then strategy, with other processes (such as design, planning, supply chains, partnering and stakeholder collaboration) receiving much less attention. In short, the main identified LC practice in the Swedish context pertains to production within industrialised construction.

Identifying LC practices can be the first step in tackling certain issues within LC research and praxis in Sweden, e.g., properly understanding value within the value stream, accounting for the organisational context, balancing the foci on conventional and industrialised construction, resolving productivity-related issues, and capturing the state-of-art. As future work to corroborate the results of the present study and further facilitate the tackling of the aforementioned issues, in-depth empirical studies (interviews, surveys, visits to construction sites and production plants) across a wide spectrum of the Swedish construction sector, are recommended. A longer-term aim is to suggest new and/or updated LC principles and tools, mainly focusing on context-specific social and cultural aspects, and also support decision-making via advanced technologies.

The identified practices, problematisations and recommended future work of the current study, may focus on the Swedish context, but can be used as blueprints for studies in other specific construction contexts sharing tangential characteristics.

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CHALLENGES IN THE DIGITAL TRANSFORMATION OF LEAN DESIGN METHODS: A CASE STUDY

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Lean design, a major lean construction focus, entails a number of various methods which are practically implemented. Among them, the lean design-inspired concept Project Studio (PS) has been utilized since 2011 by a major Swedish contractor, to facilitate and standardize the design process in conjunction with collaborative planning. PS promotes the face-to-face communication and collaboration of designers within the same physical project space, by using visual analogue tools, fostering creativity, and facilitating mutual learning. Following the digitalization paradigm shift in the construction industry, the aforementioned contractor sought to digitally transform existing flows, processes and tools, as part of its operational strategy. This course of action included PS, which was digitalized in 2017 via cloud applications seeking to optimize its performance, increase scheduling availability, and facilitate the question-answer handling outside of the PS physical project space. In the current paper, the digital transformation of PS is critically analysed. Methodologically, the abductive reasoning of qualitative analysis is adopted, by working iteratively between a preliminary targeted literature review performed through the concept-centric framework, and the qualitative field data obtained in a case study that was conducted by observing an in-company competence course. While it was noted that through the digitalization of PS some benefits were indeed brought about (e.g. higher detail of deliverables and remote access capabilities), the major results of this analysis were rather alarming. The critical observations showed a large variation on the understanding and utilization of the cloud tools (which in themselves could not adequately replace any of the PS existing working methodologies), more time-consuming meetings, frequent misinterpretation of digitally exchanged information, mobility reduction in the PS physical project space, and stakeholder dislocation. These results can be tied with the general discussion of the possibly negligent way of introducing and utilizing digitalization within construction (following the current hype), the largely unfounded perception that digital tools make processes self-propelled, and the still existent unavoidable discrepancies emanating from the disassociation between developers and implementers.

Keywords: Lean Design, Project Studio, digitalisation, cloud-based tools, challenges

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INTRODUCTION

Lean design (LD) is a major focus of lean construction (LC) and aims at optimizing the management of the design phase of a construction project (London 2008). Such an optimization can entail that LD is integrated with frameworks, concepts and tools of collaborative planning (Herrera *et al.*, 2020), such as visual management (Tjell 2016).

There are evidently construction firms implementing an integration of LD and collaborative planning to attain the aforementioned optimization (Tzortzopoulos *et al.*, 2020a). Among them, a major Swedish contractor has utilized Project Studio (PS) since 2011. PS is a LD-inspired methodological concept to collaboratively plan, facilitate and standardize the design process. By using visual analogue tools, PS promotes face-to-face communication and collaboration of designers within the same working space, thus fostering creativity and facilitating mutual learning. Interestingly, PS was digitalized in 2017 via cloud applications, in an effort to optimize its performance, increase schedule availability, and facilitate the question-answer handling outside of the PS physical project space. This was decided by the contractor as part of its operational strategy, which sought to digitally transform existing flows, processes and tools - a decision that is not particularly surprising, as it follows a major current paradigm shift of digitalization within the industry (Elshafey *et al.*, 2020).

However, the full effect of this paradigm shift has not yet been adequately evaluated and can be subject to scenarios (Lavikka *et al.*, 2018). This inconclusive evaluation can also concern the digitalization of LC (including LD), especially in contexts where the results of implementing lean are, in many cases, still tentative - such as in relation to construction productivity in Sweden (Koch *et al.*, 2020). Therefore, it would be useful to document practical cases of such a digital transformation, in order to understand the potential disruption that has been possibly brought about in the corresponding specific context. The insights derived from such context-specific cases can then be juxtaposed and help form a bigger picture tied to wider discussions on the way digitalization is introduced, facilitated, and implemented within construction.

THEORY

LC emerged as a particularization of lean manufacturing for construction (Koskela 1992). It aims at waste elimination (namely, the elimination of unnecessary tasks), efficient resource usage, workflow optimization, on-time delivery of information and materials to construction sites, cost minimization, and customer value maximization (Tzortzopoulos *et al.*, 2020b).

LD is one of the five major foci of LC, along with lean project management, lean supply, lean partnering, and cooperative supply chain management (London 2008). Specifically, LD introduces several LC tenets that can be fundamentally applicable in the design phase of a construction project; these can include, among others, active and systematic early client involvement, value maximization, identification of stakeholder needs, simultaneous realization of product and process design, and just-in-time decision-making in order to reduce waste (Gambatese *et al.*, 2017). While several of these tenets have also been proposed in a scattered manner by a number of managerial frameworks pertaining to the design phase, lean design can group them into a single framework of best practices (Herrera *et al.*, 2020).

In order to optimize the management of the design phase, LD can utilize several lean concepts and tools, such as the Last Planner system (LPS) (Fosse and Ballard 2016),

target value design and set-based design (Alves *et al.*, 2017), design structure matrix (Tzortzopoulos *et al.*, 2020b), and choosing by advantages (Tzortzopoulos *et al.*, 2020b). It can also be integrated with other frameworks, such as Virtual Design and Construction (VDC) (Kunz and Fischer 2012), Building Information Modelling (BIM) (Dave and Sacks 2020), location-based planning (Seppänen 2020), and collaborative planning methods like visual management (Tjell 2016). Collaborative planning can be especially suitable for integration with LD, since it fosters cooperative and collocated social processes that are at the core of the lean concept and have proved to be particularly beneficial in the framing of tools like, for example, LPS (Fosse and Ballard 2016). More specifically, collaborative planning builds upon the same ground as LPS; it ensures that the tacit knowledge of participants is being used and embedded in the planning, thus improving its quality, accuracy, and adherence to the decided-upon plans (Seppänen *et al.*, 2010, Friblick and Nordlund 2013).

Over the last two decades, the utilization of VDC and especially BIM, has furthered the possibilities of a wider digitalization in the construction sector by enabling new tools and forms of collaboration (Alaloul *et al.*, 2018). With the increased digital transformation of the construction industry, aspects of LD are also in the process of being digitalized (Tezel *et al.*, 2020). This emerges in good agreement with practice, since the design process today is mostly digital; the deliverables are in CAD format, and there has been a gradual shift from delivering paper drawings to digital ones (Harty and Whyte 2010). At the same time, the use of the underlying data existing in the structures of the aforementioned digital frameworks, enables a more integrated information and communication flow through design and construction (Alaloul *et al.*, 2018) - a central LD goal (Gambatese *et al.*, 2017).

METHOD

In this section, there will be an elaboration on the research method regarding the literature review capturing the fundamentals of the current study (featured in Theory), the conduct of the case study, the synthesis of the review findings and case study outcomes, and the critical analysis of the synthesized results (featured in Case Study, Analysis, and Results).

For the literature review, the concept-centric framework augmented by units of analysis (Webster and Watson 2002) was used. This framework was supported by the references-of-references and “snowballing” techniques (Greenhalgh and Peacock 2005). The main concepts of the review were “lean design”, “collaborative planning”, and “digitalization”. The emerged units of analysis included, indicatively, “virtual design and construction”, “visual management”, and “collocation”. The conducted search was aimed to be targeted but still comprehensive (MacLure 2005); therefore, a wide collection of search engines featuring engineering and/or managerial content, was utilized. There was an application of operators to seek the terms of the searched concepts and units of analysis everywhere in each of the relative publications found in the search engines: title, abstract, keywords, text, author affiliations, and references. This process initially resulted in a large number of aggregated hits per research engine and per year. Refining the initial results by specifying incrementally more targeted units of analysis, led to finding the studies that were finally included in the paper.

The case study itself was approached with a qualitative lens, as the research was about understanding and depicting a present situation involving socio-technical phenomena and interrelations between humans (Yin 2009, Easterby-Smith *et al.*, 2014). Data in such case studies can be collected in a number of ways (e.g. observations, interviews,

informal communication, collection of written documentation) (Yin 2009). For the current paper, a mix of such methods was used, and most prominently internal analyses, observations, informal communication, secondary obtainment, and collection of written documentation. Such mixing can enable the triangulation and validation of the collected data (Easterby-Smith *et al.*, 2014). This was deemed important for the validity of the paper's critical results and was also something of special relevance for the current study, since two of the co-authors have been and still are employed by the company where the case study was conducted. Throughout the case study, one of the co-authors that have been employed by the firm used their well-established company network to fully access new and ongoing information, while the rest of the co-authors were allowed a typically partial and ordained company access.

The synthesis and critical analysis of the literature review results and the case study outcomes, followed the abductive reasoning of qualitative analysis, where observations and explanations of phenomena are developed by working iteratively between theory (i.e. the literature review results) and data (i.e. the empirical findings of the case study) (Bell *et al.*, 2019).

Case study, analysis and results

As mentioned in the Introduction, a major Swedish contractor introduced and has been utilizing the LD- and collaborative planning-inspired concept Project Studio (PS) since 2011. PS integrates LD and collaborative planning tenets to plan, facilitate and standardize the design process. This introduction also followed the (then) rising demands that both VDC application and the corresponding internal strategy should be able to handle megaprojects. The aim of introducing PS was to enable all involved design team members to contribute with their full knowledge and creativity (by encouraging a shared responsibility among them) for the development and delivery of the design documentation with the right quality and at the right time.

The approach of PS consisted of three aspects: structured work methods of visual management, collocation, and VDC. The first aspect (structured work methods) engaged the involved design members through analogue visual management tools such as pull planning (e.g. with Post-It stickers on a whiteboard), A3 sheets, and to-and-from matrices. The objective was to increase collaboration and enable the design team members to stay focused on the project goals throughout the design phase. The second aspect (collocation) was about creating trust and understanding among all the involved design team members, who shared a common physical project space which was called the PS room.

Its goal was to create an environment where knowledge embedded in action could be shared among the team members, as it was believed that a lot of knowhow could be disseminated by observing the actions of others. Furthermore, informal communication was facilitated, as it was considered that a lot of cooperative solutions can increase quality, provided that they are well worked through during the creative part of the design phase. The third aspect (VDC) enabled continuous data and information streams throughout the entire life-cycle (and especially the design phase) of the respective projects.

Through the implementation of PS, it was observed that changes and optimization were easily implemented during the design phase, leading to higher-value and less expensive solutions in comparison to cases where obstacles were discovered late during construction. However, there were material and procedural difficulties in the implementation of PS as it was; these included post-it stickers not being "sticky"

enough and thus making the pull planning process cumbersome for the designers, long notes that had to be taken manually, knowledge facilitation mainly for people in the PS room and seldomly for external colleagues, the PS rooms requiring large spaces that were sometimes difficult to provide within the respective office premises, design managers consuming too much time digitalizing the notes after the PS meetings, and information connected solely to the physical space occupied by the PS room.

These difficulties led to a gradual process of digitalizing PS. Sometime before 2016, the design team members began using an application to take and share photos of the post-it notes on the visual timetable. Finally, the contractor decided to start testing a fully digitalized version of PS in 2017 via cloud applications (e.g. Apricon, Yolean, or online “whiteboards” where “stick notes” in the form of written text could be uploaded). The aim was to optimize the performance of PS by increasing scheduling availability and facilitating the question-answer handling outside of the PS room. However, as will be shown below, this digitalization was impaired by a loss of focus on understanding and implementing the essential aspects of PS itself and was coupled with relative challenges.

The observation and analysis of such challenges was conducted through a case study in the calendar year 2019, embedded in an in-company competence course. Four internal design managers (two men and two women) from two different Swedish regions where the contractor operates, were coached by an internal lean specialist in a number of sessions, in order to make root cause analyses about their respective challenges and outcomes regarding the digitalization of PS. The coaching was conducted in a way that the design managers were handling in their assignments on a regular basis, and afterwards received feedback to gradually enrich their analyses. The authors of the current paper participated in various degrees and with different roles (e.g. observers, facilitators, note-takers) through this year-long case study, and had a series of meetings for the juxtaposition, processing and analysis of their accumulated data and observations after the in-company competence course sessions.

Initial observations entailed that while the first introduction of PS back in 2011 followed, among others, a demand of optimizing the handling of megaprojects (as was mentioned before), the digitalized PS was respectively applied for middle-sized projects in each of the regions. Middle-sized projects are ones with a budget of 50-500 MSEK (ca £4.2-42 million). Such projects are often considered challenging, because they are given little time for the design phase, even though they can hold a high degree of complexity. Consequently, less ideal collaborative constellations of designers can be formed during the design phase, often leading to suboptimal results regarding the design solutions and documentation. Accordingly, while it was assumed that the digitalized PS would make the design phase more effective and would help resolve the issues leading to the aforementioned suboptimality, the outcome was actually the opposite. The digitalization of PS actually impeded the concept from being used in the intended way - as described in the following.

In one of the observed regions, digitalized PS was extensively applied. It was noted that some benefits were indeed brought about; these included a higher detail of deliverables, remote access capabilities, better progress documentation, and better allocation of documentation responsibilities. However, and despite these benefits, the application was found to not yield the expected leverage. The digitalization, while initially conceived as a way to optimize PS without losing the focus on the actual method, ended up being considered as the driving force for PS, in the hopes that it

would automatically save time and provide increased accessibility for the design team members. However, the case study findings led to the realization that by applying the digital tools, the focus on the actual work method was lost and a number of setbacks were apparent. It was found that there existed a large variation on the understanding and utilization of the cloud tools (which in themselves could not adequately replace any of the PS existing working methodologies).

The meetings ended up being more time-consuming, and sometimes derailed in a situation where the participants were just trying to interpret the digital information previously exchanged. Notes stemming from the digitally exchanged information had to be prepared between meetings - while in the case of the “analogue” PS, the notes would have been directly shared in the PS room. The actual visual aspect of co-handling information was largely lost, and the digitally exchanged information was frequently misinterpreted. There was mobility reduction and stakeholder dislocation in the PS room, which could mean that material that could be previously communicated face-to-face and elaborated on right there and then, ended up needing further elaboration after it was exchanged digitally. The digitalization actually increased the time the designer managers needed to tune in to the schedule, which proportionally decreased the time for actual productive collaboration. In the effort to reduce the design manager’s manual handling of information in the design phase, the digitalization of PS actually prolonged the time that the designers had to spend on this phase. Moreover, the design managers themselves faced the risk of losing out on the project overview, since the digitalization of PS meant, in some cases, that the incorporation of solutions was done solely by the designers themselves due to their dislocation.

In the other region, the implementation of digital PS was in its early stages. That region initially reached out for more digitalization, as they believed that by applying digital tools, they would improve the regional offices’ potential of working with the collocated design approach which was required by the company. This reaching-out was also driven by material and spatial limitations in the regional office, as the premises were not considered ideal for implementing the “analogue” version of PS. Furthermore, some clients perceived that the demands of PS for collocated physical participation unnecessarily increased the design cost. However, while some benefits (like remote access capabilities) were realized to some extent, it was found that the resources applied during the digitalization of PS were not utilized in their full capacity for being properly implemented in the respective projects. An initial lack of fully understanding the PS method was accentuated by introducing the digitalization of the respective tools and processes, as a lot of focus was directed on learning to use the digital systems rather than the LD and collaborative planning tenets that are essential to PS. There existed, again, a large variation on the understanding and utilization of the cloud tools, followed by inertia in certain standard digital processes (e.g. logging in and out). The visual co-handling of information was impaired, resulting in time being consumed in the interpretation of information that was previously exchanged digitally. The designers were dislocated, and they somehow continued to face material problems, as the lack of space for the implementation of PS, was now replaced by a lack of sufficient access to monitors for the implementation of digital PS.

The work carried out by the two groups led to an internal company workshop, which took place in the end of 2019 and was also attended by the authors of this paper, concluding the data gathering for the currently delineated case study. In this

workshop, more than 80% of the whole company's design managers participated. Its purpose was to discuss the drivers and challenges related to implementing digital tools in the company's current design approach. During the workshop, the challenges and outcomes of digitalizing PS were discussed and showcased by the internal lean specialist; during this process, the results of the analysis of the current case study were confirmed and validated.

DISCUSSION

While belonging to the same company and sharing similar motivations for implementing both the initial PS and its digitalized version afterwards, the two regional offices varied in their material, digital and human resources, their relationship with the respective project clients, their initial understanding of PS itself, and the level of digitalization they implemented at the time this case study was conducted. However, the observations from the gradually enriched root cause analyses conducted by the design managers of both offices, were largely consistent in their identification of challenges and outcomes (both positive and negative) of digitalizing PS. It can be understood that the negative outcomes outweighed the positive ones - a result that is rather alarming and leads to a number of critical reflections.

While not having this intention, the digitalization of PS violated central LD and collaborative planning tenets, upon which the method of PS was collectively based. Major violated LD tenets included, among others, the systematic stakeholder (mainly, the designers and design managers) involvement during the design phase, and the just-in-time decision-making in order to increase value. Major violated collaborative planning tenets included, among others, the direct exchange and embedding of the designers' tacit knowledge, and the taking place of social processes (like e.g. collocation and visual management) that in turn facilitate visual planning.

These violations and negative outcomes are due, in part, to a largely unfounded perception that digital tools could make processes self-propelled. In the observed cases, the professionals seemed to rely (at least, initially) on the digital tools as the drivers rather than facilitators of the PS method. This led to situations where instead of tailoring the tools to fit the method, the method started being inconsistent to fit the structure of the tools. A stark example is the one regarding the solutions supposed to be visually communicated through pull planning during the PS sessions; while the physical dimensions of the material post-it notes in the "analogue" PS entailed that all noted information should be short and on-point, the digital notes uploaded on the cloud tools could fit whole paragraphs of text, making them very similar to actual e-mail exchanges and beating the point of being laconic and precise.

Moreover, there are still existent discrepancies emanating from the disassociation between developers and implementers of the digital and/or cloud systems. While developing such tools can necessarily entail a mechanistic and more static understanding of the concepts, methods, and principles for which the tools are developed in the first place, their actual implementation can follow an unpredictable and out-of-the-box path. It is largely impossible to envision all different implementation scenarios when developing the respective tools, which may entail that a level of disassociation is unavoidable. However, it may be suboptimal to justify the negative outcomes and major challenges in the digitalization of PS on the grounds of this "unavoidable" disassociation, by accepting it on an "it what it is" basis. Indeed, the disassociation between the tools' development and implementation could be mitigated by more active collaboration between the developers and the implementers.

In that sense, it would be beneficial to establish a platform where the users of PS and other LD and collaborative planning methods, processes and tools (who are, at the same time, implementers of the digitalized and/or cloud systems), can form a continuous feedback and experience exchange platform with the developers. Such a platform could include collaborative workshops and information-exchange fora.

The identified challenges in digitalizing PS can also be tied to a wider discussion of the possibly negligent and in some cases hype- rather than requirements-driven way of introducing and utilizing digitalization within several contexts of the construction sector. This can also apply to general-purpose technologies, like machine learning and blockchain. A number of recent studies have drawn attention on similar and related considerations, like e.g., Moscati and Engström (2019), and Elshafey *et al.* (2020).

However, we do not claim that digitalizing LD and collaborative planning, as it was reflected in the digitalization of PS, should be avoided. Indeed, we believe that it can be valuable and useful, provided that the optimization of the respective core methods and flows is given attention. Our study has shown that a number of benefits were indeed realized in the first place, and any negative outcomes were almost exclusively connected to a lack of understanding of the way the new digital tools can be coupled with the underlying concepts, methods and processes without violating them. Therefore, resolving such challenges should not be translated into avoiding digitalization itself, but rather carefully and knowledgeably embedding it in the respective context. The situation of having to work with different and unavoidably long-distance processes that were disruptively brought about by the recent coronavirus pandemic, has also shown that digitalization and cloud communication and collaboration might be the principal ways to conduct business in certain contexts. This entails that approaching these processes optimally is even more crucial.

CONCLUSION

Lean design can be centrally integrated in conjunction with collaborative planning, in order to better facilitate, standardize, streamline and optimize the design phase of a construction project. In practice, a major Swedish contractor has attempted to reap the benefits of such an integration, by utilizing the lean design- and collaborative planning-inspired concept Project Studio since 2011; this concept promotes face-to-face communication and the collaboration of designers within the same physical project space, by using visual analogue tools, fostering creativity, and facilitating mutual learning. In 2017, after years of successful implementation, the firm opted for digitalizing Project Studio via cloud applications, seeking to furtherly optimize its performance, increase scheduling availability, and facilitate the question-answer handling outside of the Project Studio physical space. In this paper, we tried to critically analyse this process of digital transformation, by conducting a qualitative case study that was preceded by a targeted literature review.

The results show that while some benefits were indeed brought about by this digital transformation (e.g. higher detail of deliverables and remote access capabilities), the digitalization of Project Studio was rather problematic. There has been a large variation on the understanding and utilization of the cloud tools (which in themselves could not adequately replace any of the Project Studio existing working methodologies), more time-consuming meetings, frequent misinterpretation of digitally exchanged information, mobility reduction in the Project Studio physical space, and design team members' dislocation. These results can be tied with the general discussion on potential problems emanating from the possibly negligent way

of introducing and utilizing digitalization, not only within lean design, but within the construction sector in general. Moreover, there is a largely unfounded perception that digital tools can make processes self-propelled, resulting in a loss of focus and/or competence in understanding and utilizing the underlying methodologies which are being digitally transformed. Finally, there still exist discrepancies emanating from the disassociation between the developers and the implementers of digital solutions.

This work is delimited by focusing on a case study conducted within a specific contractor company and in a specific context (that of the Swedish construction sector). While the derived insights can be a starting point for a relevant problematization, this study cannot solely and by itself lead to generalized conclusions pertaining to the full Swedish context, let alone the construction industry *en large*. Therefore, the conduct of a series of progressively wider observational case studies is recommended as future work; this can take place first in more companies within the same context, and then in more contexts (the construction sectors of other regions or countries).

Despite any setbacks, the digital transformation of lean design and collaborative planning, as well as numerous other aspects of construction, is a train that cannot (and, largely, should not) be stopped. Therefore, going through with it in the most informed way is important for the actual attainment of the respective envisioned benefits. We hope that our study can offer a step towards the right direction.

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ETHNOGRAPHY, IMPRESSION MANAGEMENT AND SHIFTING PRACTICES

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The use of ethnographic methods in construction management is increasing. Impression management challenges the ethnographic researcher, who follows one actor on a building site. Shadowing allows a researcher to follow particular participants to observe their bodily movements and use of artefacts. Impression management happens when the observee acts in a different way than he/she would routinely, due to the presence of an audience. In the case of shadowing, the researcher can become an audience, as will the readers of the findings from the investigation. A study into contract managers' practices on-site uses shadowing as its primary method for data collection. A contract manager is being observed to gain an insight into the practices in which he participates. However, impression management presents a very noticeable challenge from the beginning of the study. We show how the researcher is perceived as an audience and how this prompts the observed contract manager to reflect on the practices on-site in dialogue with the researcher. On this basis, we raise the question, whether the continued performance of impression management by practitioners due to prolonged fieldwork can lead the observed practice to shift. In conclusion, we argue that the use of shadowing on a building site allows for insights into the complicated practices on site, but it may also influence and displace these practices.

Keywords: ethnography, impression management, research methods, shadowing

INTRODUCTION

We are on a building site. A discussion between a contract manager and his subordinate about construction solutions is about to take place. As I am at the beginning of the study and the contract manager may not be used to my presence, I suggest going elsewhere. The contract manager says; "No need, you have a good effect on me". The subordinate turns up. He is a graduate of the university college, where I used to teach. I haven't taught him myself, but he knows who I am and calls me by my name. The two discuss a construction solution. At a point, the subordinate sketches a solution. He looks nervously over the shoulder at me. The contract manager laughs. I am caught off guard and say: "I don't have any opinion at the moment". This prompts the contract manager to say: "It is fantastic to be in the company of a woman without any opinions". This is becoming one of his catchphrases.

The use of ethnographic observations in construction management research is increasing (Pink *et al.*, 2013). Ethnography is part of the toolkit for investigating practices (Gherardi 2012; Nicolini 2012; Czarniawska 2013; Bueger 2014). In this

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paper, we will use Gherardi's (2012: 3) definition of practice as “[...] a practiced, habitual, taught and learned activity that constitutes the job and requires expertise.”. Ethnography allows for observing bodily movements and the usage of artefacts and these observations can be used to interpret the implicit knowledge of the practitioners to give insights into their practice (Bueger 2014). An often-stated advantage of the ethnographic description is that the findings become compelling; the findings show the observee’s practices rather than just telling about them (Kärreman 2016). Compelling stories from life as a professional in the construction industry has been produced by Grosse (2019), who by using an auto-ethnographic approach is able to reflect on his own emotions and actions. Löwstedt (2015) also inserted himself as an active participant on-site, which has resulted in clear descriptions of work on the building site. Both researchers actively performed the practices on-site. Other researchers observe the practices on-site for shorter or longer terms (cf. Pink *et al.*, 2013). The ethnographic reports will always be influenced by the researchers as the ethnographers become a filter between the observee and the reported, as they choose what to write down and how to report (Emerson *et al.*, 2011). However, the description is also influenced by the observees' choices when deciding how to perform their practice. This is seen in the above description of an observation from a building site, where the researcher’s presence on-site prompts the construction manager to seemingly reflect on his practice as well as the role of the researcher.

The opening observation demonstrates the challenge with the compelling thick descriptions arising from ethnography caused by the performance of the observee as well as the observer. Goffman (1959: 235) is recognized for his work with impression management and argues, “*when an individual appears before others, he knowingly and unwittingly projects a definition of the situation of which a conception of himself is an important part*”. For ethnographic studies, it means that both the researcher and the observee will adjust their behaviour in accordance with their perception of the situation. Impression management may thus cause the observees to reflect and learn about how their behaviour affects their performance, which may cause them to change their behaviour.

The purpose of this paper is to address if fieldwork on a building site prompts impression management on behalf of the actors, which may change practices on-site. A construction manager is being shadowed. We show how the researcher’s presence on-site prompts the construction manager to change behaviour and reflect on his practice in dialogue with the researcher. On this basis, we consider the role of impression management; how the observee is influenced by the researcher as an audience, and how the observee might be changing his/her performance of his/her practice.

Ethnography, Impression Management, and Practice Shift

Although the challenges presented are not new, they still deserve attention due to the context of the project organization on-site as we discovered during our investigation into inter-organizational collaboration on a building site. We begin this theoretical section by outlining how we understand the practices on a building site. This is followed by sections describing the challenges of observing practice on a building site and how practices may be performed for the researcher on site.

Perspectives on Practices

The practice-based approach allows for investigation into how work is done, what sense it makes, and what relations it establishes rather than the traditional

interpretation of work with its focus on task analysis and workflow (Gherardi 2012). Practice theory is often used to understand difficulties in knowledge sharing and learning between practices (Carlile 2002; Bechky 2003). Nevertheless, even though practice-theory is very much about boundaries, it is important not to consider practice as a unit with clearly defined boundaries. This would “*re-introduce structuralist and functionalist pre-occupations that practice theory had tried to eliminate...In other words, the attempt to bind the operational unit of analysis by drawing up lists of inclusion and exclusion criteria takes us outside practice theory and more towards a traditional functionalist and positivist paradigm*” Nicolini (2012: 180). It is therefore important to respect that it is difficult to distinguish one practice from another and to observe widely. Bueger (2014) thus finds that practices are often nested inside each other.

As a unit of analysis, practice is thus strangely undefinable in terms of boundaries even though it promises to create an understanding of what people do when they work. In this study, we acknowledge Feldman and Orlikowski's (2011) idea of three ways to research practice: (i) as a phenomenon (what does the actors do, which tools do they use, etc.), (ii) as a perspective (by using a practice theory to understand an organizational phenomenon and see how practice shapes the organizational reality); and (iii) as a philosophy (we can discover how the practices produce the organizational reality, practice is part of reality). The organizational phenomenon studied is collaboration, which we at present consider moments in the practices of the contract manager. Schatzki (2010: 130) describes: “*the chain of action that link football players on the pitch are mostly made up of actions that are moments of football practices.*” The chain of action can thus be a football game, where the interaction between actors should be considered a moment rather than the practice itself.

Observing Practice

Researching practice as a perspective involves an interest in an organizational phenomenon, in our case collaboration. We consider collaboration as moments in practice, so our attention is directed at practices as a phenomenon. It is only at the analytical stage we will begin to focus on collaboration and how it shapes organizational reality (practice as a perspective) as well as how practice becomes organizational reality (practice as a philosophy).

One way to gain an understanding of practice is through ethnography. The ethnographic approach always encounters at least four challenges: problems of participation, time, space, and invisibility (Czarniawska 2013). It is recommended to stay in the field for a long time to minimize the effect of impression management, so the observee learns to trust the observer and relax (Hammersley and Atkinson 2007; Czarniawska 2013). Löwstedt (2015) argues that a high level of engagement can be one way to gain insight from the site even in short periods. Moeran (2006: 72) argues that the researcher should attempt to achieve a status as a person-in-the-know; a person in front of which particular performances cannot be maintained. He found this status “*was not something organic, developing with the amount of time we spent together. Rather, it was a formal relationship that was automatically extended and accepted as soon as I took my place on the team.*” He then argues for a shift from participant observation to observant participation. Direct engagement or participation is not always an option for researchers due to their skills/wishes, and so a non-participation observation technique may be employed.

Non-participation observation can either be shadowing or stationary observation (Czarniawska 2013). Shadowing solves the problem of space as it allows the researcher to move with the observee. It becomes possible to follow the action, which at times can be challenging as Marshall and Bresnen (2013) experienced. However, as we have discovered, shadowing does not deal with the problem of invisibility; the observees can be very aware of their audience and perform accordingly. Researching practice as a phenomenon is thus challenged by impression management.

Performing a Practice - Impression Management

Impression management concerns itself with maintaining an impression of the self. It involves two different kinds of sign activity: the expression that the performer gives and the expression he/she gives off (Goffman 1959). The performers are active in this sign activity and can use defensive and protective practices to maintain their impression. The individuals are maintaining some impression towards with their team. They are also as a team working together to maintain a team impression - and they do this in front of an audience, which is an opposing team (Goffman 1959). Goffman (1959: 201) argues that the result of the human want for social contact and companionship takes two forms: "*A need for an audience in front of whom to test one's performed self and a need for teammates with whom to enter into collusive intimacies and relaxation when out of sight of the audience*". The idea of teams performing to and for each other can be used to create a link between the individual and the organization, argues Moeran (2006: 70); "*It is this meeting of opposing-but-colluding teams that forms the basis of the business pas de deux that is to be danced thereafter.*" In this way, the performance of the individuals needs to be adjusted so it can be accepted by their team. They are performing as their organization is expecting them to. And in the language, he/she is not referred to as Mr./Mrs. X but as "Organization X" (Moeran 2006).

The sign activities and performances take place in front of an audience but also in a setting. The front region or stage is used "*to refer to the place where the performance is given*" (Goffman 1959: 110). The performance is given to the other participants e.g., at a meeting. The front region often takes place in a specific setting; it can be an office or meeting room. A back region or stage is, where "*suppressed facts make an appearance...it is here the performer can relax; he can drop his front, forgo speaking his lines, and step out of character*" (Goffman 1959: 115). Goffman (1959) advises that one of the most interesting times to observe impression management is when the performer switch from the front stage to the backstage and from the backstage to the front stage. A performed scene can lead the audience to assign personal qualities to the performer, so this performed self then becomes a product of the scene and not a cause of it. This performed character is not evolving organically, it is a dramatic effect and the performer is concerned with whether it will be credited or discredited. For a one-man team it means that when he/she seriously commits himself/herself, which leaves him/her exposed if his/her performance is rejected by the audience, he/she will make sure his/her claim is likely to be approved by the audience. This can be a claim to be professional. Goffman argues that individuals will relax their maintenance of impression in front of persons they know well and perform very carefully in front of unknown persons.

Schön and Argyris consider impression management differently; they see it as a way of "*sustaining and perpetuating ... dysfunctional behaviours*" (Chriss, 1995, 550). Chriss (1995: 550) continues that their work on action research by organizational

consultants sets out to "show organizational actors how to make the transition from Model I self-sealing behaviour to Model II behaviour, which should be open and honest". Chriss (1995) argues that Schön and Argyris consider impression management to be model 1 thinking, which is a way of thinking that allows actors to reject change. Argyris (2002) has coined the terms single and double loop learning. Single loop learning is learning how to solve the present problem, and double loop learning deals with learning to solve why the present problem came into existence so a similar situation can be avoided in the future. We consider if impression management may at times prompt small changes in practice through single and double loop learning

METHOD AND DATA COLLECTION

In this paper, we report data from a study with a focus on inter-organizational collaboration on a building site. The ethnographic method, shadowing is used to collect data on a building site. In the present study, shadowing was chosen, so it became possible to follow a contract manager to gain insights into his practice when working together with people from other organizations. For this reason, a project split into several main contracts was needed.

The chosen project is a refurbishment project where housing association dwellings are upgraded, while others are completely demolished. The project is split into four main contracts and a contract manager from one of these is shadowed. The implications of impression management may be greater when it is a specific actor, rather than many actors, that are followed. However, the organizational implications of the main contract mean that it is difficult for the researcher to follow different contract managers within the same main contract organization, as she needs to gain the trust of the observee to minimise impression management

At first, the researcher followed the contract manager to other sites (see the introductory observation) to get an understanding of his workday. This approach was deemed inappropriate after two weeks, as the contract manager spent considerable time on projects of a design-and-build nature, where the inter-organizational collaboration is between contractor and sub-contractors and not between main contractors as in the chosen project.

In the project, the contract manager's organization has an office hut on-site. It consists of three offices and a meeting room. The contract manager and the researcher occupy one of these offices. The contract manager is responsible for all sub-contractors as well as the organization's contract. There are two desks opposite each other. The organization's site manager of the tradesmen directly employed by the organization occupies the next office. An intern, who is helping the site manager in his day-to-day job, occupies the last office. The intern is from the local university college, where the researcher was teaching until the beginning of her Ph.D. studies. Two different persons have occupied the intern position so far. The contract manager, the organization's site manager, and the intern perform as a team in interactions with other teams. The office hut is the contract manager's back region.

The researcher is at site two days a week. The days have been chosen so the researcher can be present at the health and safety meetings, client meetings, and the time planning meetings. All the meetings are chaired by the building site manager, who is a representative of an organization specialized in site management. Representatives for all contracts on-site attend the health and safety meetings. The

client meetings are attended by representatives from the client, the architect, and the four main contracts. Time planning meetings are attended by representatives from the main contracts. At these meetings, the researcher is the only female present. All these three types of meetings are held in the afternoon, so the researcher can follow the preparation to them in the site office before the meeting. The meeting takes place in a meeting hut, which becomes the front region for the contract manager. The performance is given to the other participants at the meeting as well as the researcher.

The researcher is also on-site the following day, where the meetings (front stage) are often discussed and evaluated in the site office (the backstage). This is done to follow Goffman's (1959) advice of investigating this meeting point for impression management. At the time of writing, the researcher has been present on the site for 152 hours.

At first, the researcher set out to become a familiar part of the work setting. A part of this involves taking notes. The process of notetaking is very disrupting, so at first, she postponed the notetaking until a later time. She has now begun taking notes in full view. Emerson *et al.*, (2011) argue this as the best way, as the observee needs to get used to it. The notes are written by hand in a little notebook. The researcher, as an audience, will be perceived to have considerable knowledge of the construction industry due to her former teaching position. It may also influence the performances she observes that she is female. The implication of gender on impression management should not be neglected; although at present we will focus only on whether or not impression management is happening and how it may influence the observations, and not on any potentially related gender aspect.

EMPIRICAL OBSERVATIONS

Now, we will first revisit the opening observation and then present further observations from the site to illustrate how the researcher can be considered an audience for the observee as well as how the observee can perform a practice.

The Observed Practice with the Researcher as an Audience

In the opening observation, we see how the observee wants to act as an agreeable superior and finds it easier to do this when he has the researcher as an audience. In a way, he is extending his one-man-team to include the researcher. In this way, she becomes both the team player who can understand his motives as well as the audience, who evaluates his performance. In addition, the observee remarks that the researcher does not have any opinions in an effort to calm his subordinate, who is uneasy with the observation. He is explaining how the other team (the sub-ordinate) can expect his team to behave. The contract manager himself does not seem to believe this lack of opinions but accepts that she will not express her opinions at present. The reported ethnographic description is thus influenced by the observee's wish to perform as a professional in the industry enhanced by the researcher's presence although she wishes to perform the observation without becoming an active participant. The strategy of having no opinion on behalf of the researcher does not seem to function in this case. A researcher could also choose to express naïve wonder about the practice to make the observee reflect (Ybema *et al.*, 2009) or to participate more actively in the interactions, observant participation.

The Performed Practice with the Observee as a Performer

In the first week on-site, the researcher participated in a meeting between the contract manager and one of his sub-contractors. The sub-contractor's representative recently

graduated from the college, where the researcher has been teaching. He is one of her former students as well. The meeting takes place in the office hut's meeting room:

We are in the meeting room. The contract manager and a sub-contractor are present. The sub-contractor recently graduated from the college, where I have been teaching. He followed one of my project management classes a few years ago. The meeting is called to adjust the paper flow between the two organizations. There have been some changes to the original offer and price, due to extra work and work, which will not be executed anyway. At the beginning of the meeting, the contract manager laughs and jokes with the sub-contractor: "You don't have to sit so upright, just because [the researcher] is here; You are not at an exam". He repeats this incident later at the client meetings as well as when he tells about his experiences with a researcher on site to members of his organization. ...Three months into the observation, the contract manager's organization is on site. They want a story about how it is to have a researcher on-site. One of his replies is: "Actually, she calms things down a bit [the discussion in the meetings]"

These two observations illustrate how the observee knows that others are affected by the presence of the researcher. He recognizes that they are performing impression management.

It seems that the contract manager is getting a chance to get to know himself as a project manager. It is through his performances and the reflections about the performances that he reveals himself to himself (Goffman 1959; Chriss 1995). Furthermore, the researcher will later report her findings, at which stage his actions both in the front stage and backstage will become public. The observee may consider the researcher to be on his team but also at another team, the research community at large. A situation, which can lead to issues between informal privacy and scientific norms for public dissemination (Ybema *et al.*, 2009). The contract manager's performance will eventually be evaluated by the peers of the contract manager. This group can be considered part of an audience represented by the researcher even if they are not present (Goffman 1959). The argument that impression management is the link between the individual actions and the organization (Moeran 2006) might be extended to include impression management as the link between the contract manager and his peers (although the evaluation of his performance will be influenced by the researcher's ability to portray it).

After a client meeting approximately 2 months into the observation, the contract manager tells the researcher of his reflections on one of the discussions at the meeting regarding a problem, which did not involve him, but only the other meeting attendees:

I can't help thinking about you being present. Look at what I wrote on my notes - "Who takes the responsibility?"

Again, we see reflexivity on behalf of the observee. The observation also illustrates the front and back regions. The front region is the office, where the organizations meet. It is a professional setting, where the observed contract manager expects his collaborating partners to perform accordingly, and so expects someone to take responsibility. However, the expectation to him is that he should not interfere, as the problem does not concern him. We see two opposing, but colluding teams performing their "dance". He returns to his backstage (his own office), where he does not have to perform with his collaborating organizations as an audience. He relaxes and comments on the situation. At the meeting, the contract manager is thus performing impression management for the benefit of the other participants. This is normal and the researcher should be aware that the observee may try to maintain an impression towards the researcher as well as the other people in an interaction (Czarniawska

2013). The contract manager was performing model I thinking. Later, the contract manager is in his back region. The researcher is his audience. He is annoyed with the situation, so he comments on it. He may just be annoyed about wasting time because no one would assume responsibility - or he may be performing impression management toward the researcher and indicating that he is aware that no one took responsibility. It remains clear, however, that the researcher's presence at the meeting is causing him to reflect over his practice as well as the practice of his peers. It is the impression management towards the researcher, which causes the reflection.

We see an observee, who has motives for performing to high standards, as his performance will be revealed to a greater audience through the researcher's observations, although at the same time, he seems genuinely interested and curious in reflecting on his performance and context.

DISCUSSION: SHIFTING PRACTICE

We have illustrated, how a contract manager is reflecting on his and others' behaviour due to the presence of the researcher. He interprets the "sitting upright" of the former student and the "calms things down" as the others adjusting their behaviour due to the presence of the researcher.

Impression management may be considered by Schön and Argyris as dysfunctional and self-sealing behaviour, but it seems, with a researcher as an audience, to prompt reflection, which in turn may be turned into behavioural changes. At present, the reflection is taking place backstage when the contract manager is asking who will take responsibility, where he wishes to solve the present problem (single loop learning). In this situation, the researcher could have prompted further reflection by asking why no-one is taking responsibility, which may have prompted double loop learning. The reflection may cause the observee to change behaviour, influencing the research into practice as a phenomenon.

Furthermore, we set out to investigate the organizational phenomenon of collaboration. In future research, we intend to apply Wenger's (1998) community of practice theory to understand the practices on-site (practice as a perspective). He argues that members in a Community of Practice (CoP) negotiate meaning by a mixture of participation and reification. Participation is dependent on whether the individual is perceived by the others to have the right to belong to the CoP as well as perceived to have the right to express or negotiate his/her opinion (Wenger 1998). Membership and access to the negotiations may then be dependent on the actors' impression management. Goffman (1959: 66) argues that when we ask if a performance is true or false "*we really mean to ask whether or not the performer is authorized to give the performance in question*". The link between impression management and access to the negotiation of meaning and the impact on the practices on-site must be established through empirical data. It may inform us how practice shapes the reality of the organizational life on-site (practice as a perspective). However, the influence of the researcher as an audience can influence the observed impression management. The presence of the researcher may thus contribute to shaping the organizational reality on-site.

This brings us to consider researching practice as a philosophy; practice as a part of organizational life. Practices are "repetitive patterns, but they are also permanently displacing and shifting patterns" (Bueger 2014: 387). If the actors on-site at the end of a prolonged observation study routinely incorporate impression management activities into their daily practices, a situation where the practices shift can occur.

These routinely performed practices become the new organizational practices on-site and the impression management activities will not only shape the organizational reality but also become part of the organizational reality.

We argue that impression management can become an agent for change in practices on an observed building site - although it is not possible to determine, whether this change is for the good of the project or not. The implications of a shift in practice on an observed building site are difficult to estimate, as it is impossible to compare to an un-observed building site; there can be no benchmark.

CONCLUSION

We have argued that impression management plays a role in ethnographic observations: It may be directed at the researchers and their connected team (the research industry as well as the construction industry) or it may be directed at the other teams in the interaction. The performance directed at the researchers may not have taken place, had they not been present. In this way, the presence of researchers can prompt the practices that they are investigating to displace and shift. We further suggest that Goffman's dramaturgical perspective can provide valuable insights into how actors are performing their practice as well as evaluating whether their opposing team is authorized to take part in the negotiations on-site. As the paper is based on early results from an ethnographic study, it may be that over time the observees will terminate their maintenance of impression management in front of the researcher. At present, this does not appear to be the case, but rather that the fieldwork may cause the practices on-site to shift, and thus influence the practices in the project.

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GOOD ENOUGH QUALITY: MULTIPLE QUALITY CULTURES IN A SWEDISH REGION

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Despite decades of efforts, the construction sector is still haunted by defects and impaired quality. The Swedish investments in buildings and infrastructure is impressive and counted in billions of euros these years. Yet the investment costs have not achieved concrete improvements and the quality of the realized infrastructure and buildings is at least controversial. The actors involved are despite their efforts unable to deliver an excellent quality, but merely a quality on an acceptable level. This paper aims at analysing the context which produces such a low-quality drawing on the concept of organisational culture inspired by Alvesson 's adaption of Geertz 's work. Organizational culture is here described as bearing multiple forms and occurring in complex constellations. As in construction, the projects and their interorganisational features are important, we cautiously choose to think of quality culture within a single urban region, assuming that projects and companies operate in the same shared environment. Out of the literature we have selected four major aspects of quality culture: The concept of quality, the formal legal quality control system, the relation between production and quality and the guiding micronarrative. The empirical material consists of 27 interviews of professionals of the sector and projects documents analysis. The results show that these four aspects unify and separate characteristics of quality cultures. Quality is assigned different meanings creating several quality cultures. Moreover, the formal quality control system is unable to bridge the major decalage between project and headquarters producing instead alternative set of quality cultures. The constellations of quality cultures in construction are thus in internal contradiction and continual instability. The resulting antagonistic dynamics resembles that of an orchestra of dissonances.

Keywords: quality culture, symbolic interactionism, urban regions

INTRODUCTION

The lack of attention to quality in projects is a recurrent issue (Basu 2017). During the production, time and cost are often the focus, whereas quality is “relegated to mere ‘lip service’ and ‘tick box compliance’ (Basu 2017:1). Deming (1986) posited that quality is defined by the satisfaction of the customer. However, in the construction industry waiting for the customer satisfaction to judge of the quality would be very expensive as a number of defects occur during the production that leads to costly rework and may seriously lower quality at delivery (Mills *et al.*, 2009, Aljassmi and Han 2012). Usual explanations to account for quality issues are related to design failures, redesign, multiplicity of actors during production or uniqueness of projects. Here, however, we propose to address the topic by revisiting the discussion on quality

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culture using a symbolic interactionist approach. The quality culture concept stems from Total Quality Management (TQM) and focuses on the "values and beliefs that foster total quality behaviour" (Kanji and Wong 1998). In TQM it is believed that quality culture is something that can be planned, installed, and managed. The symbolic interactionist approach, however, enables us to look at culture analytically through the shared meanings, symbols and narratives expressed by the interviewees when they discuss quality work. The empirical material draws on a research project aiming at mapping and analysing the status of the Swedish "self-control" system. This legally enforced system, obliges

building projects to plan, monitor and complete quality control. Our explorative research project gathered material from seven interviews with key actors in the industry and five case study of building projects taking place in the Gothenburg region: four new built dwelling and one retrofit. Here, we focus on the participants' own interpretation of their work with quality. Previous studies in this region report a level of quality commonly recognized as acceptable yet not excellent, the cost of defects averaging at 5-10% of the final product price. Our contribution lies in the identification of different quality cultures, and their combination which may form different constellations at and across building sites and adds to the rare studies of quality control in Sweden and departs from previous contributions identifying single quality culture (Cheng and Lui 2017, Tang *et al.*, 2009).

METHODOLOGICAL APPROACH

The paper adopts a qualitative interpretive sociology approach (Alvesson 2003) to its research questions and aims, theoretical framing, empirical material and analysis. We felt that behind the legal frames, engineering tools and other functional elements a more interpretive approach was missing such as offered by symbolic interactionism (Alvesson 2003, Hatch and Cunliffe 2013).

The Unit of the Urban Regions Building Industry

Adopting quality culture is not unproblematic in a context where projects are central locus of quality (Basu 2017, Coffey 2010). Projects gather members of multiple organisations, who are constantly substituted and may be active in several projects simultaneously. So, we choose here to focus the urban region of Gothenburg. We assume that the organisations are active in related projects and networks. The notion urban region is tentative and used to underline the focus on the industry operating close to or in the regional main city. Thinking of driving distance for subcontractors the area is roughly 50 km times 50 km. Other studies have indirectly documented the same area (Bröchner *et al.*, 2002, Carlsson 2017, Styhre 2011). At a more pragmatic practical level, operating in this urban region mitigated the present study's limited resources, closeness and access was important. This delimitation is not implying however that we necessarily assume that the culture is different in other regions, but our empirical field work has covered this region only.

Empirical Material

The key actors, companies and building sites were selected using the researchers' local network, based on the access possibility and included different types and sizes of companies: Architects, consulting engineers, material suppliers, large contractors, medium and small contractors. Four dwelling construction sites and one retrofit site of a public institution were selected. As such the sample cannot be seen as representative however it does support an explorative and illustrative aim.

Twenty-seven semi-structured interviews and the analyse of 12 audits and quality-control plans documents were carried out. The interviews of key actors include a building materials supplier, an architect, a consulting engineer and two quality managers in contractors' headquarters and two control inspectors, who were part of the regulative setup. For the five case studies, we visited the building sites and carried out interviews with the five site managers, one foreman, one quality manager on site, one representative of 13 sub-contractors, of which seven were technical installation companies. The 12 audits on the five sites were in some cases carried out together with the sub-contractors and in other cases with site managers. The content of the inspection and test reports present on site were examined critically.

Initially, the analytical strategy followed an abductive approach (Alvesson and Sköldbberg 1997). As visits and interviews were carried out elements of quality cultures emerged. The interview framing was kept semi-structured, but with inspiration from ethnographic interviewing (Heyl 2001). All interviews and audits were taped, and, selectively transcribed sorting out of passages that appeared interesting at the outset. The first analytical round examined each key actor and building site in isolation. The interview transcriptions were revised to include more recorded passages. During the second round, actor-oriented interpretations of quality and the quality control system emerged, more specifically company-, site manager- and craftsman-oriented. In a third round of analysis adopting the symbolic interactionist culture lens, common, distinct and ambiguous elements emerged across the company representatives, sites and actors. It has been chosen to not enter references in Swedish as they are too numerous for a conference paper.

THEORETICAL FRAMEWORK

Culture and Quality Culture

Studies claiming that culture is a national feature has been spearheaded by Hofstede (1991). His approach also has followers in quality culture, pointing at tensions between science and craft, and local conflict solving practices avoiding independent auditing (Bröchner *et al.*, 2002). Organizational culture studies on the other hand have been dominated by two main paradigms (Hatch and Cunliffe 2013): functionalism (Schein, 2016) and interpretivism, including symbolic interactionism, Geertz, 1993, Alvesson 2003. Although other with more instrumentalist approaches such as the competing values model (Cheng and Lui 2007, Liu *et al.*, 2006, Panuwatwanich and Nguyen 2017) have been adopted for studying quality culture. Symbolic interactionism posits that society and its phenomena are socially constructed by people and reproduced by the networks of shared symbols and meanings making shared action possible (Alvesson, 2003, Hatch and Cunliffe 2013). Symbols can be expressed verbally, physically and by actions. The rare culture studies informed by symbolic interactionism are usually related to a specific setting such as a production or an organization (Alvesson 2003). In this perspective quality culture would be viewed as a focussed aspect of the organizational culture. Thus, we define quality culture as the shared and learned meanings, experiences and interpretations of production and quality --expressed partially symbolically--which guide people's actions towards quality, quality control and the balancing between production and quality. Quality culture is shaped by people in the structures and social relations within and outside the organization. Building project are central producers of quality (Basu 2017), but in building projects members are constantly substituted. It is therefore possible and needed in an explorative manner to delimit to study of quality culture to a unit of a regional building industry.

Culture with a Symbolic Interactionism Approach

The symbolic approach culture encourages a reduction of the role of the organizational boundary as it perceives organizations as constructed and reproduced by peoples shared meaning. Alvesson (2003) uses the terms cultural traffic and social fields to understand how grander cultures and organizational cultures interact. Apart from symbols, other central concepts are that of a root metaphor and metaphors, shared meaning, narratives, myths and ceremonies characterizing the culture. In the development of organizational culture theory controversies about the way to conceptualize and analyse culture (Hatch and Cunliffe 2013, Martin 2002). Rather than taking a one-sided position in these debates, Meyerson and Martin's (1987) suggestion of a three-perspective analysis including integration, differentiation and ambiguity is followed to which we add the concept of multiple configuration proposed by Alvesson (2003). This allows the scholar to handle quite complex cultural patterns and avoids falling into the monolithic trap of waiting for a unitary concept to emerge.

Integration

The integration perspective underlines that culture is the shared understandings in a given organization. There is a consistency across cultural manifestations (Meyerson and Martin 1987). Schein is probably the most significant scholar within this perspective, (Hatch and Cunliffe 2013. Culture in this perspective is thus an integrative mechanism, labelled as the social glue between its members (Coffey 2010, Schein 2016, Alvesson 2003). In Schein's version, the common basic assumptions are the consistently shared element. Some representatives of the integration perspective clearly link it with managerial prerogatives and attempts at top-down control and change of the culture. Within this position, diversity is rarely recognised. If so, it is interpreted as a signal of weakness, or one culture is assigned the dominant role, whereas others are represented as subcultures. As Parker (2000) argues, it is often a matter of perspective what is subordinated and what is superior.

Differentiation

This perspective focuses on the lack of consensus between interpretations, experiences and assignments of meaning in specific context. A typical example is opposition to a leader, researchers adopting the differentiation perspective paying attention to non-leader-centred sources of culture (Hatch and Cunliffe 2013, Parker 2000). These researchers differ, however, in their analyses of units of differentiation by which to characterize the field. Several authors' analyses see culture as a product of such social structures as countries, regions, enterprises, departments, professions and groups (Alvesson 2003). These different groups and cultures coexist in the studied organization. Moreover, it is often argued that some cultures are superior to others, the "others" being seen as subcultures Parker (2000). Other studies, like Alvesson's, focus on the everyday work practice producing local cultures, cutting across social structures and advocating a more cautious approach in the interpretation of differentiation in cultural manifestations; arguing for an analysis that discriminates social structural differences from cultural. Panuwatwanich and Nguyen (2017) work illustrates the differentiation perspective. Although, Vietnamese construction firms are dominated by clan and hierarchy cultures, organisations characterized by either clan or adhocracy cultures are assumed favourable for TQM, whereas those characterised by both market and hierarchy cultures are less favourable (Panuwatwanich and Nguyen 2017).

Ambiguity

Already seen from the differentiation perspective, cultural manifestations may seem ambiguous. Potentially, there are differences in meanings, interpretations of symbols etc., which are incommensurable and irreconcilable leading to fragmentation (Alvesson 2003, Hatch and Cunliffe 2013). Moreover, in the continual process of creating and recreating meaning, members of different cultures may orient themselves differently at different times (Parker 2000). This perspective acknowledges the uncontrollable uncertainties that provide the texture of contemporary life (Martin 2002); however, Alvesson (and Parker) warns against too easily assigning cultural phenomena to ambiguity, thus pointing out that ambiguity might originate from social structures or social practises (Alvesson 2003). Although ambiguity is an important aspect of culture, Alvesson (2003), Hatch and Cunliffe (2013) and others point out that despite this, groups and organizations must develop at least some degree of mutual understanding of how to deal with problems in order to make cooperation possible. Alvesson (2003) talks about bounded ambiguity. Even if culture does not produce clarity and consensus throughout an organization, it can offer guidelines for coping with ambiguous meanings and how to deal with tricky issues. Bounded ambiguity may also be seen in switches between different social circumstances, legitimising various ideas and meanings.

Multiple Configuration

Whereas the dominant view among culture study scholars is integrationist, few are differentiating, and even fewer attempt to synthesise these approaches (Martin 2002). Parker and Alvesson both try to offer a way of at least juxtaposing the three perspectives. Alvesson stresses level differences; that is, whether cultures are macro cultures for example, national or local. He suggests that cultures potentially overlap and interact. Parker suggests overlapping, subordinating, subordinated cultures (Parker 2000). Comparably, Alvesson introduces the multiple cultural configuration view (Alvesson 2003). It assumes that organizations can be understood as shaping local versions of broader societal and locally developed cultural manifestations in a multitude of ways. People are to different degrees connected with an organization, sub-organizational unit, profession, gender, class, ethnic group, nation etc. This explains his observations of cultural overlap in an organizational setting, which is rarely tightly connected to the social structures of the organization. Alvesson's central argument for introducing multiple configuration is to combine the insights of the above-mentioned approaches. Thus, he recognizes the role of grander cultures, local cultures and possible integration and unity, but their mixture and overlapping character is a central observation.

Quality Cultures - A Summary

Summarizing the symbolic interactionist view, quality culture is shaped by people in the structures and social relations within and outside the organization. To examine the possible quality cultures, we use the analytical schema of integration, differentiation and ambiguity organising in diverse constellations.

The five projects under production each involved a similar range of players such as a main contractor, around twenty sub-contractors and suppliers of the building elements. All interviewed participants acknowledged a certain number of defects on sites and assessed the quality as good enough. None evaluated themselves as having excellent performance. The following are some examples of the mentioned defects: Pillars wrongly placed in the underground parking facility for a dwelling, electrical boxes

wrongly placed in prefabricated concrete walls, decommissioning meeting revealing that production had not started in several rooms which should be quality controlled.

At the same time, however, we recorded a large variation of quality handling and celebrated performance and a considerable variation in practices to obtain good quality using the quality control system. Three of the participating companies thus exhibited attempt to link projects and production with business aims and explicit quality management, whereas more than 25 companies, especially the subcontractors did not appear to prioritize quality as part of their business. Three of the building sites were characterized by a strive for "order and neatness" and two others had a practice different from the company. The site managers seriously engaged in self-control taking a leading role in the process. There was however also an ambiguous relationship to the quality control routines. The routines are viewed as necessary, but it is their formal aspects, "they need to be carried out" rather than their efficiency that are put forward by the respondents.

ANALYSIS

The Integration Perspective

The "good enough" position shared during interviews and site visits implies the impossibility to reach high level quality under the present fragmentation and price-oriented contracts. As none of the companies or building sites identified themselves as excellent, and a common assignment of meaning to quality level as of "good enough" performance is in play. The "good enough" notion is supported by the limited repercussions of Swedish law and regulations failing in practice to fully demand compliance with building specifications and regulation. This is accompanied by norms and values, which refer to and accepts as legitimate up to about 10% of the building costs as a defect and insufficient quality cost range. Quality deviances are then an issue of pragmatic negotiations with the customer. The other central common factor was the consensus and collaboration among the actor: "we are locking arms here" (site manager) (see also Bröchner *et al.*, 2002). The design and production had priority over quality, underpinned amongst other by price-based contracting. It should finally be noted that we do not find strong underpinning for a boundary of the urban region, but rather a mixture of local, regional, national, professional and corporate influences.

The Differentiation Perspective

Three main different quality cultures were found: quality as business, site manager as central and craftsmen can do it by themselves.

1. Quality as business

Three companies employ an active quality practice. They work systematically to connect business and quality, involving an active external network. The company "takes care of quality" and communicates this to potential customers and collaboration partners. It can even be said that these companies present a window exhibition of quality and quality control (for example on their websites). What distinguishes the companies with an active quality strategy from the others, is that they appear to take quality seriously in their design and production processes. One example is a large contractor. The quality managers from the headquarter play an active role on site maintaining a focus on quality throughout the building project. They also follow up on the quality control system. The architect firm visited described how they had carried out an extensive appropriation of the quality certification systems ISO 9000 and ISO 14000. Via simplification and several revisions, they developed a system

that is strongly embedded in the design processes. The company's representative asserts that through this simplified system, they do things more correctly to start with, and can perform a more efficient design with fewer defects. This leads to an improved business: Central employees thus developed the system through simplification and sifted out the important parts. The system has now been in use for several years and been revised three times. The company also hired an external auditor to scrutinize the system. Nevertheless, a side effect of this effort has been that public clients have evaluated the company lower in tendering, because of the lacking certification.

Table 1: *Quality as business*

Dimension	Culture: Quality as Business
Quality definition	Quality is value for the customer. High quality is a business parameter
Legal quality control system	Law compliant, but not essential
Relation production - quality	Attempting to find a balance, actors on site more production oriented than quality employees
Guiding micronarrative	High quality is a business parameter

2. "Site manager as central" culture

On three sites, site managers were enthusiastically working for quality and quality control. They took upon themselves the role of leading quality control activities from the first meeting with the craftsmen and sub-contractors. When this practice functions best, quality control is an efficient tool for early discovery of defects and implies that efforts can be initiated. The site managers' way of working also involves an element of decency that strives for order and neatness in the processes on-site. This way of working, however, is not something any of the investigated companies support. It is therefore identified as an at least somewhat distinct quality culture. It has been found elsewhere, that site managers are carriers of particular norms and ideals (Styhre 2011). The identified quality culture is in correspondence to this, meaning that site managers can draw on a shared system of symbolic meaning (i.e. the project manager as king), when they require that sub-contractors should participate actively in the quality control exercise. And this creates space for leadership; however, the order and neatness approach can be interpreted as ambiguous, when it gives way to the craftsmen quality understanding, upon which the site managers are directly dependent. Moreover, a function of corporate repair, i.e., legal and contractual support, might also be needed to underpin local practice, if something goes wrong.

Table 2 *Site manager as central*

Dimension	Site manager central figure
Quality definition	Craft based
Legal quality control system	Order and neatness We work in a legal manner
Relation production - quality	Project manager as king – His priorities are the active ones.
Guiding micronarratives	No help from the corporate office

3. *Craftsmen can do it by themselves*

Finally, outspoken scepticism towards formal quality control was found on two sites. The craftsmen felt that their craft competences assure an inner quality, even if this does not lead to excellent quality in the building as such. This craftsman position is also embedded in formal crafts education and certification (for example, electricians

and plumbers). Since these craft-based norms and ways of working stand in an oppositional position to the formal, legal quality control system, it is interpreted as an independent quality culture. As mentioned above, the craftsmen can draw on a culturally embedded set of norms regarding their practice in quality work. And their craft identity is also a rich source of legitimacy. To this, it can be added that the direct interaction with materiality serves to underpin, but also to a certain extent challenge, the craftsmen's quality culture. In this culture we also find narratives myth on quality control papers being filled out "post festum" with an array of pens and back dating them to make believe they were done during the process. We have not witnessed such a ceremony, but the narrative/myth about the symbolic event were active. The central role of craftsmen in the Swedish building process thus has characteristic consequences for the production of the building, quality, and the quality control system.

Table 3: *Craftsmen can do it by themselves*

Dimension	Craftsmen can do it by themselves
Quality definition	Quality grows out of competences and direct practices
Legal quality control system	Quality regulation irrelevant – a paper system
Relation production - quality	Production the most important, quality grows naturally out of it
Guiding micronarratives	Craftsmen's pride

The Constellation of Cultures

Having identified the four quality cultures, the attention now turns to the second part of the research question: if/when characteristically quality culture is found, what are the relationships between them? The four cultures analysed above are not substitutions for each other, nor can each be expected to dominate a building project and/or company. Rather, they stand in a somewhat complementary relation to each other. Even if site managers are often assigned considerable power on site in the studied region (Styhre and Josephson 2006), their practices and norms are folded out within the governance frame of a *laissez faire* company strategy. Moreover, the site managers are dependent on the craftsmen and their culture. But it is not possible to imagine a building realized only on the basis of the craft-based quality culture, even if the culture were superior or dominant within the domain of the single sub-contract. The four quality cultures are grouped in a constellation of co-existing competition and cooperation, a multiple configuration (Alvesson 2003). It is also characteristic that the cultures are spatially separated and temporally co-existing, due to the distance between the numerous building sites and companies' offices. The craft-based culture also involves a negative choice in insisting on being in opposition to the official quality control system. Finding an oppositional culture is frequent in the differentiation perspective (Alvesson, 2003). The constellation of quality cultures as such serves to legitimize the present "acceptable quality" regime in the region.

DISCUSSION

Using a symbolic interactionist culture analysis lens reveals some important explanations of the present status of quality practices in Swedish construction, even if on a modest and geographically limited research basis. One of the central tensions that run through the material is the practitioners' cultures (craftsmen and site managers) versus formal quality systems and business. This contrasts Bröchner *et al.*

(2001) identification of tension between craftsmanship and applied science traced back to German master masons coming to Gothenburg in the 1850s. The present study appears to show how quality control systems supported by regulation can influence the production of quality only up to a point. It could be assumed that the business potential would be a sufficient motivation for quality production, but few contractors in the study seem to believe so. Companies find it more attractive to let their site managers and (contracted) craftsmen be responsible. When site managers take the lead, it leads to compliance with the quality control system. The relation between company headquarters strategy and quality, site managers' quality work, and the craftsmen's practice forms a constellation of quality cultures can be described mutually supportive yet maintaining a "good enough" level of quality. It is a state of ambiguous responsibility or irresponsibility. The common acceptance in the industry of the good enough quality is supported and underpinned from several positions in the region. This culture constitutes a barrier to change of the routines and legal framework. The "quality is business" culture is rare and counter to the good enough culture. The differentiation perspective reveals that assigning meaning to quality and quality control systems cuts across the groups of professionals and companies. Quality is not related to one professional group even if the craftsmen believe so.

CONCLUSION

This paper set out to analyse quality culture in the urban region of Gothenburg. First, it established a theoretical frame of understanding, viewing practices, shared norms and procedures of quality as quality cultures. This draws on symbolic interactionist theory on culture viewing quality culture as a focussed aspect of organisational culture. Quality cultures is understood as shared meaning about what quality is, how to control it through a quality control system, the balance between production and quality and involving a guiding micronarrative. Counter to mainstream organisational and corporate culture studies the main unit of production of quality, culture, and quality culture is considered to be the projects, that are interorganisational in character. Construction professionals frequently change projects. Therefore, the creation of shared meaning, narratives and ceremonies are done on a larger arena and more interorganisational than organisational culture concepts would sensitize us towards the urban region. The study finds an overall integrative "good enough" quality culture and three differentiated quality cultures: quality as business, site managers' quality work, and the craftsmen's practice. These four forms a constellation of quality cultures that can be described as stalemate in maintaining a "good enough" quality, they cannot deliver excellent quality. It is a state of ambiguous responsibility. The constellations of quality cultures are thus in internal contradiction and continual unrest. The resulting antagonistic dynamics resembles that of multiple instruments playing different tunes simultaneously, an orchestra of dissonances.

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OFFSITE MANUFACTURING AND CONSTRUCTION INDUSTRY TRANSFORMATION: A MULTI-LEVEL SOCIOTECHNICAL TRANSITIONS PERSPECTIVE

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Offsite manufacturing (OSM) is currently one of the innovative approaches for construction that is at the forefront of industry transformation initiatives. Despite its espoused benefits, OSM is yet to become mainstream. Adoption of OSM in the UK is currently limited to discrete attempts at organisational and project levels. In this paper, the multi-level sociotechnical transitions (MLS) theoretical framework is used to review and synthesize relevant literature to conceptualise how an industry-wide uptake of OSM rests on the creation of a dominant platform around which other innovations will coalesce, in order to ‘break through’ and trigger changes in the existing configurations defining the way the construction industry works. To create step changes in the industry through widespread use of OSM, the paper highlights the government's role as a ‘strong’ actor in developing the UK’s platform approach into a stable innovation to propel a reconfiguration of the existing sociotechnical regime. Beyond this ‘top-down’ techno-centric solution, the need for its co-evolution with policy, construction market dynamics, actor practices and existing technologies are drawn out in conclusion. The dynamics of these co-developments is identified as a direction for future research.

Keywords: multi-level, offsite manufacturing, sociotechnical transitions

INTRODUCTION

The UK construction industry is often berated for poor productivity, delayed projects, a slow work pace, unsafe work practices and for delivering projects that exceed planned costs (Farmer, 2016; Wolstenholme, 2009). These problems are partially attributed to the industry’s lack of innovation and fragmentation (HM Government, 2013, 2018). The challenge, therefore, has been to find ways of transforming the industry in order to deal with these ‘ills’ by improving productivity, safety, timely delivery and cost-effectiveness. In the past three decades, there has been a gradual shift of government-led reforms to improve the industry - from more management-focused approaches that sought to gel the industry together by promoting collaborative practices, to more technology-centred initiatives incorporating a mix of coercive and voluntary measures (Dainty, Leiringer, Fernie and Harty, 2017). Mandating the use of building information modelling (BIM) on all public sector projects is an example of the former (IPA, 2016), and the decision of the government to give a presumption in

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favour of the use of offsite manufacturing (OSM) for project delivery links with the latter (IPA, 2019). These reform initiatives, however, are yet to produce the key performance goals that underpin their implementation.

More recent efforts at industry transformation by the UK government focus on changing the industry's practices from 'traditional' approaches to 'modern' methods of construction (MMCs), with the uptake and use of OSM and digital technologies (e.g. BIM) at the forefront (HM Government, 2018). Government Construction Strategies (Cabinet Office, 2011; IPA, 2016), Industrial Strategies (HM Government, 2013; 2018) and a Construction Leadership Council (CLC)-backed review of the sector's labour model (Farmer, 2016) underpin the growing emphasis on MMCs and OSM in particular. The latest Industrial Strategy (IS), 'Construction Sector Deal' outlines government's partnership with industry to promote the use of digital technologies and OSM in attaining goals including reducing construction and whole lifecycle costs by over a third, and halving delays of construction projects and greenhouse gas emissions by 2030 (HM Government, 2018). Supporting the government's effort to promote an industry-wide use of OSM is the vision to create 'a sector that can build new homes in weeks - and even days - rather than months; that can deliver new buildings at a third of the cost; that can provide affordable, energy efficient homes' (ibid, p.3). Tied to the reform agenda, Farmer's (2016) review of the UK construction labour model prescribes solutions including an increased use of OSM to solve the industry's productivity and labour problems.

Realising any meaningful industry-wide transformation is linked to the co-evolution of factors (e.g. user practices, technologies and policy) that define an existing configuration of preferred practices (cf. Orstavik, 2014). To modify such wide-reaching configurations, we argue, requires an initial amalgamation of micro-level developments to trigger a widescale use of OSM. Achieving this requires the implementation of well-coordinated government-industry initiatives focused on amalgamating discrete organisational and project attempts around a single innovation. This, we subsequently argue, holds the potential to trigger the transformation of the construction industry with OSM at the forefront. Using the multi-level sociotechnical transitions (MLS) theoretical lens, we conceptualise the construction industry transformation agenda as comprising multifaceted sociotechnical developments and highlight how achieving 'niche cumulation' holds the potential to trigger the desired step changes. We subsequently discuss how the UK's platform approach for OSM holds the potential to, by co-evolving with the sociotechnical regime of the industry, accelerate developments that could lead to the desired industry transformation envisioned in the government's reform documents.

The paper begins by situating OSM within the wider UK construction industry transformation agenda and how its espoused benefits underpin initiatives promoting its use. Next, the industry reform agenda based on a widespread use of OSM is discussed, with emphasis on the need for focus on micro-level developments in order to achieve the wider changes envisaged. This is followed by discussing how the MLS view applies to conceptualising the OSM-focused industry transformation agenda as a sociotechnical innovation. After presenting the review-based research method, attention is turned to the important role the government - as a strong actor - can play to trigger the co-evolution of aspects of the existing industry regime towards the envisaged transformation. Using concepts from the MLS theoretical framework, the UK government-led platform approach is conceptualised as a key development needed to drive step-changes in the way the industry works. The concluding remarks

highlight potential pathways the process of transformation could follow and identify policy implications and directions for future research.

Offsite Manufacturing and the UK Construction Industry Transformation Agenda

Offsite manufacturing (OSM) generally refers to an innovative approach to construction involving the production of non-volumetric (non) structural components or volumetric units in a factory for subsequent installation in their final positions in a structure on site (Goodier and Gibb, 2007; Ågren and Wing, 2014). OSM is also referred to as offsite construction, modular integrated construction, or design for manufacture and assembly (Abanda, Tah and Cheung, 2017). Regardless of terminology, a fundamental principle of this method of construction is to move as many 'conventional' construction activities typically executed in-situ to a regulated factory environment in a place different from the final project site. This includes having a significant number of (non) structural components such as reinforced concrete walls, floors, columns, bathroom and kitchen fittings and balconies ready-made in factories and later installed in their designated locations on site, instead of being made in-situ (Goodier and Gibb, 2007; Ågren and Wing, 2014; Abanda *et al.*, 2017). Adopting such an approach to undertaking construction projects, therefore, requires changes to processes of design, procurement, planning, on-site tasks execution, and supplier and inter-organisational networks that have been developed to align with established and preferred ways of project delivery (cf. Ostarvik, 2014).

Although considered a 'modern' construction method, OSM has been in use for several decades, dating to post-World War 2 times when housing provision was a pressing need (NHBC, 2019; Ågren and Wing, 2014). Anecdotal evidence suggests that using OSM for construction can improve planning, cash-flow forecasting, productivity, safety, waste-reduction, timely delivery and lead to lesser environmental disruption and cost savings as there is more certainty associated with the method (BCG, 2019; Abanda *et al.*, 2017; House of Lords, 2018). According to KPMG (2016, p.3), using OSM "offers an alternative to this current construction status-quo by promising transformative improvements across the asset lifecycle in time, cost, quality and health and safety", creating benefits that accrue to different parties, including contractors, clients, manufacturers and end-users (BCG, 2019). Owing to the benefits OSM promises, the recent IS and government strategies place it at the centre of the reform agenda, alongside the use of digital technologies. Achieving targets of improved construction speed, minimised waste and reduced disruptions in work plans through a widescale uptake of OSM, the policy documents suggest, will address the construction industry's ills and accrue benefits to the government in the provision of more schools, hospitals, custodial facilities, and more houses at faster and cheaper rates to tackle the housing shortage in the UK (HM Government, 2018; IPA, 2019).

Achieving an industry-wide uptake of OSM as part of the reform agenda requires multi-layered adjustments to the established and preferred ways of delivering construction projects. Like other industry reform attempts - e.g., digitalisation through the mandatory use of BIM - the changes would, in turn, impact on actors (Dainty *et al.*, 2017), established connections between existing structures and their links into the wider socio-economic context. To achieve the reform goals, government policies and industry reports propose broad recommendations focused on changes to industry leadership, training, government-client-industry integration, and

investment in research and development (Farmer, 2016; HM Government, 2018). Given the enthusiasm surrounding the transformation of the wider construction industry in the policy and strategy documents and reports, it is perhaps surprising that the recommendations give barely any attention to the primary agents of change in the construction industry - i.e. organisations, and the centre-point of construction activities that can trigger wide scale changes - i.e. projects (cf. Green, 2019). An understanding of how micro-developments at firm and project levels (i.e., the industry niche) can be amalgamated for change is crucial, from a policy perspective, if an industry-wide uptake of OSM is to be realised and the targets for a 'revolutionised' construction sector in 2025 are to be fully or partially met.

In the extant literature, many studies and reports cite OSM as the 'future' of innovative construction project delivery and the starting point for a transformed industry that delivers high quality products, is more efficient, highly productive and safer (e.g. Goodier and Gibb, 2007; Ågren and Wing, 2014; Abanda *et al.*, 2017; BCG, 2019; House of Lords, 2018). Despite the plethora of studies motivated by its 'transformative power' if adopted at scale, critical views examining the multi-layered and -faceted modifications necessary for a wide scale uptake of OSM are scarce. Missing from policy debates is an understanding of the how micro-level developments involving the primary agents of industry change (i.e., organisations) and their use of OSM for project delivery could be aggregated to create critical momentum for change.

The Multi-Level Sociotechnical Transitions Perspective

The multi-level sociotechnical transitions (MLS) theoretical framework was developed primarily by Geels (2002; 2005) and colleagues (Geels and Kemp, 2007). It is a network approach for explaining how changes (i.e. technological transitions) in the way sociotechnical (ST) functions (e.g. construction, healthcare and transportation) occur across three levels: landscapes, regimes and niches. The different levels, according to Geels (2002, p.1259), 'are not ontological descriptions of reality, but analytical and heuristic concepts to understand the complex dynamics of sociotechnical change'. The MLS view provides the needed lens to explore how a dominant stable innovation can emerge and trigger niche cumulation, while helping identify the non-technical aspects of an established regime that would have to co-evolve to make a multi-level technological transition a reality.

According to Geels (2002), landscapes are the overarching socio-material contexts of firmly established structures that govern overall sets of multifaceted sociotechnical interactions that may occur in a place. The metaphor of a 'landscape' highlights, on one hand, the rigidity of the deeply rooted structures and practices that guide societies and, on another hand, helps to convey the multiplicity of interconnected factors it comprises. The heterogeneous composition of ST landscapes includes material and spatial layouts of buildings and cities, oil prices, geo-political climates, socio-cultural values, collective concerns and economic circumstances. A landscape therefore comprises broader, non technology-specific factors that are external to, but influential on, what happens in regimes and niches. Changes to landscapes do occur, albeit very slowly. ST regimes, embedded in landscapes, refer to semi-coherent rules and established practices that prescribe norms, orient and guide activities of actors, and provide stability to sociotechnical configurations in an industry. In the MLS heuristic, regimes are made up of technology, user practices and markets, meanings, infrastructure, industry structures, policy and technological knowledge. These factors are in a continuous process of co-development in order to maintain stability or adjust

to changes in an existing regime (Geels, 2002; 2005). An existing regime may evolve in response to landscape pressures, creating opportunities for a niche-level breakthrough to re-configure established structures. Within the MLS framework, niches are crucial because they form the nucleus of technological transformations and trigger ‘radical change’ in established regimes. In niches, various actors seeking to bring innovations to established methods in an industry typically embark on unconnected attempts, developing their own discrete innovations. The emergence of a more stable technological innovation at the niche level holds the potential to coalesce other technological developments into a dominant design - creating a niche cumulation (Geels, 2005). Through well-coordinated efforts by dominant actors, niche level amalgamation could be aligned with regime developments to trigger a reconfiguration through co-evolution and realignment of actor patterns to begin a technological transformation (Geels, 2002). Geels and Kemp (2007) exemplify the preceding in their analysis of how sewer systems evolved from cesspools to integrated systems, and how waste management transitioned from landfilling to differentiated waste handling with energy re-use in the Netherlands.

Interactions across the three levels can be understood as nested, with niches embedded in ST regimes, which are in turn subsumed in landscapes. Developments in the landscape (e.g. changes in geopolitical climate, labour migration, increase in housing shortage and homelessness) can, therefore, exert pressures on existing regimes, building up tensions that may create windows of opportunity for new technologies (Geels, 2005). Whilst a macro-level landscape comprises "slow changing external factors, providing gradients for the trajectories", the meso-level ST regime “accounts for stability of existing technological development and the occurrence of trajectories” and micro-level niches create the context for “radical innovations” (Geels, 2002, p.1261). It follows from the foregoing that attaining largescale scale technological transformation entails, first of all, complex adjustments to wide-reaching factors. Secondly, it requires attention to niche level developments and their alignment with changes in ST regimes to trigger incremental regime-level changes.

RESEARCH METHOD

This research is based on a review of 31 secondary data sources using constructs from the MLS theoretical framework in order to identify macro, meso and micro developments related to OSM and construction industry transformation in the UK. The documents reviewed comprise five government construction and industrial strategies, nine publications by government departments and arms-length bodies, eight industry reports and nine relevant media publications. Three key questions underpin the study’s analytical framework: 1) What are the macro, meso and micro developments related to the take up of OSM? 2) How can the ongoing developments be understood in the context of industry transformation attempts? 3) What central development holds the potential to drive an industry-wide uptake of OSM? The concepts of ‘landscape’, ‘sociotechnical regime’ and ‘niche’ developments were used in coding the data in NVivo 12.0 and the developments identified around OSM adoption were consequently synthesized. Examining the different documents helps put forward a conceptualization of how construction industry transformation entails multi-dimensional sociotechnical developments that need to be understood if the goals envisioned in the government’s reform documents will be achieved in part or fully.

Construction Industry Transformation: A Multi-Level Sociotechnical View of Developments

Landscape and Regime Level Developments

Government economic policies (e.g. austerity measures), geopolitical developments like Brexit, a national problem like increasing homelessness, low housing supply, a global challenge such as climate change and increasing infrastructure needs for a growing population are among the landscape factors that are impacting the construction industry and pushing the need for changes in how projects are delivered. Delivering better quality buildings faster and cheaper, at scale and in ways that offer more budget and time predictability, have consequently become priority areas for the government - the single largest client of the construction industry (IPA, 2019). The wide-ranging landscape factors have built up pressure, with calls for more innovation in how the construction industry is organised and projects are delivered (e.g. Farmer, 2016).

Overarching structures, rules of practice and established norms among actors (e.g. clients, contractors, consultants, planning authorities, technology vendors) that presently govern the construction industry are deeply embedded in configurations that are not oriented to allow a widespread adoption of OSM (Farmer, 2016). Despite pressure from the landscape yielding some (miniscule) changes in the existing sociotechnical regime of the construction industry, a lot remain unchanged (KPMG, 2016). Procurement routes for the majority of projects continue to promote adversarial relations, supplier networks are developed based on broken-down work packages where the lowest bid wins and processes of construction remain heavily labour-intensive and in-situ (House of Lords, 2018). Construction sector policies advocating the uptake of OSM also lack clear pipelines of infrastructure demand and incentivising messages (Green, 2019), and lending facilities are more aligned with projects which use 'tried and tested' conventional building techniques (House of Lords, 2018). Planning requirements, regulations and materials standards, labour skills and training, and the use of novel or borrowed technologies have all evolved and are 'locked-in' to the established sociotechnical regime. Exceptions include recent policy documents (e.g. HM Government, 2018; IPA, 2019), which are intended to transform the UK construction industry. The reform agenda set out in these documents are indicative of the government's readiness to nudge the construction industry to increase the adoption and use of OSM. With well-coordinated effort from a significant actor like the government and relevant industry stakeholders, the existing sociotechnical regime - which is not well aligned to encourage a widescale adoption of OSM - could be acted upon to create a 'window of opportunity', allowing niche level developments to breakthrough.

Niche Level Developments

As earlier noted, the use of OSM for construction project delivery is not new. For over three decades, projects have incorporated elements that are manufactured in factories and installed in a final location on site (NHBC, 2019). It is therefore unsurprising that 'sub-assemblies' and 'manufactured components' are the most common forms of OSM reportedly used by around 75% of clients and contractors on their housing projects in the UK (NHBC, 2016). It follows therefore, that technologies supporting the deployment of OSM do exist and have been used, albeit in limited ways when compared to on-site construction techniques. Growing awareness of the potential benefits of OSM by government and private clients has contributed - in part - to the formation of joint ventures, the establishment of dedicated

departments/units in construction organisations, the expansion and setting up of manufacturing plants, and the creation of technological solutions in the form of platforms enabled by computer-based digital technologies for design, manufacturability and error checks, costing, fabrication and quality checks. Unlike earlier applications of OSM several decades ago (cf. NHBC, 2019), increased computing power over the past two decades has enabled the use of digital technologies hosted in software packages such as Bentley, Revit and ArchiCAD for the manufacture of components and the deployment of OSM (Abanda *et al.*, 2017). Some private UK firms (e.g. Bryden Wood, ilke Homes, Urban Splash and TopHat) and some government ministries and departments are already exploring the use of some of these digital technologies with OSM for their projects (IPA, 2019; Offsite Hub, 2019).

Current ‘top-down’ government initiatives to create a demand push for the widescale use of OSM include the commissioning of a £253m 1,680 capacity resettlement prison by the Ministry of Justice; the Department for Business Innovation and Skills giving a £22.1m grant to Laing O'Rourke for the development of offsite manufacturing solutions; and a £38m joint housing scheme between Homes England, local authorities and private developers across the country. ‘Bottom-up’ attempts by industry actors include a £75m investment by Goldman Sachs in the use of OSM for housing provision, contractors establishing manufacturing factories and the formation of joint ventures (e.g. Laing O'Rourke, Legal and General and Touchstone) (Offsite Hub, 2019). These examples highlight some of the discrete niche level developments related to the adoption and use of OSM.

The multiple efforts are limited in terms of their ability to cause significant shifts along construction supply chains. As typical of niches, various actors have embarked on different attempts, developing their own innovations. The discrete nature of the initiatives is attended by the problem of interoperability as the technologies underpinning the OSM solutions are often bespoke and firm specific, severely impeding wider uptake attempts (House of Lords, 2018). Although such manufacturing technologies serve organisational commercial interests, they narrow chances for wider uptake and sustain the multidirectional nature of niche level developments. In the absence of a stabilised dominant design, the potential for a ‘radical’ transformation of the current construction industry might not be realised. This risk brings forward the need for a ‘strong’ landscape and regime actor like the government to methodically establish and stabilise dominant innovations that could break through to the regime level and trigger wider changes to help fulfil the reform agenda.

Towards a Breakthrough: The Platform Approach

The UK government has initiated steps to roll out a platform approach to design and manufacture for assembly (P-DfMA). Both DfMA and OSM share the principle of component-based design and construction of built assets (Abanda *et al.*, 2017; Goodier and Gibb, 2007). The platform is suitable for a "process by which building products, or components, are designed in a way that enables them to be made on a large-scale using machinery and then put together in one place" (IPA, 2019, p.5). Thus, despite being called a platform for ‘DfMA’, its underlying principles align with the arguments put forward for OSM in this paper.

According to the IPA (2019, p.5), the platform approach "was selected for a number of reasons... to follow and accelerate what is currently the most promising trend in the

construction engineering sector". The platform will be initially adopted by five government departments (Education, Health and Social Care, and Transport) and ministries (Justice and Defence) as part of a move to create a client-demand push for the use of OSM for project delivery. It is the government's position that "adopting digital and manufacturing techniques wherever appropriate in government-led building projects will help drive better performance in the construction sector..." (IPA, 2019, p.1). With public sector procurement accounting for over 51% of the value of UK construction work (ONS, 2019), the government is using its position as a dominant client to push suppliers in the industry towards its desired transformation goals. The platform approach, therefore, represents the single most recognisable development that holds the potential to lead to any 'real' step changes towards an industry-wide adoption of OSM.

The platform is underpinned by the three principles of 'design for manufacture', 'platform centredness' and being 'open for manufacture, use and procurement' (IPA, 2019). Designing for manufacture presents a shift away from design for on-site construction - which prevails in the existing preferred practices of the industry - and focuses on component-based project delivery. Unlike conventional approaches to design, the underlying principle emphasizes standardisation and interoperability of digitally designed components to be used in procurement and the construction of built assets. The components designed should be easily manufactured, scalable, and used repeatedly across projects. The skills requirement for a shift towards this 'manufacturing-led' design holds implications for the future of technologies used for design and the professional services offered in this area. Using a platform approach means that the components designed should be usable across different kinds of built assets, without limitations on their use in different project schemes. By ensuring that components comply with quality standards and are interoperable, the government anticipates enabling the creation of a new market for entrants to exploit. Enforcing interoperability implies changes in manufacturing platforms and configurations to suit the production of standardised components.

As with other technological innovations (cf. Orstavik, 2014), the new markets that would emerge around this platform approach would consequently impact the technologies used, and the supplier networks needed, by clients and contractors for projects. To be open for manufacture, use and procurement means that anyone should have the opportunity to make, use and buy components for legitimate purposes. Furthermore, it suggests a multi-party access to the design and use of the components for different projects, requiring components to follow outlined parameters for interoperability. This principle comes with a significant shift away from bespoke designs for projects and may change how clients request the services of design professionals. The identity of the latter may be challenged as access to interoperable components becomes more open for multiple industry actors. A multiparty access to the design and use of components would change existing procurement routes, risk allocation, and common forms of contract in the existing regime where clients are risk averse and contractors have to, in essence, charge a fee to take on the risk as part of delivering a project (cf. Green, 2019).

In summary, the platform approach is designed to change the processes of planning, design, procurement, construction and management of built assets. It represents an attempt by the government to: streamline public sector procurement for buildings for which there is value for money in using OSM; create and sustain a market for innovations around the approach for projects owned or procured by the five

government departments and ministries, their arm's length bodies and devolved authorities; and (re-)focus innovative developments related to OSM and digital technologies in the UK construction sector around a single platform to ensure incremental developments. Here, the government, as a strong / dominant actor, can be seen as accelerating the creation of niche cumulation whilst repositioning policy at the regime level to favour a breakthrough. With recent policy serving as a backbone for the implementation of the platform approach, and with the reform agenda at its forefront, the implementation of the platform holds the potential to trigger changes in the existing sociotechnical regime.

CONCLUDING REMARKS

This paper reviewed and discussed recent multi-layered developments related to the UK's construction industry reform agenda with a focus on OSM. The current trajectory of developments has limited potential to create any significant step changes that would lead to industry transformation. It consequently highlighted the potential of the government's platform approach to be a central innovation that could create the much-needed momentum to trigger 'real' changes towards the realisation of industry reform goals. Through the lens of the MLS theoretical framework, this development can propel a breakthrough from niche to regime levels. However, it is not expected that the platform approach would completely dominate the existing regime after the breakthrough. An industry-wide embrace would follow the pathways of complementary use, co-existence and finally competition with prevailing construction techniques until actors begin shifting their collective practices across the industry.

While the platform holds some potential in triggering changes, we do not claim it is the sole development to drive a widescale uptake of OSM. Beyond this 'top-down' techno-centric solution, achieving the desired industry transformation requires a co-evolution of the platform with policy, construction market dynamics, actor practices and existing technologies used for project delivery. How these co-developments will occur provides one direction for future research. It is expected that actors benefitting from the existing regime will resist changes. However, the government, as a strong actor, has the resources and influence to implement policies that could lessen resistance across the industry, facilitate co-evolution and help revise actor patterns in order to sustain incremental developments towards the envisaged transformation. Another direction for future research could explore coercive or incentivising OSM-related policies and consequent industry responses in tracking developments towards a reconfiguration of the existing ST regime as part of the transformation agenda.

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MACHINE LEARNING FOR ANALYSIS OF OCCUPATIONAL ACCIDENTS REGISTRATION DATA

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Regardless of the efforts of employers and public organizations to eliminate occupational accidents, the latter is a persistent problem in the construction industry. In the Swedish construction context, there is a desire to identify causes and factors playing a role in work-related accident prevention, as there are large underused databases of collected registrations that represent knowledge on causes and the context of accidents. The aim of the current contribution is to review the application of machine learning (ML) in the improved prevention of accidents and corresponding injuries, and to identify current limitations - and most importantly to answer the question of whether ML actually reveals more than what is currently known about accidents in construction. A systematic literature review on the use of ML for analysing data of accident records was carried out. In the reviewed literature, ML was applied in the prediction of accidents or their outcome, and the extraction or identification of the causes affecting the risks of injuries. ML combined with data mining (DM) techniques such as Natural Language Processing and graph mining, appears to be beneficial in discovering associations between different features and in multiple levels of clusters. However, the literature shows that research on ML in accident prevention is at an early stage. The review of the literature indicates gaps in the justification of methodological choices, such as the choice of ML method and data processing. Moreover, characteristics of the injury rates and severity are shown to be clashing with the mechanisms of the ML classification algorithms. This should probably lead to abandoning severity as a parameter and changing the approach towards the asymmetric data classes (denoted "unbalanced" in ML methodology), leaving space for finding the important causes. An overreliance on internal validity testing and lack of external testing of the algorithms' performance and prediction accuracy persists. Future research needs to focus on methods addressing the problem of data processing, explaining the choice of methods, explaining the results (especially the variance in ML algorithm's performance), merging different data sources, considering more attributes (such as risk management), applying deep learning algorithms, and improving the testing accuracy of ML models.

Keywords: accident registration, Machine Learning, occupational accident prevention

INTRODUCTION

Maintaining a safe workplace and reducing the frequency of serious accidents are continuous important quests in the Swedish and international construction industries. In Sweden, reports show that occupational accidents and near accidents continue to hinder productivity (Berglund *et al.*, 2017). The downward trend has levelled since

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2010, but the number of occupational accidents increased in accordance with the increase in the number of employees in the construction industry (frequency of 10.8 accidents/1000 workers) (Samuelsson 2019). In the Swedish context, these low figures are compared to a zero-accident goal, as for example purported by the association “Keep the Zero” (Håll Nollan 2020). Simulation of the workplace to identify various possible risk factors and dangerous situations in advance are two out of many possible tracks of technical solutions (Berglund *et al.*, 2017). There is an opportunity to exploit the large number of gathered registrations of accidents and near accidents in the domain of large contractors. In addition to that, Artificial Intelligence subdivisions such as ML and DM have increasingly been applied in finding underlying patterns and increasing the predictability of the risk of occupational accidents (Bilal *et al.*, 2016, Vallmuur 2015, Hegde and Rokseth 2020). Regardless, Vallmuur (2015) criticized the approach of analysing textual injury records for lacking the description of methodologies in processing the data and training the ML models. While Bilal and Oyedele (2020) suggested that the application of ML surpasses the development of a prototype and reliable models need to be trained based on informed decisions instead of only the expertise and intuition of engineers. Shayboun *et al.*, (2019) concluded that responsibility in action-taking, accountability in decision-making, and the continued crucial need for human reasoning, are important considerations to be taken. The literature review of the current effort is part of a project aiming at applying ML to a data record registered by a large contracting company in Sweden. The aim of this effort is to analyse the current literature in the application of ML to accident reports in the construction industry context. The analysis discretizes the reviewed articles into the following themes: the methodological choices of the ML algorithms, data collection and pre-processing, training of the system and validation performance, analysis and implementation of results, and the managerial implications. Moreover, the question of whether ML can reveal more than what is currently known about accidents in construction is raised.

The paper is structured according to its status as a literature review commencing with a method and continuing with a themed review. It then proceeds by synthesizing the findings in the discussion, followed by a conclusion.

METHOD

The literature review was conducted using the concept-centric framework augmented by units of analysis (Webster and Watson 2002), and it was based on a search regarding the application of ML to the analysis of accident registries in the construction sector. First, a list of relevant journals was prepared (Webster and Watson 2002), namely Safety Science, International Journal of Occupational Safety and Ergonomics, and Automation in Construction. Then, the concepts of the literature review emerged from using the search terms “occupational accidents”, “accident prevention”, “machine learning” and “construction projects”. This framework was strengthened by using the references-of-references and “snowballing” techniques (Greenhalgh and Peacock 2005) and aiming at a targeted but still comprehensive search (MacLure 2005).

The review was conducted in iterations; 169 publications were abstract-scanned, 54 fully read, and 7 were finally selected for the current effort. The main reason for selecting these few papers was that an in-depth elaboration on central studies in the cross-section of the aforementioned concepts was sought, rather than the accumulation of references that might be peripheral. This work is also a preliminary part of a

project aiming at applying ML to registered accidents by a large contracting company in Sweden. Due to the latter reasons, the literature search started with a broad scope of review and search words. However, the selection of papers for this effort was at a narrow-targeted list that is only related to the use of ML on reported accidents' data in the construction industry.

The themes emerging from the selected ML articles were organized in the following: choice of algorithms, data collection and pre-processing, training of the system and validation performance, analysis and implementation of results, and the managerial implications of the ML modelling. The iterations of the literature review and the emergence of the aforementioned themes followed the abductive reasoning of qualitative research, where observations and explanations of phenomena are developed by working iteratively between theory and data (which, in the present case, is the content of the references accumulated with each iteration), thus facilitating the revision and refinement of earlier conceptions (Bell *et al.*, 2019).

LITERATURE REVIEW

Choice of Algorithm

The literature shows that ML has been methodologically applied for different purposes, with this playing a significant role in the choice of the utilized algorithm(s). For example, Choi *et al.*, (2020) used a variety of algorithms they deemed suitable for forecasting purposes (such as logistic regression (LR), and AdaBoost), in order to predict the likelihood of fatality; Poh *et al.*, (2018) used classifiers (e.g. random forest (RF)) for the level of severity of accidents; Tixier *et al.*, (2016b) used algorithms such as the stochastic gradient tree boosting (STGB) to predict the type of energy involved in the accident, the injury type, the affected body part, and the severity of the injury; and Ayhan and Tokdemir (2019) used artificial neural networks (ANNs) for accident outcome prediction. Moreover, a natural language processing (NLP) algorithm was applied as a method for extracting features from textual data in accident injury reports (Zhang *et al.*, 2019), while Tixier *et al.*, (2016a) developed their own NLP algorithm. DM was also applied in conjunction with ML to graphically view groups of attributes that together lead to risky situations (Tixier *et al.*, 2017).

The predictions related to accidents were mostly treated as a classification problem. Popular classification algorithms were used both in single and ensemble learning models, and included, indicatively, k-nearest neighbour (KNN) and support vector machines (SVM) (Zhang *et al.*, 2019). The ensemble model outperformed all single classifiers with an accuracy of 68% in classifying 11 causes of accidents using the data extracted with NLP (Zhang *et al.*, 2019). On the other hand, the choice of Tixier *et al.*, (2016b) on using both RF and SGTB was explained by the authors to be based on the logic that the purpose of the research is to test if fundamental construction attributes can be used in predicting safety-related outcomes, while simultaneously there is a lack of general rule on which algorithm is better than the other.

Data Collection and Pre-Processing

The data used in Zhang *et al.*, (2019) consisted of 16323 accident reports related to construction sites that are registered in the Occupational Safety and Health Administration (OSHA), collected between 1983 and 2016. But this data was not labelled (i.e. the instances were not initially attributed into the sets of specific classes), and the selection of the dataset shifted to 1000 labelled records published by previous research. Choi *et al.*, (2020) collected the data through the Ministry of Employment

and Labour in the Republic of Korea. The dataset contained 137323 injuries and 2846 deaths, and included information about the age, sex, length of service for each injured worker, the type of construction, employer scale, and the data of the accident. However, Choi *et al.*, (2020) encountered limitations in their access to certain parts of the dataset, due to the related data protection law in the Republic of Korea. Poh *et al.*, (2018) had the advantage of expanding the data type. The data covered 27 construction projects from a single contracting company in Singapore (consisting of 19 building projects and 8 infrastructure projects) over a period of seven years (from 2010 to 2016); it included 785 safety monthly inspection records, 418 accident cases, and their corresponding monthly project-related attributes. Another approach was to collect data through a structured template (Ayhan and Tokdemir 2019). The templates consisted of six categories for accident causes, such as human factors, workplace factors, the course of an accident, and time of occurrence.

As described above, there can be challenges and variations in the data collection, size, variety, and structure (e.g. labelled vs unlabelled instances). Critically, these challenges also tie with challenges in handling and processing the data. A common practice found in the accident registry analysis is the handling and processing of textual data, as can be found in e.g., Tixier *et al.*, (2016a). Zhang *et al.*, (2019) applied NLP to extract the causes of accidents and the objects which contributed to the accidents, from labelled accident reports - but found that the performance of the NLP was not achieving the full potential of extraction. The result of the classifier was not very satisfactory with an accuracy of only 68%; Zhang *et al.*, (2019) explained this result by arguing that natural language is not precise and that developing comprehensive rules to cover all meanings of different expressions is not feasible. To avoid the previous limitations of NLP, Tixier *et al.*, (2016a) developed a new domain-related NLP algorithm to automatically scan and extract features from unstructured accident records. The motivation of programming a new NLP algorithm over the existing ones was that it was based on hand-coded rules and dictionaries of keywords related to the domain of accidents, which resulted in higher levels of accuracy. Tixier *et al.*, (2016a) reached a precision of 95% in scanning 80 attributes, 7 injury types, 9 energy sources, and 5 body parts, after having a team of relevant experts review the algorithmic results in order to find true positives, false positives, and false negatives.

The challenge in handling and processing data does not end at the extraction of features from textual data but can also be found in the data featuring classes with a large variation in the number of instances they include (so-called "unbalanced" classes). This problem places a challenge in ML because the training of the model can fall short to recognize the more sparsely populated classes. Class variation in terms of volume of data has been found in the injury severity, energy type involved, and body parts injured. In Choi *et al.*, (2020), the injury data was represented 48 times more than the fatality data. The authors approached this as a challenge that needs to be tackled; in doing so, they suggested three methods for resampling: random oversampling (ROS), random under sampling (RUS), and the synthetic minority oversampling technique (SMOTE). They ended up choosing ROS because it was a better fit with the categorical values in the dataset. Poh *et al.*, (2018) also encountered the same phenomena, as the instances in the dataset included a total of 35 "Major Accident" cases, 336 "Minor Accident" cases, and 256 "No Accident" cases. The authors applied SMOTE to overcome this problem. In the dataset of Tixier *et al.*, (2016b), the class "pressure" in energy type and "neck" in body parts were disproportionately represented. Stratified oversampling was used to reduce this effect.

The disadvantage of oversampling methods is that they reduce the accuracy of the majority class. Tixier *et al.*, (2016b) looked for a balance in the overall error with resampling proportion tuning integrated into the parameter optimization of the algorithm. In general, the three cases of unbalanced classes were approached using some sort of oversampling technique without clear justification of this choice or deeper explanation of the implications. The critique of the notion of “unbalanced” when oversampling is used, lies in the implicit assumption that a phenomenon should generate balanced datasets, which is not the case in the causes and consequences of accidents. Moreover, the critique of oversampling is that the ML designer moves into an unknown ground by assuming similarities in different parts of the studied phenomenon. Future conceptual development of ML for accident analysis needs to correct these faulty assumptions and find ways where ML can support the understanding of accidents.

Training of the System and Validation Performance

In Tixier *et al.*, (2016b), SGTB outperformed RF, achieving high performance of the Rank Probability Skill Score (RPSS) in predicting the energy type. The superiority of the SGTB might be explained by the fact that it reduces error by reducing variance and bias, while RF only reduces variance. However, predicting injury severity was not successful. Either additional layers of attributes were required (such as the amount of energy released), or injury severity could be a result of random components of similar events.

In the work of Poh *et al.*, (2018) and Choi *et al.*, (2020), RF outperformed other classification algorithms, such as, indicatively, SVM, KNN, and AdaBoost. The classification by Poh *et al.*, (2018) into “No accident”, “Minor accident” and “Major accident”, achieved an accuracy of 78%, while in Choi *et al.*, (2020) the value of the Area Under the Receiver Operating Characteristic Curve (AUROCC) metric was 0.9198; this was considered as satisfactory, as the ideal value of AUROCC is 1.

Ayhan and Tokdemir (2019) chose to apply only ANNs and conventional multiple regression to predict the outcome of accidents. The conventional multiple regression failed compared to the ANNs, but 13 different iterations were tried. The ANNs’ performance was evaluated with R-square values and mean percentage errors. Considerable difference was found between training and testing accuracy, as the testing accuracy dropped by 50% for the fatality class.

Analysis and Implementation of Results

More methodological advancement can be found in the work by Tixier *et al.*, (2017), as they proposed the use of graph mining and hierarchal clustering on principle components (HCPC) to analyse 4387 injury reports. HCPC is an unsupervised data mining technique that groups observations into levels of clusters (Tixier *et al.*, 2017). The clusters were manually inspected to find relevant safety clashes and organized by the authors in main themes; e.g., the congested workplace and confined workplace combined increased the risk of many other different attributes. The injury reports were automatically scanned by the developed NLP algorithm of Tixier *et al.*, (2016a) for 80 binary attributes, which were also identified by previous research. The authors based their work on five different algorithms and analysed them in terms of centrality, closeness, and betweenness. To use the algorithms, the data was split into subsets of injury type, namely struck by or against, caught in or compressed, fall on the same or to lower level, overexertion, and exposure to harmful substance. The results were extensive; to mention a few, it was found that the improper procedure/inattention

plays a central role in the misuse of tools such as hammer and rebar. This was explained by the authors by noting that the human-related errors were shared across all groups of attributes. Moreover, confined workspace, working at height, and scaffolding, were closely related, which implied that constrained working space was a potential environment for falling. Also, a strong centrality appeared between the piping and the unpowered tool, bolt, and steel sections, which implied that these were major contributors to the caught in between or compressed injuries. The close proximity of welding to improper body positioning and working overhead and scaffold, showed that the possibility for workers to be injured through exposure to a harmful substance, was amplified when adopting non-natural body positioning.

The fuzzy inference decision-making system of Ayhan and Tokdemir (2019) was tied up with three courses of action; if a lost workday or a fatality was predicted, the action was to stop construction, then check the method of statement of work to find the direct cause of the prospective incident, and finally set up a research team to seek out the root cause.

However, discussing principles of the implementation of results is not enough to capture the experience of employing the algorithms in the prediction of accidents or decision-making support. There is a need to investigate the users' experiences and the external validation of the ML models. Most importantly, it is crucial to understand the practical implication of applying the ML models for testing the accuracy of training, testing, and observing the change in workplace safety processes.

Managerial implications

The practical implication of the ML analysis and utilization of results is very important in understanding how construction can benefit from the research. Few authors discussed that; Tixier *et al.*, (2017) suggested that safety knowledge in the form of binary attributes can be used in combination with Building Information Modelling (BIM), as attributes can be assigned to physical elements and spaces to automatically identify and report potential hazards in the design phase. Poh *et al.*, (2018) suggested using the RF model in the cases where the input regarding each project in the company is used to predict the projects in which generate high risks. Choi *et al.*, (2020) conceptually presented a system based on access control systems on construction sites, where the data of age, length of service, construction type and the season were used as input. The model of fatality prediction could identify safety managers, workers, contractors, and work teams who were at a high risk of major accidents.

Ayhan and Tokdemir (2019) also acknowledged the vagueness of ANNs in understanding the results. Therefore, the fuzzy set theory was suggested to achieve a more trustworthy prediction. Specifically, the authors suggested a fuzzy inference method by comparing expert module and the prediction, then taking the worst outcome. As explained in the previous subsection, the fuzzy inference decision-making system was tied up with specific courses of action.

DISCUSSION

The evaluation metrics and performance of the models appear to be different between the literature efforts reviewed. This contributes to hindering the possibility for current and future benchmarking of results in comparison to previous efforts. The same applies to the choice of algorithms. The RF outperformed other classification algorithms (Poh *et al.*, 2018). However, the SGTB outperformed the RF classifier in

Tixier *et al.*, (2016b). Overall, the approach of choosing the classification algorithm is experimental and rarely coupled with an analysis for the logic behind choosing algorithms, and the reasoning for higher prediction capability in one algorithm compared to others.

The literature review shows a variation in the data sources and limitations related to the availability and the structure of the data. Zhang *et al.*, (2019) preferred to use a dataset that is 16 times smaller than the available one, due to the limitation of labelling. Although this option had an advantage in the applicable ML classification, it did not exploit the available large data sample. Increasing the sample size can potentially increase precision in the sample (Bell *et al.*, 2019). Although the size of the dataset is not the only indicator of quality, it is worth to investigate whether the types of accidents in smaller datasets are representative of the cases that are found in larger volumes of data, and how unlabelled data can be exploited in the first place, especially with high volume availability. Currently, it looks like lost potential.

Moreover, extracting features from free written textual data is found to be complicated and immature (Zhang *et al.*, 2019, Tixier *et al.*, 2016a). Although Tixier *et al.*, (2016a) showed that a domain-specific NLP is yielding promising results, the success of the algorithm is depending on the quality of reports and the quality of the textual data. It is not expected from the algorithm to detect misspelled or missing words and it is not known how the algorithm would perform if applied to extract features from a different set of data other than the one used for developing the algorithm. It was also noted by the authors that the quality of the reports used was high, as they were short and very well written. Ayhan and Tokdemir (2019) argued that structured templates for collecting data about occupational accidents have an advantage compared to the free text data collection. Carefully defined templates provide a ready categorization of attributes of work events compared to the free text that might be categorised by occupation health professionals offsite. Predefined templates might be advantageous from a pragmatic point of view, but it can also be argued that an unstructured form of accident reports can allow the possibility to attain further and deeper information and reduce bias.

Methodological issues related to unbalanced datasets were found in the literature (Choi *et al.*, 2020, Poh *et al.*, 2018, Tixier *et al.*, 2016b). This is a ML learning classification problem that clashes with the occupational accidents problem. The method choices for tackling the unbalanced classes are problematic both in the resampling techniques and the definition of the ML task. Multiple methods of resampling were applied by the authors, with little explanation of the implications or the disadvantages of using these methods. The resampling techniques increase the frequency of the underrepresented class, but assuming regularity of causes in areas that are less well known seems to be problematic. The elements for causes patterns are not automatically the same; for example, the risk of one machine is not the same as the risk of another, and the same accident outcome does not necessarily emanate from the same course of events. It is crucial to search for other techniques to manage the unbalance with minimum change to the data. There is also a need for metrics and evaluation for the common resampling techniques that are to be applied.

The focus of the reviewed literature was on the outcome of an accident such as predicting the likelihood of fatality (Choi *et al.*, 2020), classification of the severity level of an accident (Poh *et al.*, 2018), predicting the type of injury, body part affected, and the injury severity (Tixier *et al.*, 2016b), and the prediction of accident

outcome (Ayhan and Tokdemir 2019). It can be learned from Tixier *et al.*, (2016b) that predicting severity level fails compared to the type of energy that is involved in an accident, a result consistent with accident research (Rollenhagen 2011). To distinguish between minor and major accidents is maybe influenced by the obligation of the industry to mostly record serious injuries (Oswald *et al.*, 2018). But severity might be less important information to predict compared to predicting the occurrence of an accident regardless of the outcome. It was suggested that the target of the ML modelling task is a crucial step in the design of applied ML (Bilal and Oyedele 2020). The unbalanced data can be mitigated by alternatively defining the goal of the ML model to focus on the risks associated with an accident instead of the accidents' outcome. This would give a better understanding of the distant events leading to the accident, instead of focusing on the outcome which might not be present in high frequency.

Few authors suggested the application of the ML models in decision making. However, theoretically discussing the implementation of results is not enough. To capture the experience of employing the algorithms in predicting accidents or decision-making support, implementation trials are required. Bilal and Oyedele (2020) suggest that applied ML methods include further steps other than modelling successful predictors. Interpretation and production deployment are the two main steps necessary for the evaluation of ML modelling. There is a need to investigate the users' experience and the external validation of the ML models. Most importantly, to understand the practical implication of applying the ML models for testing the accuracy of training and observing the change in the safety processes of the workplace. This would provide an indication of credibility and trust when the decision-making is supported by the ML recommendation.

In our problem statement, we questioned whether ML actually reveals more than what is currently known about accidents in construction. Realizing the broadness of the question, it can be posited that ML might add knowledge when comparing to local knowledge represented by health and safety professionals, because of the large volumes covered. At a time, local knowledge might be much richer in appreciating the complexity of causes and factors involved in actual accidents, provided that the local health and safety personnel have been involved in reporting. Comparing to research on causes behind accidents (Berglund 2017, Ringdahl 2013, Jørgensen 2002, Rollenhagen 2011) it appears that the deeper layers of causes, such as management strategy, industrial norms, contracts, and wage systems are poorly covered by the ML applications. A likely reason for this is the quality and character of the registered data used.

CONCLUSION

This contribution set out to review the application of ML for the improved prevention of accidents and related injuries and to identify current limitations. It was questioned whether ML reveals more than what is currently known about accidents in the construction domain. A systematic literature review on the use of ML for analysing accident records was carried out. The literature contains ML applications using data from registered accidents and their deployment in the prediction of accidents or their outcome. As the ML system intends to extract or identify causes affecting the risks of injuries, a series of ML and data mining techniques have been used. However, the research on ML in accident prevention is at an early stage. And there were identified gaps in the justification of methodological choices, such as the choice of ML method

and data pre-processing; which appear to be of an experimental character (trial and error). Moreover, the characteristics of the accident's rates and severity showed to be clashing with approaches employed in the use of ML classification algorithms. The articulated need for “balancing” data according to severity of accidents should in the future be abandoned to the benefit of a focus on risks, as severity is a difficult, if not impossible analytical category. The use of oversampling appeared to be misguided as the patterns of accidents in fewer data-covered areas cannot be easily identified. Rather, other sources for causation such as systematic accident analysis of singular accidents should be employed. Furthermore, an overreliance on internal validity testing and a lack of external testing of algorithms’ performance and prediction accuracy benchmarks persists. By mitigating these issues, future research might be able to focus on systematizing causes related to, for example, risk and energy, and thereby finding other and more important causes. Future research needs to focus on methods addressing the problem of data pre-processing, explaining the choice of methods, employing a mixed method approach merging several quantitative and also qualitative data sources, and explaining the results (especially the variance in ML algorithm’s performance). Research should be commenced into investigating more attributes (such as risk analysis), applying deep learning algorithms, and improving the testing accuracy of ML models.

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THE ROLE OF INDUSTRY 4.0 IN CONSTRUCTION OCCUPATIONAL HEALTH (OH)

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Historical occupational health (OH) challenges, in terms of a range of issues, continue to be experienced, namely not following procedures, unsafe acts, unsafe conditions, non-compliance, sprains and strains, fatigue, and heat stress among workers, materials containing hazardous chemical substances, untrained workers undertaking work, commencement of activities without conducting hazard identification and risk assessment (HIRA), data gathering and recording, and monitoring. Given the abovementioned, and the advent of Industry 4.0, an exploratory quantitative study, which entailed a self-administered questionnaire, was conducted among registered Construction Health and Safety (H&S) practitioners to determine the OH challenges experienced, OH performance, and the perceived potential of Industry 4.0 to contribute to resolving the former cited challenges. The findings indicate that: A range of historical challenges, which negatively impact OH performance, continue to be experienced in construction; H&S practitioners rate themselves below average in terms of awareness of / exposure to most Industry 4.0 technologies, and Industry 4.0 technologies are perceived as having the potential to contribute to resolving the OH challenges experienced in construction. Conclusions include: A different approach is necessary to mitigate the persistent OH challenges; current technology is not capable of resolving the OH challenges; an integrated digital effort is required to resolve the OH challenges, and artificial intelligence, blockchain technology, digitalisation in general, drones, the internet of things, robots, and virtual reality are perceived as having the potential to contribute to resolving the H&S challenges experienced in construction. Recommendations include: employer associations, professional associations, and statutory councils should raise the level of awareness relative to the potential implementation of Industry 4.0 relative to OH in construction; case studies should be documented and shared; tertiary construction management education programmes should integrate Industry 4.0 into all possible modules, especially H&S and OH-related modules, and continuing professional development (CPD) OH should address Industry 4.0.

Keywords: Industry 4.0, Occupational Health, performance

INTRODUCTION

The Construction Industry Development Board (CIDB) (2009) report 'Construction Health and Safety Status and Recommendations' highlighted the considerable number of accidents, fatalities, and other injuries that occur in the South African construction industry. The CIDB (2009) contends the high-level of non-compliance with H&S legislative requirements is indicative of a deficiency of effective management and

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supervision of H&S on construction sites, as well as planning from the inception / conception of projects within the context of project management.

According to The Council for Scientific and Industrial Research (CSIR) (2018), the rapid rise and convergence of emerging technologies is driving the Fourth Industrial Revolution (FIR), also known as Industry 4.0. FIR is a collective term for technologies and value chain organisation which draw together cyber-physical systems, the Internet of Things (IoT) and the Internet of Services (IoS), together with other emerging technologies such as cloud technology, big data, predictive analysis, artificial intelligence, augmented reality, agile and collaborative robots, and additive manufacturing. According to Autodesk and the Chartered Institute of Building (CIOB) (2019), digital technologies are transforming every industry, and construction is no exception. Infinite computing, robotics, machine learning, drones, the Internet of Things (IoT), augmented reality, gaming engines, and reality capture, to name just a few, are innovating the design, build, and operation of buildings and infrastructure. Considering the numerous challenges experienced in construction, especially the delivery of projects, it is inevitable that Industry 4.0 is considered to overcome these.

Given the continuing poor OH and H&S performance in South African construction, and the cited benefits of implementing Industry 4.0 technologies, an exploratory study was conducted to determine the:

- Frequency that phenomena are experienced on projects;
- Extent of the need for performance improvement on projects;
- Respondents' awareness of / exposure to eleven Industry 4.0 technologies, and
- Perceived potential of Industry 4.0 technologies to reduce the occurrence of phenomena.

LITERATURE REVIEW

Occupational Health in Construction

OH is defined by the World Health Organization (WHO) (1994) as the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations. The principles of OH are embedded in the 'health for all (HFA)' concept adopted and published as a declaration by the WHO. The HFA states that H&S at work is an important matter, and the general health and well-being of workers should be given due consideration at multiple levels. Despite the aforementioned, there is a paucity of literature pertaining to South African OH interventions, and little is known regarding OH in the South African construction industry.

Ill health kills and ruins lives in the construction industry. A construction worker is at least 100 times more likely to die from a disease that has been caused or exacerbated by their work, than from a fatal accident (Snashall, 2012; National Institute of Occupational Health (NIOH), 2018). Construction work itself is known as dirty, tough and hazardous, highly manual, and transient in nature. The NIOH (2018) further cites the construction industry as one of three industries with the highest rate of work-related injury risks. Hazards that workers are exposed to include chemical, biological, poor ergonomics, and psychosocial hazards, and extended exposure to such risks results in occupational and work-related diseases (NIOH, 2018).

Construction workers are exposed to many forms of hazards that cause target organ damage that is considered as an occupational disease (OD). For example, crystalline silica, as a dust, affects the respiratory system, mainly the lungs (the target organ), causing silicosis (an occupational disease). Exposure to asbestos also affects mainly the lungs and causes severe damage and fibrosis of the lung tissue and is diagnosed as asbestosis. Exposure to different forms of work exposes workers to a range of risks: fumes from welding and soldering; a range of dusts from cutting, drilling stone and various materials; gasses, and waste products. Several natural hazards are a further risk to which workers are exposed, such as biological hazards (legionella, zoonoses), temperatures and weather, spores, and sunlight (Institute of Occupational Safety and Health (Iosh, 2016).

The Role of Industry 4.0 Technologies

The traditional approach to monitoring and measuring H&S-related issues are largely manual in nature, and to overcome these limitations of manual efforts, automated H&S monitoring is considered one of the most promising methods for accurate and continuous monitoring of H&S performance on construction sites (Awolusi *et al.*, 2018). A study conducted by Gheisari and Esmaili (2016) determined that using unmanned aerial systems (UASs), commonly referred to as ‘drones’, to monitor construction activities could help identify potential on site hazards and therefore improve H&S management.

According to Ananthanarayan and Siek (2010), wearable technologies can enable the continuous monitoring of a wide range of vital signals which can provide early warning systems for workers with high-risk health issues. The HSE (2019) in turn state that there is growing evidence that wearable devices can significantly benefit H&S in the workplace through positioning and sensor technologies. A study conducted by Nath *et al.* (2017) determined that wearable technology was able to prevent work related injuries and fatalities by ergonomically designing the work environment based on previous data collected.

In recent years visualisation technologies such as virtual reality (VR) and augmented reality (AR) have been developed and used to improve construction productivity, H&S, and quality (Le *et al.*, 2015). A study conducted by Sacks *et al.* (2013) determined that VR-based training was more effective than traditional H&S training methods, which made use of classrooms and slide presentations. According to Park *et al.* (2013), AR based applications and systems have been developed to improve on-site tasks such as: data visualisation; work inspection and checking for omissions. Furthermore, they have improved on-site H&S performance to some extent.

Global Construction Review (2019) reports on an American construction robotics company which unveiled its concept for an autonomous machine that can lift, carry, and place rebar on bridges and other horizontal reinforced concrete applications. This is in response to a backbreaking task for workers and addresses the shortage of skilled labour.

RESEARCH

Research Method and Sample Stratum

A 14-question questionnaire was circulated per e-mail to 92 Professional (Pr) Construction Health and Safety Agents (CHSAs), 139 Candidate (Can) CHSAs, and 562 Construction Health and Safety Managers (CHSMs) registered with the South African Council for the Project and Construction Management Professions

(SACPCMP). 39 CHSM e-mails could not be delivered, which resulted in a net sample of 754. 7 of the questions were demographic related, 6 were closed-ended and Likert Scale type questions, and one was open-ended. 58 Responses, courtesy of 16 Pr CHSAs, 16 Can CHSAs, and 26 CHSMs, which equates to a response rate of 7.7%. The analysis of the data entailed the computation of frequencies, and a measure of central tendency in the form of a mean score (MS).

Research findings

Table 1 indicates the frequency at which nineteen OH-related phenomena are experienced on projects in terms of percentage responses to a scale of never to constantly, and MSs ranging between 1.00 and 5.00. It is notable that 16 / 19 (84.2%) of the MSs are above the midpoint of 3.00, which indicates that in general the respondents can be deemed to perceive the phenomena to be experienced on projects.

Table 1: Frequency at which OH-related phenomena are experienced on projects

Phenomenon	Response (%)						MS	Rank
	Unsure	Never	Rarely	Some-times	Often	Con-stantly		
Under-pricing	0.0	0.0	1.8	8.8	42.1	47.4	4.35	1
Late information	0.0	0.0	0.0	21.4	35.7	42.9	4.21	2
Similar or alike errors are repeated	0.0	0.0	3.5	17.5	50.9	28.1	4.04	3
Information anomalies / ambiguities	0.0	0.0	1.8	21.1	52.6	24.6	4.00	4
Inadequate coordination of subcontractors	0.0	0.0	7.0	21.1	38.6	33.3	3.98	5
Data / Statistics is / are not available	0.0	0.0	7.0	21.1	42.1	29.8	3.95	6
Management information is not available	1.8	0.0	7.1	26.8	39.3	25.0	3.84	7
Non-compliance	0.0	0.0	5.3	31.6	50.9	12.3	3.70	8
Unauthorised people fulfil functions	1.8	1.8	8.8	28.1	43.9	15.8	3.64	9
Unhealthy / Unsafe plant and equipment	0.0	0.0	14.0	26.3	47.4	12.3	3.58	10
Materials containing hazardous chemical substances	0.0	0.0	15.8	31.6	36.8	15.8	3.53	11
Injuries	0.0	1.8	17.9	26.8	37.5	16.1	3.48	12
Fatigue among workers	1.8	0.0	16.4	34.5	36.4	10.9	3.43	13
Sprains and strains among workers	0.0	1.8	12.3	43.9	33.3	8.8	3.35	14
Difficulty monitoring the process and activities of construction (in terms of OH)	1.8	1.8	17.9	35.7	33.9	8.9	3.31	15
Accidents	0.0	0.0	17.5	42.1	35.1	5.3	3.28	16
Heat stress among workers	0.0	7.1	25.0	41.1	21.4	5.4	2.93	17
Fatalities	1.8	7.0	43.9	35.1	12.3	0.0	2.54	18
Occupational disease	8.9	14.3	28.6	35.7	10.7	1.8	2.53	19

Only 2 / 19 (10.5%) of the phenomena have MSs $> 4.20 \leq 5.00$, which indicates the frequency is between often to constantly / constantly - under-pricing, and late information.

11 / 19 (57.9%) of the MSs are $> 3.40 \leq 4.20$, which indicates the frequency is between sometimes to often / often. 5 / 11 (45.5%) MSs of similar or alike errors are repeated, information anomalies / ambiguities, inadequate coordination of subcontractors, data / statistics is / are not available, and management information is not available are $> 3.80 \leq 4.20$ - the upper part of the range. The remaining 6 / 11 (54.6%) MSs are $> 3.40 \leq 3.80$ - non-compliance, unauthorised people fulfil functions, unhealthy / unsafe plant and equipment, materials containing hazardous chemical substances, injuries, and fatigue among workers.

5 / 19 (26.3%) MSs are $> 2.60 \leq 3.40$, which indicates the frequency is between rarely to sometimes / sometimes - sprains and strains among workers, difficulty monitoring the process and activities of construction (in terms of OH), accidents, and heat stress among workers.

The MSs of the last ranked phenomena, namely fatalities, and occupational disease, are $> 1.80 \leq 2.60$, which indicates they are experienced between never to rarely / rarely. However, it should be noted that both MSs are within 0.07 of the upper point of the range.

Many of these phenomena are frequently referred to in the literature (HSE, 2017; Autodesk and CIOB, 2019; HSE, 2019a; HSE, 2019b), and furthermore, Industry 4.0 technologies have been identified as being able to reduce the occurrence of phenomena as per the literature (Autodesk and CIOB, 2019).

Table 2 indicates the extent of the need for performance improvement on projects in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint of 3.00, which indicates that in general the respondents can be deemed to perceive the need for improvements to be major as opposed to minor.

It is notable that 6 / 17 (35.3%) MSs are $> 4.20 \leq 5.00$, which indicates the respondents perceive the need for improvement to be between near major to major / major - improved planning and control of activities on site, improved communication, workers with technical skills, link processes across the stages of projects, integration of information (construction), and integration of information (procurement).

The remaining 11 / 17 (64.7%) MSs are $> 3.40 \leq 4.20$, which indicates the respondents perceive the need to be between some improvement to a near major / near major improvement - integration of information (design), healthier and safer plant and equipment, digitalisation of information, improved security, workers with technology skills, improved materials management, identification of hazardous materials, deployment of technology, simulation of activities, and automation of activities on site. 9 / 11 (81.8%) MSs are $> 3.80 \leq 4.20$ - the upper part of the range.

These needs are varied; however, the empirical findings reflect the findings of the literature in terms of the implied need for performance improvement (Autodesk and CIOB, 2019; CIDB, 2016). Furthermore, they can be responded to by Industry 4.0 technologies (Autodesk and CIOB, 2019).

Table 3 indicates the respondents' self-rating of their awareness of / exposure to eleven Industry 4.0 technologies in terms of percentage responses to a scale of 1

(limited) to 5 (extensive), and a MS ranging between 1.00 and 5.00. It is notable that only 3 / 11 (27.3%) of the MSs are above the midpoint of 3.00, which indicates that in general the respondents can be deemed to rate themselves as above average, as opposed to below average - Internet of Things, drones, and digitalisation of information. However, it should be noted that smart sensors have a MS of 2.96.

Table 2: Extent of the need for performance improvement on projects

Need	Response (%)						MS	R
	U	Minor..... Major						
		1	2	3	4	5		
Improved planning and control of activities on site	0.0	0.0	3.6	9.1	30.9	56.4	4.40	1
Improved communication	0.0	0.0	7.0	8.8	29.8	54.4	4.32	2
Workers with technical skills	0.0	0.0	3.6	19.6	23.2	53.6	4.27	3
Link processes across the stages of projects	1.8	0.0	12.3	8.8	22.8	54.4	4.21	4
Integration of information (construction)	0.0	1.8	8.9	8.9	26.8	53.6	4.21	5
Integration of information (procurement)	0.0	0.0	8.8	14.0	24.6	52.6	4.21	6
Integration of information (design)	0.0	1.8	7.0	8.8	38.6	43.9	4.16	7
Healthier and safer plant and equipment	0.0	0.0	7.0	21.1	28.1	43.9	4.09	8
Digitalisation of information	0.0	0.0	1.8	25.0	39.3	33.9	4.05	9
Improved security	0.0	0.0	8.8	19.3	31.6	40.4	4.04	10
Workers with technology skills	0.0	0.0	1.8	30.9	34.5	32.7	3.98	11
Improved materials management	0.0	0.0	3.5	29.8	35.1	31.6	3.95	12
Identification of hazardous materials	1.8	1.8	7.0	21.1	33.3	35.1	3.95	13
Deployment of technology	3.5	0.0	8.8	19.3	45.6	22.8	3.85	14
Simulation of activities	0.0	0.0	14.0	21.1	35.1	29.8	3.81	15
Automation of activities on site	0.0	3.6	14.3	26.8	39.3	16.1	3.50	16
Workers with IT skills	0.0	5.4	16.1	25.0	35.7	17.9	3.45	17

It is notable that no technology is rated above average to extensive / extensive (MSs > 4.20 ≤ 5.00). Only 1 / 11 (9.1%) MSs is > 3.40 ≤ 4.20, which indicates a rating of average to above average / above average - Internet of Things. However, it should be noted that drones have a MS of 3.40.

Only 6 / 11 (54.5%) MSs are > 2.60 ≤ 3.40, which indicates a rating of below average to average / average - drones, digitalisation of information, smart sensors, 3-D printing, blockchain, and Artificial Intelligence (AI) / Machine Learning.

The remaining 4 / 11 MSs are > 1.80 ≤ 2.60, which indicates a rating of limited to below average / below average. Virtual Reality, robotics / exoskeletons, and Augmented Reality fall within the upper half of this MS range, whereas nanotechnology falls within the lower half.

Table 3: Respondents' awareness of / exposure to eleven Industry 4.0 technologies

Need	Response (%)					MS	R	
	U	Limited.....		Extensive				
		1	2	3	4			5
Internet of Things	1.8	10.9	7.3	18.2	29.1	32.7	3.67	1
Drones	3.6	9.1	16.4	18.2	32.7	20.0	3.40	2
Digitalisation of information	3.6	10.9	12.7	27.3	30.9	14.5	3.26	3
Smart sensors	7.3	16.4	20.0	23.6	16.4	16.4	2.96	4
3-D printing	1.8	21.8	21.8	29.1	18.2	7.3	2.67	5
Blockchain	20.4	16.7	20.4	22.2	14.8	5.6	2.65	6
Artificial Intelligence (AI) / Machine Learning	3.8	18.9	30.2	22.6	18.9	5.7	2.61	7
Virtual Reality	5.5	32.7	16.4	20.0	18.2	7.3	2.48	8
Robotics / Exoskeletons	9.1	29.1	27.3	16.4	9.1	9.1	2.36	9
Augmented Reality	12.7	40.0	14.5	14.5	9.1	9.1	2.23	10
Nanotechnology	10.9	32.7	27.3	16.4	7.3	5.5	2.16	11

Table 4 indicates the potential of Industry 4.0 technologies referred to in Table 3 to reduce the occurrence of nineteen phenomena in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint of 3.00, which indicates that in general the respondents can be deemed to perceive the potential to be major as opposed to minor.

It is notable that no MS is $> 4.20 \leq 5.00$ - near major to major / major potential.

13 / 19 (68.4%) MSs are $> 3.40 \leq 4.20$, which indicates between potential to near major / near major potential - 6 / 13 (46.1%) the MSs, namely information anomalies / ambiguities, under-pricing, late information, OH data / statistics is / are not available, similar or alike errors are repeated, and management information is not available fall within the upper half of this range, namely $> 3.80 \leq 4.20$. The phenomena whose MSs are $> 3.40 \leq 3.80$ include difficulty monitoring the process and activities of construction (ito of OH), non-compliance, inadequate coordination of subcontractors, unauthorised people fulfil functions, unhealthy / unsafe plant and equipment, accidents, and fatigue among workers.

6 / 19 (31.6%) of the MSs are $> 2.60 \leq 3.40$, which indicates between near minor potential to potential / potential - materials containing hazardous chemical substances, injuries, sprains and strains among workers, fatalities, occupational disease, and heat stress among workers.

Despite the respondents' generally low self-rating of their awareness of / exposure to the eleven Industry 4.0 technologies, they recognise the potential of Industry 4.0 technologies to reduce the occurrence of the phenomena as per the literature (Autodesk and CIOB, 2019).

Table 4: Potential of Industry 4.0 technologies to reduce the occurrence of phenomena

Phenomenon	Response (%)					MS	R	
	U	Minor..... Major			5			
		1	2	3				4
Information anomalies / ambiguities	5.5	3.6	1.8	14.5	38.2	36.4	4.08	1
Under-pricing	5.5	1.8	3.6	16.4	38.2	34.5	4.06	2
Late information	3.6	3.6	3.6	12.7	40.0	36.4	4.06	3
OH data / statistics is / are not available	5.4	3.6	1.8	21.4	37.5	30.4	3.94	4
Similar or alike errors are repeated	5.4	0.0	3.6	28.6	42.9	19.6	3.83	5
Management information is not available	3.6	1.8	12.7	14.5	40.0	27.3	3.81	6
Difficulty monitoring the process and activities of construction (ito of OH)	3.6	3.6	7.1	23.2	41.1	21.4	3.72	7
Non-compliance	3.6	1.8	8.9	23.2	44.6	17.9	3.70	8
Inadequate coordination of subcontractors	3.6	3.6	12.5	21.4	30.4	28.6	3.70	9
Unauthorised people fulfil functions	7.3	9.1	9.1	20.0	23.6	30.9	3.63	10
Unhealthy / Unsafe plant and equipment	3.6	7.1	8.9	23.2	37.5	19.6	3.56	11
Accidents	3.6	5.4	12.5	26.8	37.5	14.3	3.44	12
Fatigue among workers	5.4	3.6	12.5	33.9	28.6	16.1	3.43	13
Materials containing hazardous chemical substances	3.6	8.9	16.1	17.9	37.5	16.1	3.37	14
Injuries	3.6	7.1	16.1	23.2	35.7	14.3	3.35	15
Sprains and strains among workers	3.6	7.1	16.1	25.0	35.7	12.5	3.31	16
Fatalities	3.6	12.5	14.3	23.2	30.4	16.1	3.24	17
Occupational disease	7.3	12.7	12.7	20.0	36.4	10.9	3.22	18
Heat stress among workers	5.4	10.7	17.9	25.0	28.6	12.5	3.15	19

DISCUSSION

The findings indicate that nineteen OH-related phenomena are experienced on projects, and in the case of 84.2%, frequently as opposed to infrequently, which indicates that in general OH challenges exist, and persist. Under-pricing, late information, similar or alike errors are repeated, information anomalies / ambiguities, inadequate coordination of subcontractors, data / statistics is / are not available, and management information is not available predominate. The deployment of Industry 4.0 technologies is perceived as having the potential to mitigate all the challenges.

The extent of the need for performance improvement on projects relative to aspects or interventions that could improve OH is between some improvement to a near major / near major improvement. Improved planning and control of activities on site, improved communication, workers with technical skills, link processes across the stages of projects, integration of information (construction), and integration of information (procurement) predominate, which primarily amplifies the need for information, and the management including integration thereof.

The respondents rated themselves above average in terms of their self-rating of their awareness of / exposure to eleven Industry 4.0 technologies in only 3 / 11 (27.3%)

cases - Internet of Things, drones, and digitalisation of information. However, despite this, they perceive Industry 4.0 technologies to have the potential to reduce the occurrence of the phenomena.

Eleven (100%) Industry 4.0 technologies are perceived as having more major than minor potential to reduce the occurrence of nineteen OH-related phenomena. The predominating phenomena are information anomalies / ambiguities, under-pricing, late information, OH data / statistics is / are not available, similar or alike errors are repeated, and management information is not available.

CONCLUSION

Given the frequency that phenomena are experienced on projects and the extent of the need for performance improvement on projects, it can be concluded that the respondents' OH perceptions reflect the general research findings relative to OH performance in South African construction, and that there is a need for improvement, potential to improve, and a need to process test Industry 4.0 technologies to determine whether they contribute to a quantifiable improvement in OH performance or not.

Given the respondents' below average self-rating of their awareness of / exposure to eleven Industry 4.0 technologies, it can be concluded that there is a need for interventions to raise the level of awareness, and to integrate such technologies into built environment / construction / construction OH / H&S education and training.

Given the perceived potential of Industry 4.0 technologies to reduce the occurrence of nineteen construction resource-related H&S phenomena, the perceived need for the implementation of Industry 4.0 in construction is amplified.

RECOMMENDATIONS

Built environment stakeholders, which includes construction project managers, designers, quantity surveyors, contractors, and construction H&S consultants should process test Industry 4.0 technologies to determine whether they contribute to a quantifiable improvement in OH performance or not.

Built environment, especially construction management, and construction H&S-related tertiary education, and construction OH / H&S-related training should include, or rather embed Industry 4.0 in their programmes.

Construction employer associations, and built environment associations and statutory councils should promote, and preferably provide Industry 4.0-related OH / H&S continuing professional development (CPD) and evolve related guidelines and practice notes.

The Construction Industry Development Board (CIDB) should evolve a position paper relative to Industry 4.0 in construction and deliberate the development of a related industry standard.

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BIM IN CONSTRUCTION PRODUCTION: GAINS AND HINDERS FOR FIRMS, PROJECTS AND INDUSTRY

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The construction industry strives to implement digitalization and Building Information Modelling (BIM). Studies of BIM in construction claim that a pronounced BIM strategy, knowledge of the subject and a willingness to change are important factors to succeed, but even when such conditions are in place, BIM implementation in construction production is scant and has limited impact. So how should the construction industry go from grand digital visions to practical application in reality? By identifying gains, obstacles and success factors on company, project and sector levels the paper aims to set out a road map for successful BIM implementation in construction production. Data sets, both qualitative and quantitative from eleven studies of using BIM in construction production, show that although the industry is making progresses in implementing BIM and digitalization, the full potential is far from realised. Specifically, the research presents an analysis of factors in relation to (1) strategy and innovation, (2) technology, (3) organizing, and (4) ecosystem. Conclusively, all these levels are strongly interdependent and need to be considered by adopting a holistic approach to reach an enhanced implementation.

Keywords: BIM, ecosystem, implementation, production, strategy

INTRODUCTION

The visionary idea of Industry 4.0 has been introduced to describe the trend towards digitisation, automation and the use of ICT in manufacturing. Despite the many promises and initiatives for improvements, the construction industry is far behind other industries, such as the automotive and mechanical engineering sector, in terms of integrating innovative technologies (Hampson *et al.*, 2014). Within the construction environment, Building Information Modelling (BIM) has been identified as the central technology in digitisation in the process of converting information from a physical format into a digital one (Oesterreich and Teuteberg 2016; Azhar 2011) and in efforts to increase digitalisation as to leveraging this process to improve business competitiveness. BIM can be defined as: “set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in a digital format throughout the building’s life cycle” (Succar 2009).

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Thus, BIM is both a technology and a process for project and asset management (Bryde *et al.*, 2013).

BIM can be applied from design to facility management, in processes of tendering, design, planning, construct, and use and maintain (Hartmann *et al.*, 2012), thus, involving different actors, including contractors, clients, architects, designers, subcontractors, suppliers, and facility managers. Hence, BIM encourage the integration of the various stakeholders (Azhar 2011), but in an industry characterised by a temporary project nature (Winch 2003), high fragmentation with numerous relationships among the many actors (Dainty *et al.*, 2001) and increasing complexity of projects (Chan *et al.*, 2004), integration appears to be the holy grail in the industry. In line with that, grand visions in relation to BIM implementation define a future state of enhanced collaboration and improved integration that in turn leads to improved performance and reduction of project costs, achieved over time.

Previous research point to benefits and challenges in the implementation of BIM. Improved profitability, reduced costs, improved time management and client-contractor relationships are brought forward, but also the legal pitfalls with proprietary and risk sharing that have to be regulated in the contracts, otherwise hindering successful implementation (Azhar 2011). The IFC interoperability is another barrier for BIM implementation in relation to collaboration between firms (Delgado *et al.*, 2017; Farghaly *et al.*, 2018). Furthermore, the absence of qualified staff delays the spreading of BIM in construction (Ho and Rajabifard 2016). Although exact numbers are difficult to calculate, comparing non-BIM and BIM projects shows tangible economic gains for the latter. In general, the total design costs increase, but at the same RFI reduction, reduced rework, schedule compliance, and decreased change orders lead to increased productivity and net costs savings (Chelson 2010; Barlish and Sullivan 2012). Other studies recognize the role of government policies as central for facilitating BIM adoption in the industry (Davies *et al.*, 2015).

However, besides a few exceptions (e.g. Oesterreich and Teuteberg 2016; Bryde *et al.*, 2013), research on BIM implementation beyond specific construction projects is scant (Davies *et al.*, 2015). Therefore, the paper aims to contribute to previous research by utilizing a data set of various actors, for example, contractors, consultants, and architects, from different firms in the Swedish construction industry in the exploration of BIM implementation. In line with this, the aim of the paper is to scrutinize obstacles, gains and success factors on company, project, and sector levels for understanding the co-evolution of BIM implementation.

Theoretical Considerations

BIM entails both technical aspects and processual working methods (e.g. Mondrup *et al.*, 2012), including how to cope with information content and exchange as well as business model features. BIM is thus able to manage the complex setting of different actors and their surrounding environments, but with challenging conditions of different hardware and devices as well as various needs and incentives for different actors to adhere to adoption, the road for increased implementation is not straightforward. In line with this, as to cover for the many aspects, several studies apply a socio-technical perspective in the scrutinization of BIM as to acknowledge a technological core (3D CAD, intelligent models and information management) with social layer components (synchronous collaboration, coordinated work practices as well as institutional and cultural frameworks). In order to asses and evaluate organizations' BIM implementation, various maturity models have been proposed

(Sacks *et al.*, 2018). The BIM Maturity Matrix (Succar 2009), for instance, offers a framework based on technology, process, policy, collaboration, and organization, with emphasis on differences between the organization's BIM capability and maturity.

Taking into consideration that BIM entails interdependencies between technological, process and organizational/cultural features, a theoretical lens is required that acknowledge BIM as an ecosystem where products, processes, organizations and people form a complex network (Gu *et al.*, 2015). BIM as a collaborative approach is thus contingent on how these various pieces fit together as to provide a comprehensive understanding of the systemic challenges. The ecosystem perspective acknowledges both the micro level of projects and organizations and the macro levels of industry and society, as well as the interplay between those levels, as a basis for understanding the patterns and co-evolution of BIM (Singh 2016).

Inspired by the socio-technical lens and the call for a holistic assessment of BIM as an eco-system, the research model from Bosch-Sijtsema *et al.* (2016) is utilized for exploration of facilitators and hinders for BIM implementation on micro and macro levels. This holistic research model is the result of a joint effort between industry and academia within the Centre for Management of the Built Environment in Sweden (CMB) as to guide research efforts and implementation strategies within the Swedish construction sector. Within the scope of the paper, the research model (see Figure 1) has two purposes: (i) to sort the factors of gains and obstacles in the data sets, and (ii) to analyse the interdependencies of products, processes, organizations and people in BIM implementation addressing company, project and sector levels.



Figure 1: Holistic research model to BIM implementation

METHOD

The data consists of qualitative interviews (n=114), observations and quantitative questionnaire data (n=183, mean response rate 31,3 %) gathered from 14 bachelor- and master theses supervised by the authors. The theses were carried out between 2011 to 2020, and cover a number of companies in Sweden, from medium sized to the largest contractors and consultants. All theses aimed to explore the implementation/lack of implementation of BIM in construction production. The data cover issues relating to project-, company- and in some instances sector level. Furthermore, in terms of actors the data cover the whole range from construction workers, engineers and different BIM- and management roles.

RESULTS

The result table below presents the analysed results of 14 bachelor- and master theses summarized in Tables 1 and 2. The analysis of the result has been done by using the holistic research model (see Figure 1) including four factors; ecosystem, strategy and innovation, technology and organizing, sorted into gains and obstacles connected to

BIM implementation related to company, project and sector levels. See Tables 1 and 2 for compilations of these results.

Table 1: Data from Theses. Gains/opportunities at company (C), project (P) or sector (S) levels

		Gains/opportunities * = potential gain, not derived from implementation	C	P	S	Ref.
Ecosystem	Standards	Turnkey contract gives opportunities for information flow *	X	X		2
	Laws, regulations, requirements	IFC requirements gives software interoperability *	X	X	X	2, 12
	Costs	BIM reduces paper drawings, saves money and environment	X	X	X	2, 11, 12
		BIM reduces time for understanding construction projects	X	X	X	2
Strategy & innovation		Earlier start of the building construction,	X	X	X	2
		Increased efficiency (less errors), e.g. it avoids reworks, BIM helps to stay within the budget of the project *	X	X		1,2,3, 5,9, 10,12
	Productivity, performance	Accurate quantities can be taken directly from the BIM	X			5,10, 11,13, 14
		Digital information and checklists in one place (efficiency)	X			10,11
		Up to 50% reduction of change orders	X	X		5
		Send information to produce rebar at the factory	X	X		5
		Construction cost control during design	X	X	X	5, 13
	Methods and processes	Better and common understanding, communication and collaboration between professionals and workers	X	X		1,2,5, 9, 10, 14
		Knowledge transfer to the next projects	X			2
		Amount of information attainable is higher	X			1
Specific BIM professions to support digitalisation in construction process		X	X		4, 6,7	
More accurate planning*		X	X		3	
Cooperation with BIM between firms	Improved insight gives better plan and liability for workers	X			1	
	BIM for construction logistics: improved coordination*	X	X		3	
	More flexible extraction of info (compared to drawings)	X	X		5	
	Better understanding/interest among the different disciplines	X	X	X	5, 12, 14	
Technology	Technological components	Model and design-review coordination	X	X		6, 12
		Tablets gives mobility and quality control possibilities	X			2
		BIM reduces visual conflicts and errors (clash detection)	X	X		2, 12
	Interoperability	ID numbers of BIM objects can be connected to timetables *	X			1
		Synchronized codes through the entire production chain *	X	X		2
	BIM software allows the integration of stakeholders' models	X			9, 12	

Table 2: Data from Theses. Obstacles/hinders at company (C), project (P) or sector (S) levels

		Obstacles/hinders	C	P	S	Ref.
Standards		Lack of standardization for codes/names	X	X	X	1, 2, 12, 13
		Turnkey contract needs to be updated to include BIM			X	2
Ecosystem	Laws, regulations, requirements	Need for industry standards on legal binding models	X	X		2, 8, 9, 12
		Design-Bid-Build contracts complicated for BIM application			X	1
Costs		BIM costs more money compared to traditional design	X	X	X	2, 11
		Consultants want a new payment model for BIM design	X	X		9
Strategy	Productivity, performance	Lack of case studies regarding efficiency/quality	X			1, 2, 5, 8, 11, 12
		Limited use of BIM for visualisation on construction site		X		2
		Quality of BIM is not good enough (lack of information for the construction site)	X	X		1, 2, 11,
		Use 2D-drawings and BIM lead to diverging information	X	X	X	11
Methods and processes		Lack of education, knowledge transfer and support on BIM for employees on construction site	X	X	X	1, 2, 4, 5, 7-9, 11, 12, 14
		No template system in work to organize the data contained within the BIM-model	X	X		2, 12
		Lack of dedicated time for employees to drive and practice BIM related issues and learning software use		X		1, 4, 11, 12, 13
Organizing	Cooperation with BIM between firms	Unfamiliarity with BIM professional roles	X	X	X	6, 7, 9
		BIM for logistics: different work methods cause loss/overload of information	X	X		3
		Clients lack in knowledge and in setting demands on BIM	X	X	X	5, 12
		Designers lack in skill on BIM requirements and design	X	X	X	5, 12
		Difficult to agree on a suitable level of detail in the model	X	X	X	5, 12
Technological components		Lack of supporting BIM in tablets and smartphones	X			2
		Difficult to take measurements in the model	X	X	X	5, 13
Technology	Interoperability	Software/tools are un-user-friendly and complex	X	X	X	1, 2, 5, 11-14
		BIM is not automatically synchronized in software	X	X		1
		A lot of different programs for different disciplines	X	X		1, 3, 11
		Lack of filtering information for BIM objects	X			11

References for Tables 1 and 2: [1] Blomberg, 2019; [2] Norberg and Brantitsa, 2018; [3] Carlson and Kraemer, 2019; [4] Eklund and Galliher, 2018; [5] Götborg and Olsson, 2016; [6] Gunnemark and Heinke, 2014; [7] Hansson and Johnsson, 2016; [8] Landgren and Lys, 2019; [9] Motiejunas, 2016; [10] Sandahl and Sernemyr, 2018; [11] Westerlund, 2019; [12] Alassadi and Khallouf, 2020; [13] Josefsson and Lindhe, 2020; [14] Siahkalrudy, 2011.

ANALYSIS AND DISCUSSION

By sorting the factors of gains and hinders in BIM implementation in accordance to the first issue pointed to in the research model, some interesting patterns are revealed (see Table 2). Focusing on the identified obstacles in the theses' studies, consistency is observed regarding model quality, lack of education and on-site technical support, lack of user-friendly software, as well as interoperability problems (both at the software level and standardization level). Also, aspects of unclear professional roles and the common problem of falling back to traditional, non-BIM ways of working, during times of high pressure are identified. In addition, a substantial number of obstacles can be connected to the cost of implementing BIM together with the lack of sheer numbers regarding improved efficiency and reduced project cost. A recurring theme is that BIM is known to provide better communication and understanding within a project, but tangible, quantifiable gains in terms of actual costs are less easy to find (see Table 1).

The latter is especially interesting, as several examples contain concrete numbers/values for increased quality and reduced costs as outcomes of implementing BIM. Clearly, these benefits have not gained traction or obtained any notable visibility throughout the industry. The decision to and also the cost for implementing BIM commonly refer to the project level, wherefore it appears crucial to present these benefits at all levels in the organizations, and not only at strategic and top management levels. In addition to reduced cost, increased quality, production efficiency, as well as improved communication and understanding, several identified gains are connected to efficient re-use of data and automation, such as, automatic quantity take-offs and generation of reinforcement specifications. Furthermore, the theses highlight many additional gains that BIM can provide - but are currently not utilized - such as 4D planning, 3D site layout plans, and integration with logistics systems.

In general, discussions regarding digitalization within the construction industry are often synonymous with BIM implementation, which is not necessarily the case. For instance, digital checklists and issue management systems are reported as being very efficient digital tools, yet they are not dependent on BIM. Often these functions are part of different BIM-tools, such as Dalux, but they do not actually require the use of BIM but can be used together with traditional (digital) 2D drawings. As such, a clear distinction between digitalization and BIM has to be made. Mixing 2D and BIM in the same project is further recognized as a successful approach to ease the transition to BIM. However, at the same time, the availability of traditional construction documents enhances the risk of falling back to traditional working methods, which makes it somewhat a double-edged sword.

Furthermore, as seen in Götborg and Olsson (2016) there is the possibility to take BIM implementation to the fullest (i.e. no traditional 2D-drawings at all) with a successful outcome. As evident, obstacles still exist, however, without the possibility to fall back to traditional non-BIM ways of working, the projects are essentially forced to find new ways around these obstacles - ultimately leading to new and improved working methods. Taken together, analysis of the theses shows that several of the gains and/or obstacles have been identified by different organizations and different roles, wherefore taken together, the data set provides a representation of the state of the sector.

The second issue in relation to the research model concerns analysis of interdependencies of products, processes, organizations and people in BIM implementation addressing company, project and sector levels. No sequential or linear process is discovered in terms of that certain hinders must be overcome, before certain other steps can proceed. However, several interdependencies exist among the factors. Technology and organizing are strongly interdependent as technological components and interoperability must be in place as to reap the benefits of methods, processes and the different ways of working with BIM. In the same way, a high quality of technology cannot be exploited without the support and training of the people that are supposed to use the technology for their working methods. These two factors go hand in hand so to speak.

Furthermore, advanced and accurate technology in itself is not going to solve the many obstacles and hinders observed in BIM implementation, if not being adjusted to the specific needs of various organizations and the people within these organizations. This includes adjustments in relation to the purpose of using the technology, and the products that are used. For example, there is a better understanding among the different disciplines (e.g. carpenters, HVAC) by using BIM compared to 2D Model coordination, but still different work methods may cause information loss or overload. Furthermore, software and tools are still un-user-friendly with different programs lacking appropriate filtering information for BIM objects, thus, this is another example of the lack of alignment between people, products and technology in relation to the processes.

Many of the identified gains in terms of cost reduction and improved productivity and performance are also contingent on the alignment between technology and organizing, thus, the strategic potential for BIM also adheres to strong interdependencies among processes, people and technology. Thus, the fact that BIM costs more than traditional design, which is an obstacle observed on both micro- and macro levels, cannot turn into a gain by making BIM cheaper, but by providing more value when addressing with the interdependencies among technology, organizing and strategy and innovation. Thus, adjustments among these factors are more crucial, and shows greater potential than to direct all efforts into just one of the factors.

On the sector level, the lack of standardization, regulations and laws as to form an ecosystem where several organizations can connect, delays the adoption of BIM methods severely, especially in terms of no clear legal responsibility for the model as BIM is not a legal contract document. Instead, organizations invest their efforts in 2D drawing as they are the legal requirements. As such, the lack of consistency as to cope with the interdependencies among the macro level in the form of an ecosystem and strategy and innovation for organizations and projects on the micro level hampers BIM implementation.

CONCLUSION

Previous research identifies that in general, larger firms, particularly major contractors and/or public clients, operating on design-and-build basis are the ones that have led BIM adoption (Davies *et al.*, 2015). In practice, that may still hold true, however, successful BIM implementation is in fact contingent on numerous factors. Firstly, technology advancements - and thus the software vendors - is still a very important factor as both gains and obstacles can be traced back to the need of powerful and user-friendly BIM software, which has been lacking in the industry. Secondly, without implementing BIM to the fullest (i.e. no traditional 2D-drawings), projects always

have a 'back-up' which allow them to retreat on traditional organizing in times of pressure or when obstacles emerge. Thus, taken together, utilization of advanced technology products and methods is interdependent with management processes that provide for and support implementation to its fullest. In order to reap the benefits of these technologies and processes, education, training and support of people as users of the technology are of outmost importance. As such, there is an interplay between the quality of technology and products, and the quality of the support for people.

Thirdly, also the various needs of different organizations when using BIM and accordingly, that technological components and interoperability are designed to diversify operability, appear crucial. Thus, the technology must be adapted to the purposes of using it, including how various organizations can align BIM to their working methods. However, coping with the interdependencies among product features, processes, people and technology, and achievements of alignment among them, is not enough per se in individual projects as to enhance implementation. BIM in the form of strategy and innovation processes for individual organizations is contingent on development of project methods to be applied in several projects. This is the only way the necessary investments of time, money and other resources can be justified.

Thus, how the interdependencies on the micro-level of companies and projects are dealt with appears most central for the perceived gains of increased BIM implementation, but also on how various companies and/projects exploit these opportunities. Finally, if laws and regulations hinder implementation or a lack of standards apply, hence, the macro level of the ecosystem is not in place, the spread of achievements on the micro level of organizations and projects will be hampered. Accordingly, alignment between the interdependencies among macro- and micro levels, and the technical and the social layers, is key in the strive for an increase in BIM implementation and enhanced use of BIM technology for project management processes. More specifically, by using a holistic approach, and connecting the ecosystem, strategy and innovation, organizing and technology factors, connected to BIM implementation related to company, project and sector levels, this study has shown that all these factors and levels are interconnected. It is therefore important to approach BIM implementation in construction production from a systemic perspective, including the potential in revising existent management processes, as to release the ability of Industry 4.0 visions.

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THE SDGS: A FRAMEWORK FOR BUILDING A COMMON GOOD FOR THE BUILT ENVIRONMENT

INTEGRATING CIRCULAR ECONOMY AND CONSTRUCTABILITY RESEARCH: AN INITIAL DEVELOPMENT OF A LIFECYCLE "CIRCULARITY" ASSESSMENT FRAMEWORK AND INDICATORS

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Hitherto, the Circular Economy (CE) in construction literature has lacked a holistic framework for assessing the "circularity" of construction activities. This has delayed full transition of the construction industry to CE. The 'Lifecycle "Circularity" Assessment Framework (LCAF)' proposed in this paper presents a significant contribution as it facilitates measuring the industry's transition to CE through twelve "circularity" indicators (CIs) that signify high-level requirements of a construction CE. Grouped in five themes relevant to different stages of a project lifecycle, these indicators assess the "circularity" of construction activities, rather than of tracking their casual links with individual CE concepts. A systematic review assessed "circularity" within the 'constructability' literature, as both 'constructability' and CE share a philosophical focus on resource value, using the proposed framework. Results revealed a weak, but increasing, association between CE and 'constructability', and a variable engagement with different CE themes and indicators. The literature has engaged with indicators that fall inside its comfort zone, i.e., those related to design and construction. This misses the opportunities offered through engaging with other, more challenging, CE themes and indicators providing directions for future research. Moreover, the proposed framework reshapes the relationship between CE and sustainability, 'flipping' the traditional view of CE being subordinate to sustainability. It also has a potential to extend into rating "circularity" by construction firms/projects to identify areas of good practice and those for "circularity" improvements.

Keywords: circular economy, Lifecycle Circularity Assessment Framework (LCAF),

INTRODUCTION

The term circular economy (CE) was first introduced by Pearce and Turner (1990). CE has its roots in a variety of ideologies and schools of thought such as regenerative design, performance economy, cradle-to-cradle and industrial ecology (Sauvé *et al.*, 2016; Rizos *et al.*, 2017; De los Rios and Charnley, 2017; EMF, 2013). Moreover, cleaner production (CP) is a relevant concept that can be used to achieve the goals of

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both CE and sustainable development (Ghisellini *et al.*, 2016). Reviewing the scope of CE in the literature reveals two limitations: first, there is no consensus in the literature on the scope of CE. Ghisellini *et al.*, (2016) believe CE should cover the entire life-cycle of any process, taking into consideration its embedded context, and lead to material or energy recovery along with improvement of the entire living and economic model. This holistic approach to CE requires reshaping the entire chain of production, consumption, distribution and recovery (Ghisellini *et al.*, 2018). However, the CE concept is frequently viewed in the literature from the closed material loops and waste management perspectives (e.g. Sauv  *et al.*, 2016; De los Rios and Charnley, 2017; Preston, 2012). Second, the relationship between CE and ‘sustainability’ is not explicitly addressed, which “is blurring their conceptual contours and constrains the efficacy of using the approaches in research and practice” (Geissdoerfer *et al.*, 2017). The CE concept is frequently perceived as a subordinate to sustainability, being considered as a pathway to product sustainability (De los Rios and Charnley, 2017), and a strategy to achieve a more 'sustainable development' and a harmonious society (Ghisellini *et al.*, 2016). However, actual CE research focuses on waste management having little linkage with sustainable development (Kirchherr *et al.*, 2017); whereas sustainability research in construction is limited to high-performance green buildings and retrofitting (Sanchez and Haas, 2018), and energy consumption and carbon emissions (Pomponi and Moncaster, 2016).

The lack of a valid framework and tools to measure the overall transition of different industries from ‘linear’ to ‘circular’ models (EMF, 2015a) is directly linked to the ambiguous scope of CE. Sauv  *et al.*, (2016) believe that CE tends to have narrower objectives than those of sustainable development; it includes a fragmented collection of concepts derived from different scientific fields, some being poorly established (Korhonen *et al.*, 2018). The diversity of concepts, schools of thought, and stakeholders operating in significantly different environments have all blurred the CE concept (Kirchherr *et al.*, 2017). CE research is characterised by a partial approach (Pomponi and Moncaster, 2017), engaging with conceptual discussions about individual concepts of CE, with no practical implementation strategies provided (Su rez-Eiroa *et al.*, 2019). Trends of CE research in construction include construction and demolition (C&D) waste management (Ghisellini *et al.*, 2018), sustainable construction (Kibert, 2016), and industrial symbiosis (Smol *et al.*, 2015).

The first comprehensive definition for 'buildability' (the initial form of 'constructability'), was provided by the Construction Industry Research and Information Association (CIRIA) in 1983 (Kifokeris and Xenidis, 2017). Early definitions of ‘constructability’ reveal shared objectives with the CE concept; better knowledge and expertise management to review construction processes early in pre-construction and design stages to facilitate ease of construction (CIRIA, 1983), achieve overall project objectives (CII, 1986), and predict obstacles prior to the construction stage (IPENZ, 2008). Nima *et al.*, (2001) listed 23 constructability concepts (CCs), with many in line with CE principles such as: use of prefabrication and off-site construction to avoid adverse weather conditions; planning for good site management, efficient use of resources and improved productivities; efficient use, reuse and recovery of temporary facilities and construction equipment; and improved collaboration through effective use of information technology.

Early constructability definitions have two main limitations. First, they fail to address the totality of the building life-cycle, with a focus on the construction stage, but not on the operation and decommissioning stages. Second, they are motivated mostly by

economic, rather than environmental and social objectives. Later definitions (e.g. Gambatese *et al.*, 2007) start to acknowledge the whole building life-cycle, with the IRC (2013) proposing a framework to show how the scope of 'constructability' grew from facilitating building construction to the whole construction life-cycle and improving building performance. This is a natural response to technological and ecological changes and growing societal concerns of sustainability, and it can thus be posited that both constructability and CE have shared objectives of retaining the value of resources for as long as possible whilst also minimising waste.

RESEARCH AIM, OBJECTIVES AND METHODS

Constructability literature provides no empirical evidence of any engagement with CE concepts, and therefore the posited sharing of objectives needs to be assessed using a systemic approach examining industry conformity with CE requirements and exploring areas for "circularity" improvements. Subsequent presenting of such improvements to the industry in the context of objectives shared with a known 'philosophy' (constructability) may result in wider adoption of them. This requires:

1. Proposing a holistic framework, using a 'project life-cycle assessment (PLA)' approach, for "circularity" assessment of construction activities and practices.
2. Assessing conformity of 'constructability' research and practices with CE requirements using the proposed framework.

The 'Lifecycle "Circularity" Assessment Framework (LCAF)' proposed in this paper could have been introduced without the inclusion of "constructability". However, the innovative nature of this initial framework necessitated the need to explore its applicability within a context, i.e., 'constructability'. This gives the proposed framework some meaning and provides an example of how construction processes would benefit from its adoption. This framework includes five main themes aligned with different stages in the project lifecycle. The literature was reviewed for relevance of generic CE concepts and requirements to the five themes. Consequently, these were grouped into twelve "circularity" indicators (CIs) embodying high-level requirements of CE in construction. A systematic review of the literature, including 132 articles, was then conducted to explore whether 'constructability' research and practices fulfil CE requirements, and support the transition of construction to CE.

A Framework for "Circularity" Assessment

Reviewing CE literature in general reveals a few attempts to identify principles, strategic focus areas, and related metrics or indicators to measure the transition to CE. For example, Su *et al.*, (2013) categorize CE practices into four areas: production, consumption, waste management, and other support; each includes practices at different managerial levels of CE: micro, meso and macro. The first three areas perceive CE from the material perspectives, whereas the fourth highlights the role of governments and NGOs in promoting CE. Ellen MacArthur Foundation (2013) introduced a generic framework of four "building blocks" to promote the transition to CE, including: circular product design and production, new business models, building reverse cycle, and cross-cycle collaboration. This shifts the focus from material-centred perspectives, and instead highlights the role of better planning, collaboration, and the use of new business models in the transition to CE. The European Environmental Agency (2016) provides a generic set of policy questions for CE assessment classified under five main areas: material input, eco-design, production, consumption, and waste recycling. This framework is adopted by Elia *et al.*, (2017) to

assess different CE concepts based on ability satisfy five CE principles: reducing material inputs, reducing material losses, reducing emissions, using renewable/recyclable resources, and increasing product durability. Suárez-Eiroa *et al.*, (2019) use these principles, complemented with two transversal principles ('designing for CE' and 'educating for CE'), to group practical strategies of CE.

CE literature has two shortcomings: firstly, suggests no valid indicators for assessing the actual transition to CE; and secondly, the transition to CE is not discussed in a specific context i.e., industry. This first issue is addressed in the 'Circularity Indicators Project' (EMF, 2015a) that suggests a tool to measure how advanced products and companies are in transitioning to CE using four criteria: inputs in the production process, utility during in-use stage, destination after use, and efficiency of recycling. The 'Delivering the CE' report (EMF, 2015b) also suggests a toolkit to measure a country's level of "circularity" using four metrics, each is linked to one or more relevant assessment criteria. These include resources productivity, circular activities, waste generation, and energy consumption and greenhouse gas emissions.

In construction, Sanchez and Haas (2018) argue that CE principles must be integrated into the construction process. This can be facilitated by more involvement of clients as key drivers in project teams (Haugbølle and Boyd, 2017), including CE decision gates and "pre-project" or "front-end" planning (Sanchez and Haas, 2018), and design and education as transversal elements (Suárez-Eiroa *et al.*, 2019). The UK Green Building Council (2019) report attempted a holistic approach to embedding principles of CE in construction projects, by providing guidance on how to address principles of CE in project briefs. It consists of a list of high-level CE principles to be applied in all construction projects but provides no valid framework of indicators to assess overall "circularity" of project outcomes and does not extend beyond the project brief.

Proposing a 'Lifecycle "Circularity" Assessment Framework (LCAF)':

This paper argues for the project-based nature of the construction process to be embedded in "circularity" assessment, and any framework developed for this purpose to address the totality of the project life-cycle. This requires a link between CE requirements, as perceived in the literature, and different stages of the project life-cycle some of which currently are not well-addressed or are absent (e.g. the 'decommissioning' stage). This does not promote 'closing material loops' as a key CE requirement and limits the potential of construction practices to implement CE principles.

The 'Lifecycle "Circularity" Assessment Framework (LCAF)' proposed in this paper adopts a 'project life-cycle assessment (PLA)' approach to measure conformity of the 'constructability' literature to high-level requirements of CE referred to as "circularity" indicators (CIs); rather than tracking its casual links with individual CE concepts. CIs are grouped into five themes relevant to main stages in a construction project life-cycle. Themes include: (1) 'design for circularity' to link to the 'design stage', (2) 'reduced construction impact' to link to the 'construction stage', (3) 'sustainable utilisation and maintenance' to link to the 'operation stage', (4) 'C&D waste mgmt.' to link to 'closing material loops' during 'construction' and 'decommissioning' stages, and (5) 'CE mgmt.' for managerial requirements that cannot be included in other themes.

Generic CE requirements identified in the literature are classified according to their relevance to the five framework themes. Subsequently, these are grouped into twelve "circularity" indicators (CIs) embodying CE requirements relevant to different themes.

Designing for CE plays a transversal role in promoting circularity across product life-cycle (Suárez-Eiroa *et al.*, 2019), which signifies a fundamental change in design practices (De los Rios and Charnley, 2017). In the first theme, 'design for circularity', three CIs are used to assess "circularity" of design practices: 'design solutions to maximise future circularity', 'use of low-impact and innovative materials', and 'embed recycled materials in design'. The first CI is aspirational, as it assesses plans for future "circularity" at the project end-of-life, whereas the other two CIs are active, as they measure "circularity" achieved during project delivery. The second theme, 'reduced construction impact', includes two CI encapsulation requirements relevant to 'reduced material inputs' through more efficient construction processes and equipment sharing, and 'innovative construction methods' e.g., off-site construction and 3D printing.

Table 1: The proposed 'Lifecycle "Circularity" Assessment Framework (LCAF)'

Circularity Themes	Circularity Indicators
Design for Circularity in Construction (Design Stage)	<ul style="list-style-type: none"> • Design Solutions to Maximise Future Circularity: (design for disassembly, longevity, and modularisation) • Use of Low-impact Innovative Materials • Embed Recycled Materials in Design
Reduced Construction Impact (Construction Stage)	<ul style="list-style-type: none"> • Reduced Material Inputs: efficient const. processes, sharing equipment • Innovative Construction Methods: e.g. off-site construction, 3D printing
Sustainable Utilisation & Maintenance (Operation Stage)	<ul style="list-style-type: none"> • Durability of Building, Asset, or Project: efficient use, repair, maintenance, and repurpose • Reduced Environmental Impact of Operation: CO2 emissions, energy consumption, and domestic waste Mgmt.
C&D Waste Mgmt. (Closing Material Loops)	<ul style="list-style-type: none"> • Construction Waste Mgmt.: waste minimisation material & equipment recovery for onward reuse • Demolition Waste Mgmt.: Integrating the 3R framework & waste mgmt. hierarchy
CE Mgmt. (Business Models, Education, and Data Mgmt.)	<ul style="list-style-type: none"> • New Business Models and Strategies • Planning, Collaboration, and CE Data Mgmt. • Education, Training, and Stakeholders CE Awareness

The third theme, 'sustainable utilisation and maintenance', provides a new understanding of the link between CE and 'sustainable development'. Two CIs are used to group sustainability requirements relevant to the operation stage in construction projects: 'durability of building, asset, or project', and 'reduced environmental impact of operation'. The first indicator includes sustainability requirements related to efficient use, repair, maintenance, and project re-purposing, whereas the second indicators relate to carbon emissions, energy consumption, and waste production and management. The fourth theme, 'C&D waste mgmt.', is concerned with closing material loops in construction. CE is frequently viewed in the literature from the waste management perspectives (Kirchherr *et al.*, 2017), so here two main CIs address the main sources of waste in the construction process. The 'construction waste mgmt.' indicator focuses on waste minimisation strategies, and material and equipment recovery for onward reuse, whereas the 'demolition waste mgmt.' indicator has more focus on integrating the 3R framework and waste management hierarchy. A fifth theme, 'CE mgmt.', is added to include all managerial requirements that cannot be included in other groups. A transition to CE requires a systemic change in the way we do business (McAloone and Pigozzo, 2018), and a complete reform of both production and consumption processes (Yuan *et al.*, 2006), which should be transformative rather than just delivering incremental efficiency gains (Preston, 2012). The fifth theme includes three CIs encapsulating managerial requirements relevant to 'new business models and strategies', 'planning, collaboration, and CE data mgmt.', and 'education, training, and stakeholder CE awareness'.

SYSTEMATIC REVIEW

Scope and Strategy

The purpose of this systematic review is to assess the literature for articles associating between the 'circular economy' and different 'constructability' practices using the

proposed LCAF framework. Figure 1 demonstrates scope, search strategy, numbers of articles, and analytical strategy used in the systematic review. ‘Google Scholar’, ‘Scopus’, and ‘Web of Science’ databases were used to search relevant literature with no time boundary. The actual search was conducted in December 2019 using the following keywords: "Circular Economy" AND ("Building*" OR "Construction") AND (“Constructability” OR "Constructibility" OR “Buildability”). This covers the three different ‘constructability’ terms used in the literature.

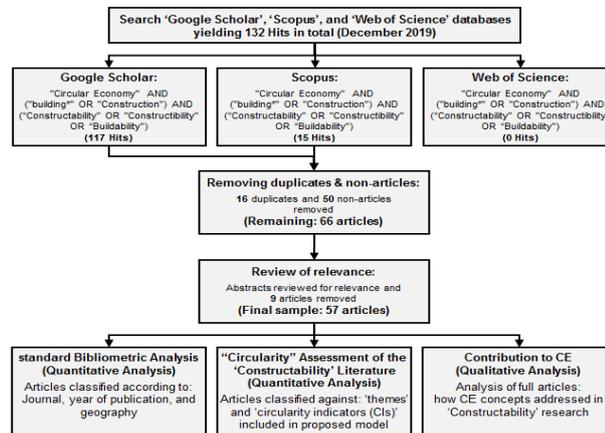


Figure 1: Scope, keywords and strategy adopted in the systematic review

The initial search yielded only 132 hits using three search engines, Figure 1. This reveals a weak association between ‘circular economy’ and ‘constructability’ despite the well-established literature on both topics individually in the 'Construction' and 'Building' literature. For example, the initial search on 'Google Scholar' yielded 49,400 hits for “circular economy”, 42,200 hits for different terms of 'constructability', and only 117 hits for the association between the two topics. Similarly, ‘Scopus’ returned only 15 hits, while the 'Web of Science' returned no hits. Furthermore, 61.21% (71/116) of articles in the initial sample were published in the period 2018-2019. This reveals the growing trend of integrating CE concepts into constructability practices; an evolution that supports the suggestion made earlier of a means to wider CE adoption. The initial sample was refined by removing 16 duplicates and 50 non-articles. Consequently, the remaining 66 articles were reviewed for their relevance to the scope of this research, and 9 articles were excluded as they provided no precise association between CE and constructability. The final sample comprised 57 articles, including: empirical articles, conceptual articles, and conference papers.

Data Analysis: "Circularity" of 'Constructability' Research

The final sample, including 57 articles, was analysed to examine published evidence to provide deeper insights into the adoption of CE concepts in the constructability literature. Analysis included: standard bibliometric analysis, as well as quantitative and qualitative analysis with respect to the LCAF framework proposed in this paper. Articles were quantitatively categorised according to their relevance to the 5 themes and 12 "circularity" indicators (CIs) included in the proposed framework. Moreover, studies in the final sample were qualitatively analysed to enrich discussions and capture the main argument in each of these studies. Results for different themes and associated "circularity" indicators (CIs) were depicted using radar diagrams to explore engagement of constructability literature with CE concepts and identify areas for further "circularity" development. Data analysis shows that articles in the final sample have most engagement with 'CE mgmt.' 36.84% (21/57), and 'design for

'circularity' 35.09% (20/57) themes. The other three themes of "circularity" reveal lower levels of engagement: 'C&D waste mgmt.' 17.54% (10/57), 'reduced construction impact' 15.79% (9/57), and 'sustainable utilisation and maintenance' 12.28% (7/57), Figure 2.

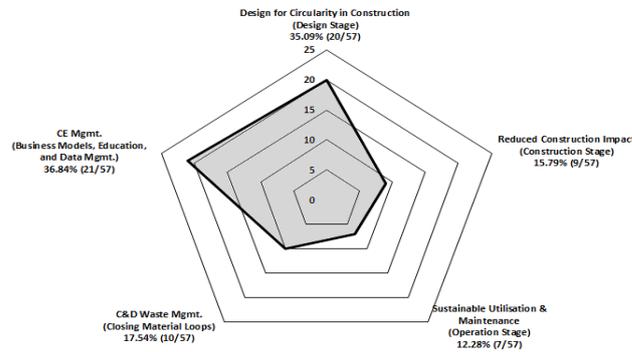


Figure 2: Engagement of literature with "circularity" themes

Data analysis across "circularity" indicators (CIs) provides deeper understanding of areas of good practice and those appropriate for "circularity" improvements, Figure 3. At this early stage of engagement with CE, constructability literature engages with CIs that fall inside researchers' 'known' comfort zone, i.e., those related to design and construction stages; require little effort and yield acceptable results. This approach has similarities with the innovation adoption curve of Rogers and indicates an industry at the first stage of CE adoption (innovators).

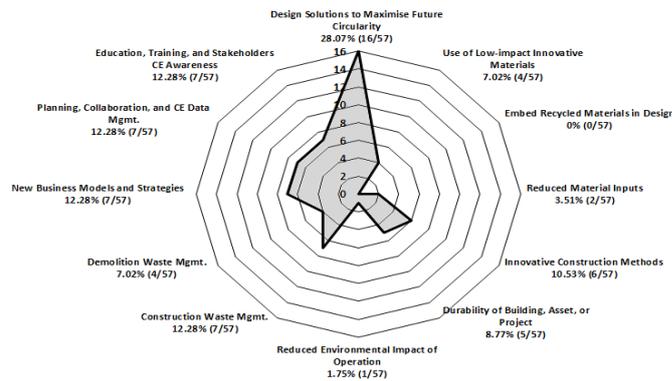


Figure 3: Engagement of literature with 'Circularity Indicators (CIs)'

The high level of engagement with the 'design for circularity' theme highlights the role that design plays in promoting circularity throughout the whole building life-cycle. However, results revealed that this engagement is mostly aspirational as more articles are concerned with 'design solutions to maximise future circularity' 28.07% (16/57); whereas fewer engaged with the 'use of low-impact and innovative materials' 7.02% (4/57), and the 'embed recycled materials in design' indicator was totally overlooked 0% (0/57).

The proposed framework includes three construction-related indicators for which variable levels of engagement were identified: 'construction waste mgmt.' with focus on waste minimisation and equipment recovery for onward reuse 12.28% (7/57); 'innovative construction methods' 10.53% (6/57), and 'reduced material inputs' (concerned with the use of efficient processes and equipment sharing) that received only 3.51% (2/57).

Moreover, articles showed little interest in 'demolition waste mgmt.' 7.02% (4/57), keeping a weak link with CE concepts related to buildings' end-of-life stage. Unexpectedly, articles revealed little engagement with 'sustainable utilisation and maintenance' indicators relevant to the 'operation' stage: 8.77% (5/57) for 'durability of building' relevant to efficient use/repair/maintenance and building repurposing; and only 1.75% (1/57) for 'reduced environmental impact of operation' relevant to carbon emissions and energy consumption topics.

In contrast, the final sample revealed greater engagement with the three 'CE mgmt.' indicators, with 12.28% (7/57) each; seeking opportunities offered by new CE managerial strategies relevant to these indicators.

CONCLUSION

This paper makes a significant contribution to both construction circular economy (CE) and 'constructability' paradigms. Reviewing CE in current construction literature reveals two main limitations delaying the transition to CE: first, the lack of a holistic framework for project life-cycle assessment (PLA) of "circularity" within construction activities; second, the lack of clarity about the relationship between CE and sustainability concepts and any overlap between them. The 'Lifecycle "Circularity" Assessment Framework (LCAF)' proposed here represents an innovative and novel departure point for the future transformation of CE in construction. This is through making the effectiveness of CE transition propositions measurable via assessment of the overall construction activities' "circularity" across the entire project life-cycle. The proposed framework includes twelve "circularity" indicators (CIs) grouped in five themes relevant to different stages of a project life-cycle. CIs represent stage-relevant, high-level requirements of CE in construction, with each encapsulating larger numbers of theme-relevant CE concepts. This helps identify areas of good practice and those appropriate for "circularity" improvements. This paper also extends the scope of CE through integrating sustainability notions relevant to the 'operation' stage into a broader framework for "circularity" assessment. This represents a shift in previous understanding of the link between CE and sustainability in construction; 'flipping' the traditional view of CE being subordinate to sustainability.

This paper argues that full transition to CE requires holistic understanding of complex CE solutions combining multiple concepts across the entire project life-cycle. Data analysis revealed a weak association of 'constructability' with CE in general, and variable engagement with themes and indicators included in the LCAF framework. Two main findings are worthy of emphasis. First, the totality of the framework, including all themes and CIs, needs to be considered, as close engagement with only one theme may initially be apparent. For example, the high engagement of 'constructability' with the design theme is only aspirational and has not resulted in actual embedment of circular materials in building design. Second, low results for individual CIs may seem casual, simple and unrelated, but a cross-theme approach can establish that more complex CE solutions may be required. For example, effective C&D waste management and closing material loops require close collaboration between all stakeholders, active CE data management, new business models in construction supply chains, and effective use of BIM tools to combine circular materials in design. Future research will seek to verify and validate the proposed LCAF framework using real-life project example(s) and feedback from construction practitioners (early adopters and early majority representing pragmatists and

mainstream market) to insure its adequacy for “circularity” assessment, and explore its potentials for supporting decision-making in construction projects. This will allow the connection between the LCAF framework and 'constructability' to drop away.

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IMPLEMENTATION OF SUSTAINABLE PROCUREMENT PRACTICES IN PUBLIC SECTOR CONSTRUCTION ORGANISATION IN GHANA

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Sustainable procurement adoption in the public sector construction organisation is still evolving in both developed and developing countries, researchers believe that its existence will aid in achieving sustainable development. This paper presents the level of implementation of sustainable procurement in public sector construction organisation in Ghana. Based on stratified and purposive sampling techniques data was collected from 193 government institutions. One-sample t-test was used to validate the data collected. The findings indicated that the simultaneous application of the economic, social and environmental aspects of sustainable procurement in construction were limited. It was revealed that nine out of the twenty-one of the three aspects of sustainable procurement practices was moderately implemented. The significant sustainable practices implemented were preventing nuisance from construction operations; providing employment to the community; clearly establishing needs and evaluate other options; value for money; decreasing water usage; reusing existing built assets; reducing water, land and air pollution and environmental management system. This suggests that government must encourage the incorporation of the considerations of economic, environmental and socially responsible policy goals within sustainable procurement practices of public sector instructions.

Keywords: sustainability, procurement, Ghana, public-sector

INTRODUCTION

The construction industry has acknowledged the vital contribution it makes to the attainment of sustainable development (Glass *et al.*, 2012). Sustainable development is about achieving economic and social objectives while minimizing adverse environmental impacts (Barkemeyer *et al.*, 2014). In the last two decades, the interest of sustainable procurement both in practice and academic research is burgeoning and substantial amount of literature has been generated (Roman, 2017; Grob and Benn, 2014). A review by Xia *et al.* (2015) showed that sustainability related research in construction has increased from 30 papers in 2000 to 127 papers in 2012 and currently researchers are posited in exploring every aspect of the sustainable parameters. Despite the interest generated and the increasing trend in research most construction

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organizations are yet to fully adopt sustainable procurement (Islam *et al.*, 2016). Most public institutions particularly in Ghana are yet to fully apply sustainability as part of their integrated strategy and organisational culture that promote values and ethics.

Conventionally, procurement in the construction industry has to the greater extent concentrated on the lowest evaluated tenderer while the obligation to sustainability concerns has been ignored (Gunatilake, 2013). Conventional performance measures (time, quality and cost) are being extended to incorporate extra factors like environmental and social measures. The sustainability performance of suppliers has become a major element of tender selection criteria (Meehan and Bryde, 2015; Sourani and Sohail, 2013). An increasing number of countries both in developed and developing countries, are taking steps towards integrating environmental, and to a lesser extent, social criteria into their national procurement (Islam *et al.*, 2017). Varnäs *et al.* (2009) studied the level of adoption and implementation of green procurement in the Swedish construction industry. The results indicated that both public and private clients consider environmental issues in their procurements. Varnäs *et al.* (2009) noted that construction organisations in Sweden, mainly apply EMS, re-use of waste materials, use of limited materials in the procurement of construction contracts. Environmental sustainability criteria are mainly used in construction procurement in Canada (Ruparathna and Hewage, 2015).

In Ghana, the Public Procurement Act, Act 663 of 2003 has been amended to include social and environmental dimensions in public procurement, thus, Act 914 of 2016. This is concerted efforts by Government of Ghana to improve the adoption and implementation of the Tiple Bottom Line in public procurement thereby contributing to the attainment of sustainable procurement. However limited studies have been done on the level of implementation of sustainable procurement practices in Ghana's context. The level of implementation of sustainable procurement practices is significantly varied for each country depending on certain barriers that they confront in their respective country such as lack of regulation, limited knowledge and skills, lack of funding, perceived high cost of sustainability (Islam *et al.*, 2016), and different surrounding pressures including the regulatory environment and government support, organisational values, and competitive pressure (Agbesi *et al.*, 2018). This paper examines the level of implementation of sustainable procurement practices in construction in public sector client organisations in Ghana.

Sustainable Development and Construction Industry

The link between the activities of the construction industry and sustainable development is related to its social, economic, and environmental impacts (Shen *et al.*, 2017). The adoption of the principles of sustainable development in construction is to create a sustainable built environment that meets human's present needs, without endangering the ability of the future generation to meet their needs (Berry and McCarthy 2011). The principles of sustainable construction are related to the triple bottom line (TBL) of environmental, social and economic dimensions that are illustrated in the sustainable development concept (Tan *et al.*, 2011). Owing to its large size and importance, the construction industry has the potential to contribute directly to the attainment of sustainable development (Bamgbade *et al.*, 2017). Du Plessis (2002) opined that sustainable construction attempts to restore equity between the natural environment and built environment thereby addressing the intricate challenges of construction and the environment. The construction industry has immense contribution towards the economic and social development of many

countries and cause considerable damage to the environment (Bamgbade *et al.*, 2017). For example, the construction industry accounts for one tenth of the global economy (Bo *et al.*, 2015). In the UK, the industry accounts for 10% of the UK's GDP and employs over 3,000,000 people in over 250,000 firms (Bamgbade *et al.*, 2017). The Ghana's construction industry contributes average growth of 7-8 % per annum to GDP (Osei, 2013). The construction sector is one of the major offenders of global resource depletion (Xia *et al.*, 2015; Zuo *et al.*, 2012). Precisely, Rode *et al.* (2011) indicated that an estimated 10% of the global energy consumption is attributed to the manufacturing of building materials. Construction and demolition account for about 40% of the solid waste generated in the advanced nations, while the operation stage of construction products releases almost 40% of the total global greenhouse gas emissions (Rode *et al.*, 2011). Buildings are estimated to consume about 40% of the total available energy, responsible for roughly 30% of total CO₂ emissions and generate about 40% of all man-made waste in all European Union countries (Rode *et al.*, 2011). Pearce (2003) highlighted the construction sector contribution to sustainable development in the form of human (workforce), social (human welfare) and environmental capital. The construction industry remains one of the most critical sectors for the adoption of sustainable development principles because of its size and the enormous amount of the resources it consumes, and the major impact of its products on the built and natural environments in particular and the society at large (Xia *et al.*, 2015; Zuo *et al.*, 2012). As a result, sustainable construction practices can contribute towards the realisation of sustainable development; thereby, effectively improving the overall performance of the industry.

Sustainable Procurement

Sustainable procurement is built on the traditional procurement practice, through the adoption of sustainable development principles. Organisations are concerned on how they and their supply chain impact on the environment, society and the economy (Walker and Philips, 2009). According to Walker and Philips (2009), there is an existing opinion to limit economic and societal development and to lessen negative effects on the environment. In addition to environmental considerations, organisations need to address social equity issues both nationally and internationally along the supply countries (Walker and Philips, 2009). Sustainable procurement is considered as a way to contribute to the larger effort of achieving sustainable development due to the impact procurement has on the environment, economy and society (Islam *et al.*, 2016; Meehan and Bryde, 2015). Thus, sustainable procurement is included as the additional connection between environmental, economic, and social aspects added in procurement decisions, and thereby depicting the idea of sustainable development (Islam *et al.*, 2016). There are growing discussions on how the environmental, economic and social aspects of sustainable procurement could be integrated into a policy for use in both private and organisations (Renukappa, 2016). Sustainable procurement is therefore described by the United Kingdom Government commissioned Sustainable Procurement Taskforce as "...a process whereby organizations meet their needs for goods, works and utilities in a way that achieves value for money on a whole life basis in terms of generating benefits not only to the organization, but also to society and the economy, whilst minimizing damage to the environment", (Procuring the Future, Sustainable Procurement Task Force, 2006). In the context of construction, sustainable procurement is a process whereby the client and participating organizations meet design and development requirements in a way that achieves value for money on a whole life basis so as to generate benefits not only for project

stakeholders but also to society and the economy, while minimizing any environmental damage (Alkilani and Jupp, 2012). Sustainable procurement practice and research is increasing (Roman, 2017; Grob and Benn, 2014). Grob and Benn (2014) pointed to the sustained increase implementation of sustainability along the supply chain. However public sector organisations are yet to fully adopt sustainable procurement and fuse it into their organisational strategies and policies (Roman, 2017; Walker et al.; 2009). Walker *et al.* (2009) is of the view that if public sector organisations were to demand sustainability in procurement of goods, services and works, a considerable amount of progress could be made towards the attainment of sustainable development. There is wide-spread recognition that sustainability has three dimensions: environmental, economic and social (Adetunji *et al.*, 2008). Construction clients and other supply chain partners are extensively involved with the design and application of sustainable procurement policies that focus on the three pillars of sustainable development (Islam *et al.*, 2016). Public clients are under intense pressure from national and international organisations to adopt and implement sustainable procurement in their policies and strategies (Islam *et al.*, 2017; Wong *et al.*, 2016; Meehan and Bryde, 2015). Islam *et al.* (2016) affirmed there is growing domestic and international legal and regulatory pressure being faced by institutions to accept and implement sustainable procurement practices in order to reduce their effect on the environment. This is linked to the significant influence clients have on the adoption of sustainable procurement due to their critical involvement in the selection of stakeholders such as consultants and contractors, and the determination of construction products (Wilkinson *et al.*, 2015; Glass *et al.*, 2011). Despite these sustained pressures on organisations to adopt to sustainable procurement practices, it is yet to be translated into full scale adoption and implementation. To reduce the negative impact of the environment, sustainable procurement can provide the vehicle to reduce greenhouse gas emissions, improve water efficiency and support recycling by considering concepts such as whole life costing, capacity building, poverty reduction and improved equity, generate income, and optimise costs.

Implementation of Sustainable Procurement in Construction

Construction organisations are yet to fully fuse sustainability practices in their procurement decisions (Islam *et al.*, 2016). Indeed, the industry lags behind other industries with respect to sustainability adoption and implementation (Brennan and Cotgrave, 2014). Notwithstanding, considerable efforts have been made to infuse sustainable practices in construction procurement. Adetunji (2008) opined that most construction organisations have addressed environmental sustainability including waste management, recycling initiatives, material innovation, pollution avoidance, reduction of generic construction material usage (water, energy), transport policy (to minimising disruption to road users during road works). Gunatilake (2013) attributed this to the availability of well-established environmental management systems. Varnäs *et al.* (2009) studied the level of implementation of green procurement in the Swedish construction industry. The results indicated that both public and private clients consider environmental issues in their procurements. Environmental sustainability criteria are mainly used in construction procurement in Canada (Ruparathna and Hewage, 2015). Procurement has served as a tool to promote social outcomes (McCrudden, 2004). Preuss (2009) advanced how UK's Local Government had used procurement to achieve social outcomes including contracting with voluntary organisations. Even though there is evidence of gradual inclusion of social dimensions in procurement decisions. Eswarlal (2014) and, Seuring and Müller

(2008) noted that consideration of the social dimension in supply chain management is very weak. Zuo *et al.* (2012) opined that the construction industry's social sustainability has not received its fair share of both industry practice and academic research compared to environmental and economic sustainability. Adetunji *et al.* (2008) stated that few social practices applied in construction procurement appeared to favour health and safety, possibly due to poor health and safety records in the industry. Notwithstanding these, there is also increasing evidence of the adoption and implementation of triple bottom line (TBL) of sustainable practices in construction in recent times. Samudhram *et al.* (2016) revealed increasing levels of economic, social and environmental performances reporting at the firm level. They argued the Triple Bottom Line (TBL) reporting approach promotes firm level economic, environmental and social performances. In the United States of America, state, regional and local governments (e.g. Maryland, Minnesota, Vermont and Northeast Ohio) are increasingly adopting the TBL as decision-making and performance-monitoring tool (Hall, 2011). Meehan and Bryde (2015) revealed that the UK's housing sector takes holistic considerations of sustainable procurement (social, environmental and economic). Renukappa *et al.* (2016) also found that most organisations in the UK have simultaneously implemented the TBL of sustainable procurement initiatives. Organisations have implemented sustainable procurement initiatives including buying construction-related materials from small/local organisations, reducing waste, health and safety, discrimination, working hours, employee compensation, ethical behaviour and rights of minorities and helping suppliers to obtain ISO 14001 certification (Renukappa *et al.*, 2016). This is being influenced by the UK's government for organisations to achieve 100% sustainable organisation' in order to bring broader objectives of sustainability to satisfy international and national directives. Islam *et al.* (2016) also reported increasing implementation levels of the environmental and social dimensions of sustainable procurement among Saudi Arabia's public and private organisations. In Malaysia, both private and public organisations have adopted and implemented some aspects of the TBL (i.e. health and safety, purchasing from local suppliers, compliance with child labour laws) in construction procurement (McMurray *et al.*, 2014).

Sustainable Procurement Adoption in Ghana

Ghana's Public Procurement Act, 2003 (Act 663) addresses some aspects of economic and social sustainability issues under section 59. The Act did not address the environmental aspect of sustainability. Even though, the environmental aspect was not covered under the law there are standalone regulations on issues like Energy Efficiency Standards, Pesticides Control and Management, Reduction in Green House Emissions, Forest and Wildlife Management and among others. Ghana Labour Law, Act 651 of 2003 raises social issues of equal employment opportunities, occupational health and safety, and child labour. These social issues were not infused into Act 663. The Act 663 was amended with the object of addressing the inadequate sustainability issues in the Act. Sustainable public procurement has therefore been infused into the amended Act, Act 914. The object of the study is to measure the level of implementation of sustainable practices in construction procurement in Ghana.

RESEARCH METHODOLOGY

This study adopted quantitative research method through administration questionnaire to 193 respondents of 36 ministries and departments/agencies, 6 metropolitan, 49 municipal and 76 district assemblies. The respondents were represented by chief

directors; project managers; district coordinating directors; engineers; procurement officers; quantity surveyors; and planning officers. The sample was stratified by scope and purposively selected.

Survey Instrument Design and Operationalization of Measures

The questionnaire items used to measure sustainable procurement practices implementation were based on data collected from literature review. The eligible respondents were involved in sustainable procurement practices and best qualified to talk about their organisations. The questionnaire was reviewed by 2 experts and 10 district engineers and public sector procurement officers and pre-tested in a pilot survey. The respondents were asked to indicate to what degree their organisation had implemented the three dimensions of sustainable procurement practices (economic, environment and social) in construction. 21 sustainable procurement practices covering economic, environmental and social sustainable practices based a five-point likert measurement scale were operationalized. The respondents rated the practices from not; slightly; moderately; frequently and extremely implemented.

RESULTS

In this study, the Predictive Analytics Software (PASW) version 18 was used to compute the mean score value of the level of implementation of sustainable procurement practices in the organisations, and the level of significance of the results were tested by a one sample t-test. A total of 123 valid responses were offered, resulting in a response rate of 63.7%. The respondents were made up of 0.8% (1) chief directors; 4.88 % (6) project managers; 3.26% district coordinating directors (4); 60.98% engineers (75); 13.83 % (17) procurement officers; 13.01% (16) quantity surveyors; and 3.25% (4) Planning officers. 66.7 % of the respondents had PhD and master's degrees; and the remaining respondents have bachelor's degrees and Higher National diploma. A greater majority of the respondents of about 83.74% had over 5 years working experiences in procurement. Considering the varied profile and experiences of the respondents it can be confidently relied on. The respondents were asked to indicate to what degree their organisation had implemented the three dimensions of sustainable procurement practices (economic, environment and social) in construction. respondents rated the practices from not; slightly; moderately; frequently and extremely implemented. Table 1 provides the mean, standard deviation and t-statistic of the various levels of implementation of sustainable procurement practices in Ghana. Any mean value < 3.0 is considered to be insignificant for the study as it is below the natural rating of 3. Standard deviation values less than 1 indicate consistency in agreement among the respondents on the reported level of results (Field, 2005). The results indicated that construction clients had implemented nine out of the twenty-one aspects of the three dimensions of sustainable procurement practices, scoring mean values of 3.00 and above. These included maximum use of limited resources (3.74); environmental management system (3.57); provide employment to the community (3.40); value for money (3.20); use of local material (3.23); reducing energy consumption(3.17); the use of recycled and sustainable materials (3.17); promoting ethical practices (3.15); minimising disruption to traffic of local community(3.13) and reducing water consumption(3.04). The mean scores for the aspects of sustainable procurement practices that asked the organisations to determine the level of implementation of preventing nuisance from construction operations; provide employment to the

community; clearly establish needs and evaluate other options; value for money; decreasing water usage; reusing existing built assets; reducing water, land and air pollution and environmental management system were significant ($p \leq 0.05$), while the remaining sustainable procurement practices were statistically insignificant ($p \geq 0.10$). The result indicated that the average mean value of economic sustainable procurement practices aspect was 3.01, followed by social (2.98) and environmental (2.93). This indicated that even the use of economic sustainable procurement practices was relatively lacking.

DISCUSSIONS

There was a moderate level of application of some sustainable procurement practices in Ghana. Further, the findings indicated that the simultaneous application of the economic, social and environmental aspects of sustainable procurement in construction by the public-sector organisations were limited. This supports the finding of Islam *et al.* (2016), that observed a limited implementation of sustainable practices by organisations in developing countries.

Constructs	Items Code	Items Description	Mean	Avg. mean	Std. Dev.	t	Sig. (1-tailed)
Social	Imp1	Health and safety for workforce and local community/residents	2.44	2.98	1.12	1.07	0.28
	Imp2	Preventing nuisance from construction operations	2.85		1.00	2.35	0.02
	Imp3	Minimising disruption to traffic of local community	3.13		1.07	0.59	0.55
	Imp4	Community security/wellbeing	2.98		1.12	0.30	0.71
	Imp5	Provide employment to the community	3.40		1.17	2.35	0.02
	Imp6	Improving working environment and conditions	2.88		1.13	1.86	0.06
	Imp7	Promoting ethical practices	3.15		0.97	0.38	0.70
Environmental	Imp 1	Decreasing energy usage	3.17	2.93	0.98	1.02	0.31
	Imp 2	Decreasing water usage	3.04		1.12	3.37	0.00
	Imp 3	Use of recycled and sustainable materials	3.17		1.01	1.88	0.06
	Imp 4	Reusing existing built assets	2.75		1.03	2.72	0.01
	Imp 5	Reducing water, land and air pollution	2.66		1.09	5.48	0.00
	Imp 6	Conserving and improving biodiversity	2.43		0.98	1.12	0.27
	Imp 7	Environmental management system	3.57		1.00	6.45	0.00
Economic	Imp 1	Clearly establish needs and evaluate other options	2.54	3.01	1.00	2.34	0.02
	Imp 2	Value for money	3.20		1.08	2.34	0.02
	Imp 3	Local/area economic growth	2.51		1.04	1.77	0.07
	Imp 4	Consideration of whole life costing	2.93		0.99	1.30	0.26
	Imp 5	Use of local material	3.23		0.96	0.32	0.71
	Imp 6	Improving the efficiency of the supply side	2.93		0.99	1.93	0.06
	Imp 7	Maximum use of limited resources	3.74		0.97	1.20	0.23

Table 1: Level of implementation of the three aspects of sustainable procurement practices, Source: Field survey, 2017

This study further confirmed that construction clients lag behind other sectors in the adoption of sustainable procurement practices as postulated by Wong *et al.* (2016); and Varnäs (2009). Wong *et al.* (2016) posited that the awareness of sustainable practices in construction had been increasing over the last decade, however, construction client organisations were hindered to adopt sustainable procurement practices as a result of the lack and non-existence of legal enforcement by government. In the case of Ghana, the adoption and implementation of sustainability in construction procurement was not mandatory till September 2016, when the Act that regulated public procurement (Act 663 of 2003) was amended to include sustainable practices (Act 914). To accelerate the implementation of sustainable procurement practices, governments should provide incentives like subsidies and tax exemptions to encourage public sector organisations to adopt sustainable construction procurement (Wong *et al.*, 2016). In addition, the full implementation of sustainable procurement in construction requires the support,

commitment and leadership from top management of construction organisations (Ruparathna and Hewage, 2015)

CONCLUSION

The study examined the level of implementation of sustainable procurement practices in construction procurement by public organisations. The study firstly revealed construction clients had moderately implemented nine out of the twenty-one of the three aspects of sustainable procurement practices, which are maximum use of limited resources; environmental management system; provide employment to the community; value for money; use of local material; reducing energy consumption; the use of recycled and sustainable materials; promoting ethical practice; minimising disruption to traffic of local community; and reducing water consumption. Secondly, public sector organisations mainly implemented some aspect of economic, followed by social and environmental aspects of sustainable procurement in construction. The significant sustainable practices implemented by the organisations were preventing nuisance from construction operations; providing employment to the community; clearly establishing needs and evaluate other options; value for money; decreasing water usage; reusing existing built assets; reducing water, land and air pollution and environmental management system.

In conclusion, Ministries, Departments and Agencies, Metropolitan, Municipal and District Assemblies are recommended to integrate sustainable procurement into their policies, strategies and goals. The public sector organisations should further make sustainable procurement practices as a demand in the engagement of contractors, consultants and suppliers by introducing sustainable procurement practices in the call for tenders, evaluation of tenders and contracts. It is further recommended that, the Public Procurement Authority (PPA) through the standard tender documents and the procedures for the procurement of goods, works and services should include sustainable procurement practices and by introducing a sustainable procurement assessment tool to track the sustainable procurement performance of public sector procurement entities

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ON THE ROAD TO NOWHERE? THE CHALLENGES OF ALIGNING CONSTRUCTION AND DEMOLITION WASTE PRACTICES WITH CIRCULAR ECONOMY

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The construction sector is still a major contributor to the waste generated within the European union and contributes with around 25-30 percent of the total amount. A crucial part to achieve a sustainable built environment and mitigate the negative effects on the environment is to support the reuse and recycle of construction materials. The EU has put pressure on the sector to increase recycling for the member states and adopt Circular Economy (CE) principles, but Sweden is still far from achieving the targeted figures. Previous studies have shown that there are tensions between the shared understanding of formal and informal processes and practices of Construction and Demolition Waste (CDW) and the principles underlying the CE model. In order to explain the slow transition to Circular Economy, we identify and analyse these tensions in the field of CDW in Sweden. To do so, we draw on the concept of institutional field logic. This concept help us to understand how individuals' behaviours are constrained and affected by the socially constructed assumptions, values, beliefs, and rules by which individuals produce and reproduce social reality and which account for the decisions they make. The empirical material gathered for this qualitative study consists of 29 semi-structured interviews with industry practitioners and policy makers and documents analysis of the legal frame and industry guidelines. Although we can identify a few initiatives of implementing CE principles, our results show contradictions and incompatibilities between the two logics which can explain the lack of improving practice and the difficulty to realise the CE benefits.

Keywords: circular economy, demolition waste, institutional logics

INTRODUCTION

In order to achieve its recovery target, the European Commission is proposing the uptake of the circular economy by encouraging CDW recovery and management. The EU Circular Economy action plan (European Commission, 2020) has established general measures to be implemented by the member states to support the transition to the circular economy. The action plan concerns all stages of the products cycle: from design, production and consumption to waste management and also the creation of a EU market for secondary raw materials.

Sweden has made the bold statement of becoming one of the world's first fossil free nations and has designed a roadmap for how to achieve this transition. Although

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initiatives to improve the result of Construction and Demolition Waste (CDW) have been taken, Sweden is still far from achieving the targeted figures (Swedish environmental protection agency, 2018).

Responsible for a large proportion of the total amount of waste, the construction industry is seen as a key actor in this transition. Multiple levels policy and legislative frameworks are putting pressure on the industry to increase its recycling figures and incorporate Circular Economy (CE) principles (European Commission, 2020). According to these principles, buildings should be constructed with components and materials, which can be redeemed and re-used for new purposes at the end of the product's life cycle so, materials should enter a new life instead of being discarded and burnt (Djuric Ilic *et al.*, 2018). CE promises an efficient use of resources and thereby reduce the environmental impact and overconsumption. However, studies in other sectors than construction have suggested that the transition to CE is not aligned with conventional linear models of production (Stål and Corvellec, 2018, Djuric Ilic *et al.*, 2018). They show that the implementation of CE is creating tensions within organisations for example, between the CE assumptions, values and practices and the ones currently established in industries; or the requirement of a new distribution of tasks and responsibility between partners (Blomsma and Brennan, 2017, Van der Byl and Slawinski, 2015, Hahn *et al.*, 2015). According to Benachio *et al.* (2020) literature review, the focus of studies on CE in the construction sector deals mostly with prescriptive models, measures and solutions, either technical or business models related (Leising *et al.*, 2018). Likewise studies on CDW mainly address commonly reiterated barriers such as the lack of material quality, absence of culture, lack of market and regulation as well as the additional cost for recycling and reuse (Jin *et al.*, 2019, Park and Tucker, 2017, Ajayi *et al.*, 2015) but rarely discuss the assumptions, values and practices of the field.

The purpose of our paper is therefore to explore how the principles of CE are mobilised in the fields of CDW in Sweden and whether or not the tensions identified in the literature also occur in this industry. Our goal is to understand the organisational settings which frame the decisions rather than the decisions themselves. To do this we adopt the lens of institutional logics. Rather than focusing on actions and measures, institutional field logic addresses the values, norms and assumptions by which individual's interpret organizational settings and what they consider and rationalize as appropriate behaviour to achieve common goals (Thornton *et al.*, 2012).

THEORETICAL FRAME

Institutional Field Logic

To discuss the tensions arising in the implementation of CE in the area of CDW, we build on the Institutional Logics. IL is a concept developed within the wider field of institutional theory as a way of explaining the interactions between normative societal structures, organizational forms, and individual behaviours (Skelcher and Smith, 2015).

Institutional field logic is defined as "the socially constructed rules, norms and beliefs constituting field membership, role identities and patterns of appropriate conduct" (Greenwood and Hinings, 2006, p.819). They include historical patterns of cultural symbols and material practices, assumptions and values by which individuals and organizations provide meaning to their daily activity, organize time and space, and reproduce their lives and experiences (Thornton *et al.*, 2012). They supply actors with

numerous taken-for-granted categories and organizing principles by which they can define, select and implement decisions (Thornton and Ocasio, 2008). Institutional logics are central to our discussion as they help us to understand how individuals' behaviours are constrained and affected by the individuals, organizations and society that constitute institutions. To study and understand individual and organizational behaviour, Thornton and Ocasio (2008) insist on the need to understand the institutional context and understand how it regularizes behaviour as well as provides opportunity for agency and change. The field level phenomena occur in the interaction between “a collection of diverse, interdependent organizations that participate in a common meaning system” (Scott, 2014, p.106). Institutional fields are comprised of several logics such as market or professional logics and thereby also contains competing forms of rationality spurred from these logics, which account for a diversity in practices. It enables variance and contestation over which behaviour should be regarded as legitimized and appropriate (Lounsbury, 2008).

Thornton and Ocasio (2008) describe how institutional logics provide a link between institutions and actions as actors engage in rational mindful behaviour shaped by the central value systems with which they identify. The contradictions inherent in the differentiated set of institutional logics provide individuals, groups, and organizations with cultural resources for transforming individual identities, organizations, and society (Bertels and Lawrence, 2016). So, institutions do not only constrain behaviour, the contradictions between logics also provide individuals with the possibility to change (Thornton and Ocasio, 2008). According to Bertels and Lawrence (2016) although new logics within a field are often viewed as ‘new’ or emerging in a given field, they are often rooted in long-standing institutional logics of a more general nature. Hence, new logics emerge when values associated to a specific logic gain legitimacy and become incorporated into structures and thereafter translate themselves into practices. These new practices are described to be both a result of, as well as a starting point to the emergence of a new logic (Silva and Figueiredo, 2017). Whereas institutional logic has been largely mobilised in many fields over the last 20 years, it has made a late entrance in Construction management (Bresnen, 2017). Institutional logic in construction management literature has focused among others on hybrid organisation and partnership (Gottlieb *et al.*, 2020), health and safety (Jia *et al.*, 2017, Lingard *et al.*, 2019), and social procurement (Troje and Kadefors, 2018).

The Market Logic

Thornton *et al.* (2012) describe 6 institutional orders or ideal types of logics that can be used to understand the process by which institutional behaviour is shaped. The ideal types thereby have the advantage of both providing explanations of particular outcomes but can also be used to predict them. They are founded and characterised by values that both differentiate and make up the boundaries between them. These values demonstrate themselves through practices and patterns of behaviour within a given context (Friedland, 2013). One of these ideal types is the market logic, which can be described as an institution which shares a core set of ideas, practices, and policy prescriptions and insist on the actors' freedom to pursue their own economic interests and view the free market as a solution to both economic and social problems (Zhao and Lounsbury, 2016). The market logic is an area that has been well studied within different fields and industries and describe both the emergence of the order and the effect it has on the behaviour within the institution (Thornton and Ocasio, 2008).

The institutional logic of markets can be described as: the source of legitimacy is described to be a company's share price, the basis of strategy is to increase profit and the basis of attention is on the status it has within the market (Thornton and Ocasio, 2002). The market logic can therefore be characterised by prioritizing profit, creating competitive advantages, and reducing costs and is often associated with negative effects on the environment. At the same time, this logic is also attentive to economic pressure and increased efficiency and the organizations environmental performance can therefore be improved through the creation of economic incentives (Lee and Lounsbury, 2015).

The dominant logic of CDWM that builds on the principles that emerged during the industrial revolution and is based on a unidirectional model of material use through “take, make and dispose” which is referred to as the linear model (Esposito *et al.*, 2018). Where it is described to be unable to shift towards a more sustainable way of managing waste due to the lack of economic incentives.

The Circular Economy Logic

The alternative logic that we identify is the Circular Economy logic. CE can be defined as: “an economic system that replaces the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks, networks associations,) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.” (Kirchherr *et al.*, 2017, p.229). The CE state that economic activities are to be decoupled from the consumption of finite resources, and benefits are gained through a systemic shift that builds long-term resilience, generates business and economic opportunities, and provides environmental and societal benefits. It is based on the 'principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems' (Macarthur foundation, 2019). Although multiple interpretations and definitions exist for the concept of circular economy (Reike *et al.*, 2018), we refer to Adams *et al.* (2017) regarding the components of CE for CDWM. In their literature review, the authors identify the following actions necessary to realize CE in the construction sector: the design for disassembling, recycling and reusing; the choice of eco-friendly suppliers, material and delivery; minimising waste and increasing reuse during construction, minimising waste and repair during maintenance and deconstruction and reuse to close the loop. Whereas Benachio *et al.* (2020) identify a paradigm shift during the last decade in CDWM towards CE, they also recognise that even though the CE principles show great potential for the industry to reduce its waste generation, the implemented practices so far have not.

METHODOLOGICAL APPROACH

This project adopts the lenses of institutional theory in particular institutional logic to discuss the empirical material. As logics are revealed through language, practices, and are manifested through symbols and materials (Reay and Jones, 2015), we build on qualitative methods to explore the tension between the established WM and the emerging CE logics. Qualitative methods enable us to gain insights into the specific logics through quotes, observations, and thick description.

The study builds on an interpretative approach and draws on material collected during the period autumn 2017 and spring 2020. The data draws mainly of 29 semi-structured interviews with 39 industry practitioners and includes four visits to construction sites and one to a recycling plant, as well as the observations of two project start-up meetings and a two hours information workshop on the potential of circular economy for CDW professionals. We also draw on a documents study on the policy framework and industry guidelines on CDWM in Sweden.

The 39 interviews include six demolition companies, three contractors, two clients, one professional association representative, two municipality officers active in environmental protection and one large recycling company in the region. We have gathered their experiences and opinions regarding the actual and future practices of handling waste. An overview of the interviewees is presented in table 1.

Table 1: Interviewees overview

Organisation	Interviews	Interviewees	Positions
Large contractors	9	12	Project-, site-, production manager
	3	3	Environmental manager
Demolitions small - medium contractors	5	9	Project-, site-, production manager
	1	1	Sustainability manager
Large contractor - subsidiary	2	3	Business development manager,
Recycling contractor	4	5	Business developer manager, coordinator
Architect	1	1	Environmental manager
Municipality	1	2	Unit manager - Environmental dept.
Construction Industry association	1	1	Officer in charge of WM
Clients/FM	2	2	Project managers
Total	29	39	

All participants were informed about the goal of the study, the recording of the interviews and the anonymity of their contribution. The interviews were transcribed and analysed according to the themes developed in iteration with the theoretical framework on institutional logics and waste management literature. To carry our analysis, we have followed the five steps model of qualitative analysis suggested by Taylor-Powell and Renner (2003): knowing the data by getting over it several times; identify key questions or topics to organise the analysis; categorize information by themes and features; identify patterns and connections within and between categories and finally interpretation by attaching meaning and significance to the analysis. The results and interpretations of the different methods of gathering data have been triangulated, have been discussed between the researchers participating to the projects.

FINDINGS

The Two Field Logics

Here we present the findings focussing on the elements which refer to the two logics.

Established WM Logic

What we call the established CDWM logic is the common description among the interviews of the taken for granted understanding and expectations of how the CDWM is organised. The focus of the industry is directed to the design, construction and maintenance phase of a building through the consumption of virgin materials. Waste is viewed as an end of life result of these processes which need to be managed according to the legislative demands including collection, handling and disposal either

through incineration, waste to energy or recycling. During the last few decades, the focus of the regulatory frame in Sweden has been to limit landfill, minimise quantity of waste and insist on the separate handling of different material by especially focusing on hazardous waste to avoid unnecessary pollution and enable recycling. 'We have the possibility to choose during normal demolition, but when it comes to asbestos, we don't have a choice, the legal frame demands it and costs are not even considered' - Manager Demolition company.

The established logic assumes that recycling can only be a small part as the quality of the waste material is substantially lower than for new products and that the market demand for waste material is negligible. The transformation of waste into competing products is said to be too expensive for achieving sufficient quality of the results and that the lack of constant supply makes the production difficult to control. On newbuilt sites, the practice of handling waste is based on a tradition where contractors and subcontractors' workers carry out the work which is often perceived as an "annoying necessity to clean after yourself" - Site manager contractor.

As it does not generate any financial gain, waste and its management is described as a cost that should be kept at a minimum. The project managers refer to their basic mission which is to "produce a benefit at the end of the project" and insist on the impossibility to change work organisation under the actual market conditions and legislation. Besides, the lack of clients' interests and incitements to engage in CE are also used as claims to legitimise the status quo. The demolition companies' interviewees argue for the maintenance of the current practices with the same argument. According to them, the company's core activities and business proposals build on the services (deconstruction, handling and transport) they offered and not on the reselling of the material. As summarised by one of the managers: "at the end of the day I need to pay my people, there is only pocket money in waste" - Site manager demolition company. When asked about the necessity to change processes in order to achieve CE, there is a common expectation that the responsibility of improving recycling and reuse should be taken by the ones earning on it and it is therefore attributed to other actors in the supply chain, often the producer of the materials.

CE Logic

The implementation of CE in the Swedish construction industry is according to our interviews only comprised of minor changes in practice and its effects are rather limited. The active adherents to the CE logic are almost exclusively the five environmental managers of our companies (architects, contractors and demolition) and all of them have been trained outside of the construction industry (chemistry or environmental management education). In their organisation, they are a part of the management support to the projects departments and also have to deal with other sustainability, health and safety related issues. They strongly advocate for CDWM aligned with the circular economy principles. '[Waste] is a very serious issue that can have drastic consequences, it is an important aspect of current business, but will become a crucial aspect of our future businesses. Where we need to be knowledgeable about it and become an industry leader' - Environmental manager large contractor. Their task is to introduce elements of CE in the companies processes but they struggle to translate the CE benefits into the established WM logic: "We thought we would save money on sorting, but we cannot see that in our statistics yet. Because the more we sort, the more the cost for containers and transport increase. But this was how we pitched it from the beginning and probably the reason they agreed to

our goals/demands. So its problematic now that we don't see any financial gain" - Environmental manager large contractor.

To motivate the project managers to engage in sorting on site one of the large contractor's sustainability manager has organised an internal competition on the quantity of waste produced by building site and publish the results on a monthly base. It is a common feel that the holistic values of CE are not easily adopted by their organisations: "we should be able to put a price tag on ethical and ecological concerns to convince the project managers to seriously engage in CE" - Environmental manager. They also openly recognise that they are only disposed with a limited power to change practices within their own organisation. All our sustainable managers are engaged in networks of interests to implement CE and they also participate in projects with research institutes on the potential of recycling materials or optimisation of work processes.

However, building on the economic aspects of reusing material, the companies we visited have implemented a few CE friendly initiatives. They have created stockage of used material collected on site to be reclaimed and even if old doors, windows and other bathroom equipment's are seldomly reused, other material such as vintage bricks, left over expanded polystyrene or wood may find a new utilisation. But according to the contractor's project managers, the use of these materials are not routinised. No value or customer interest exist, and these solutions are not aligned with the traditional practices adopted in the established logic. Some interviewees even refer to these efforts as green washing.

Paradoxically, the sustainable manager may not necessarily be involved in the rare innovative projects where buildings are constructed out of large amount of reused or recycled material. These showcases, two or three for each of the biggest contractors, seem rather to be the results of client requests and local networks of professionals who embrace the challenge of an exciting project providing there is no financial drawbacks. Being managed by independent business units at the regional level, these showcases may not include the active participation of their sustainable managers, even though they advocate for CE solutions.

Most of the contractor's managers recognise the need for a transition to CE, but still legitimised the actual practices as securing financial viability. They make small attempts or adjustments to improve CDWM on site by for example improving the logistics of waste by minimising the walking distance to the dumpsters or recycle unused material from one building site to another. However, these actions are random and do not comply with a systematic activity plan. Table 2 summarise how the established WM logic and CE logic build on different characteristics.

CONCLUSION

Drawing on the notion of institutional field logics, we have tried to explain why CDWM practices are only slowly aligning with the CE principles. Our results explain why organisations have problems to align their practices with the legislative and societal demands to engage in circularity as the basic assumptions, values and norms are contradictory to the existing logic.

Organisations avoid challenging business as usual taking place at the level of the projects by positioning sustainability units close to top management to serve as advisory service provider. The CE logic builds on people, assumptions and examples coming from outside of the construction industry, which are difficult to translate into

the established logic which is strongly anchored in a market logic. The CE clashes with the established logic as it draws on interdependency between the actors for a common gain whilst the latter builds on a sequential process where each actor should make a profit in their own part of the process.

Table 2: Characteristics of the Established and Circular Economy WM logics

Institutional logics Characteristics	Established WM	Circular economy WM
Assumptions	No demands for recycled material, low quality, high cost	Recycled material can replace virgin materials
Values	Financial reward, private	Societal benefits, public
Beliefs	Waste as waste, other actors' responsibility	Waste as product Everybody responsibility
Rules	Legislation, KPI, customer	Company policies, guidelines
Practices	Long traditions	Not stabilized - partly to be defined
Control mechanism	Audit, regulation, contract	Social obedience, certification, reputation, stakeholder pressure
Organization of time	Short term, linear	Long term, circular
Source of identity and authority	Clear professional roles and hierarchy, positioning in the field	Researcher, activists, individual belief
Source of legitimacy	Normalized practices, profit, efficiency	Climate change, holistic, backed by scientific evidence,
Base of strategy	Focus on core activities	Contribute to society
Institutional entrepreneurship	Maintain the dominant	Participation to research, networks, training
Economic system	Value created inside organization	Value through interdependencies
	Service based, sorting ratio	Material based, prevention
Bases of mission	Company and customer value	Societal value
Bases of attention	Reduce WM cost, minimize time usage	Cost efficient solutions, sustainable resource management

However, small improvements are realised under the influence of sustainability units and some practices are slowly becoming routinised. New functions or professions are created in organisations supported by new education curricula such as milieu, environmental or sustainable managers. Networks of interests are crossing the boundaries of competing organisations that aim to address these issues and diffuse the principles of the CE. We also identify "bubbling" activities which seem to be bridging the two logics at the level of the projects, but even though individuals realize the need to improve, they still face tension in terms of contradictory organizational demands. But the necessary collaboration between organisations to fully adopt the CE logic seems far from reached. The only success mentioned through the joint forces in collaboration projects so far is the standardisation of sizes of the transport pallets. So, the industry will need stronger incentives and reference frame to engage with the CE, as we otherwise risk being on the road to nowhere.

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A STUDY OF THE HOUSING NEEDS OF RESIDENTS IN INFORMAL SETTLEMENTS IN THE DOMINICAN REPUBLIC

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In 2015, a new sustainable development agenda was introduced aimed at ending poverty, protecting the planet and ensuring prosperity for all by 2030, which extends to making cities and human settlements inclusive, safe, resilient and sustainable. Despite progress being made, around one billion people currently live in informal settlements, commonly referred to as slums, which are characterised by overcrowded spaces, substandard dwellings where the occupant does not have legal rights to claim, and a lack of basic services such as sanitation and safe drinking water. It is therefore paramount to develop meaningful knowledge to overcome the real-world challenges of housing and human settlement issues faced by communities across the world, in order to contribute to building a more prosperous society, making a positive impact and committing to the common good. This research assesses the living conditions of slum dwellers in an attempt to suggest ways of overcoming housing concerns in urban areas of the Dominican Republic that are particularly vulnerable to natural and man-made hazards. The results from 167 questionnaire responses distributed amongst four slum community zones and one “improved” housing development zone shows that only seven per cent of slum dwellers have direct access to safe water, which is contrary to past studies and reports. Another important finding was a cause-and-effect-relationship between life satisfaction and electricity provision amongst slum dwellers. Furthermore, the findings indicate that current approaches aimed at tackling housing needs are not sufficient to overcome the overall problem, however, they do generate some improvement when compared to previous endeavours in the past twenty years. Finally, it is recommended that slum resettlement as a strategy should be avoided in favour of upgrading programmes.

Keywords: housing, poverty, resilience, sustainable development, urban sprawl

INTRODUCTION

This study attempts to assess the housing needs of residents in informal human settlements in urban areas of the Dominican Republic (DR) which are particularly vulnerable to natural and man-made hazards. In the pages that follow, the causes and consequences of urban sprawl as well as the factors, patterns and recommendations which could increase the efficiency of housing programmes, resulting in overall improvements of the quality of life and well-being of the urban poor, will be discussed. This research differs from previous studies by focusing on the experiences of individuals “in-site” in an attempt to uncover the true situation of slum dwellers in the DR. Now, more than ever, there is a need to address the repercussions for urban sustainability. Today, around one billion people in the world live in informal

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settlements, in effect, one out of every three people are living in cities in the developing world. This situation is more problematic in the DR as approximately half of the slum dwellers live in locations which are prone to natural disasters. Importantly, evidence suggests that overcoming adverse human settlements is among the most important factors for ending poverty, and as a result, to ensure prosperity for all.

LITERATURE REVIEW

Although studies over the past three decades have provided important information about housing needs in informal settlements, so far, there has been little discussion about how to tackle this challenge in the DR.

Horizons and Living Conditions: Urban Slums

Recent research has revealed that location choice factors have been linked to the growth of slums and that commuting costs, access to local public goods, individual preferences for neighbourhood structures, housing quality and neighbourhood amenities, as well as social ties such as common culture and similar income-generating activities are significant factors stemming from the location component. In 1948, the UN through its Universal Declaration of Human Rights recognised housing as a basic requirement for attaining an adequate standard of living (United Nations, 1949). Despite this, nearly a billion urban residents live in slums which is increasing by 25 million each year (UN Department for Economic and Social Affairs, 2006) making it a critical challenge for overcoming poverty all over the world. The term “slum” is usually used to describe informal settlements that have inadequate housing, miserable living conditions and overcrowding (Cities Alliance, 2012).

Safe Water and Sanitation

Globally, at least two billion people drink water contaminated with faeces, and around 844 million people lack even a basic drinking water-service (WHO, 2018). More than two billion people still do not have basic sanitation facilities such as toilets. Furthermore, inadequate sanitation is estimated to cause 280,000 diarrhoeal deaths annually and poor sanitation also contributes to malnutrition (WHO, 2018). Therefore, improving sanitation in slums would help to reduce premature deaths and health risks.

Lack of Safe Tenure and Durability of Housing

Secure tenure is the right of all individuals to effective protection by the State against arbitrary unlawful evictions. UN-Habitat (2003) estimates that 924 million people in urban areas of the world do not have the security of tenure. Those without official title deeds are prone to unfair evictions, and it prevents them from accessing credit and reduces their motivation to invest in their homes. A house is considered “durable” if it is built in a non-hazardous location, is a permanent structure and is able to protect its inhabitants from the extremes of climatic conditions. The building materials in the roof, walls and the floor measure the durability of the housing. Non-permanent constructions represent seventy-two per cent of all slum structures (UN-Habitat, 2016).

Habitat and Housing in the Dominican Republic

Slum problems are widespread in developing countries such as DR. Although self-built housing is common, many cannot afford to build their own homes due to the lack of economic means. Others can afford the construction of their homes but with financial constraints. As a result, many of these structures are built with low-quality

materials making them vulnerable to natural and man-made disasters. The principal indicators for assessing the housing status in a country are the housing demand and housing need. According to a definition provided by Wilson, *et al.*, (2018), housing need is “the amount of housing required for all households to live in accommodations that meet certain standards”, whereas housing demand refers “to the amount of housing that households will choose to buy, given their choices and ability to pay”.

Resilience and Risk Management: Natural Disasters and Man-Made Hazards

The urban poor are often the most vulnerable to natural disasters and man-made hazards as they inhabit overcrowded, unstable and dangerous land with no financial cushion or security. When flooding, fire, earthquakes, landslides, and cyclones strike, the urban poor are often the worse hit. The circumstances of the urban poor also make them more vulnerable to dangers such as organised crime and epidemics (OCHA/IRIN and UN-Habitat, 2007). In the same vein, rapid urbanization brings enormous challenges, including; growing numbers of slum residents, increased air pollution, and inadequate basic services and infrastructure, which also make cities more vulnerable to disasters. Across Latin America, evidence suggests that poorly functioning land markets, urban sprawl, and poor transportation on the edge of cities push low-income households to settle in “risky” areas (Hallegatte. *et al.*, 2017).

Alternatives to Overcome Slums

Upgrading Slums

Slum upgrading is a process through which informal areas are gradually improved, formalised and incorporated into the city itself by extending land and services. It is more than a package of basic services; it promotes the economic, social, institutional and community activities needed to turn around downward trends in an area. The main reason for slum upgrading is the fundamental right to live with basic dignity and decent conditions, and to prevent the formation and deterioration of new slums (Cities Alliance, 2012). It can thus be suggested that slum upgrading should be included in urban public policies in order to make the process more effective.

Slum Resettlement

Slum resettlement involves relocating the slums to the peripheries of a city, generally, in social housing projects and integrated with efficient infrastructure and job sources (Nyametso, 2012). Slum residents would leave their current location which is susceptible to health and safety hazards such as diseases and natural disasters resulting in improved quality of life (Arandel and Wetterberg, 2013). However, resettlement schemes often fail due to the distance created between a community’s place of origin (Cronin and Guthrie, 2011) and the high degree of negative impact on the livelihood of slum dwellers (Kapse, *et al.*, 2011). It can, therefore, be assumed that slum relocation would only be reasonable if slum residents are prone to natural and man-made hazards, otherwise, upgrading slums should prevail.

METHODS

A multi-method approach using a survey strategy was used for this research. The choice of this method is justified by the nature of this study since it was necessary to combine qualitative and quantitative research elements to answer complex questions.

Table 1: Methods Used to Achieve Research Objectives

Objective	Method
1 To assess the living conditions and quality of life of slum dwellers	Questionnaire
2 To evaluate the living improvements of former slum dwellers who were resettled to better housing conditions	Interview
3 To explore different options to overcome the adverse conditions of slum dwellers	Questionnaire

Research Questionnaire Surveys

Questionnaires took place amongst four slum community zones and one “resettled” housing development zone.

The first questionnaire was based on the UN’s five characteristics defining a slum household. A mix of thirty open and closed questions were used to cover six themes for evaluating the living conditions of slum dwellers. An alternative questionnaire was distributed amongst those living in the “The New Barquita” which comprised of fourteen questions, three themes and included a Likert-style rating scale.

Table 2: Questionnaire Survey Number of Participants

Community Zone	Type	No of Participants	Municipality
The Dique	Slum	51	Santo Domingo Este
Gualey	Slum	25	Distrito Nacional
Guachupita	Slum	49	Distrito Nacional
The Barquita	Slum	11	Santo Domingo Este
The New Barquita	Resettled Slum	31	Santo Domingo Norte

Semi-Structured Interviews

Semi structured interviews consisting of seven questions took place to provide insights to complex questions about tackling slum issues in the urban built environment. The interviews were conducted with five specialists within the field of urban planning and public policy. The interviews were conducted by telephone lasting from thirty minutes to one hour and a half and all of the interviews were held in Spanish and then translated into English. Respondents were selected based on their experience in the field. Interviews were conversational resulting in a large volume of data. The transcribed interviews were then systematically analysed by using sophisticated coding and additional query functions to determine themes and trends.

Research Ethics

As part of the research involved participants who were living in slum areas and therefore potentially vulnerable, it was important to ensure anyone who took part in the study did not become “subjects” of the research but instead, participants in the process. None of the authors entered the slum areas, instead the surveys were conducted by volunteers who are respected and trusted in different slum areas in the DR. As the volunteers were “known” people within the slum areas, any potential location risks were mitigated. Before commencement of the data collection process, the volunteers were instructed according to the design of the research methodology, focusing on sampling and research ethics. It is important to note that the research was guided by the good practices of ethics which includes confidentiality and anonymity

of the participants. Each participant freely gave informed consent in advance so that they had time and opportunity to consider their decision. It was also important to avoid unreasonable generalisations, resulting in prejudice towards slum dwellers and to acknowledge the limitations of the relatively small sample size which may not be representative of the entire population.

RESULTS

Household Conditions

The majority of the respondents questioned had been living on the same site for more than fifteen years. Almost three-quarters of respondents had been in their homes for more than a decade, and approximately 5% for less than a year. 41% of the respondents were living with their parents, whilst 59% reported to live close to relatives. These findings are aligned with a report conducted by UN-ECLAC (2005), where 43.5% of the urban poor in the DR were living with extended families. Several studies have shown that household structures have a significant impact on the overall well-being of families (Cohen and Casper, 2002). One of the findings from this research show that the predominant family structure in slums was the “extended family” model which may be due to the increase of the housing need and stagnation of public policies towards housing incentives and development in the DR.

Overcrowding

One of the most relevant indicators when assessing habitat conditions is overcrowding. This factor prevents people from living in adequate conditions (Cities Alliance, 2012). Various methods currently exist for measuring overcrowding; for example, either by the house size or rooms/ persons ratio. Although floor area-per-person (FAPP) is not commonly used for the calculation methodology of overcrowding in either Latin America or the DR, numerous studies have supported the FAPP method (Iniguez-Rueda, 1987; UN-Habitat, 2003, Torres *et al.*, 2017), arguing that decent dwellings are much more than a roof per head; it is adequate space as well. Since there is no standard parameter for FAPP in Latin America, the benchmark of 8.27 square meters per person has been used as the standard space required for one person as the UK Housing Act 1985 and the Scottish Housing Act 1987 mandate. The results show that many of the participants are living in overcrowded dwellings which can impact negatively on their physical and mental health, privacy, performance in education, and can cause psychological stress.

Water Supply, Wastewater Sewer System and Waste Management

The access to safe water and equitable sanitation are paramount elements for an adequate dwelling (UN-Habitat, 2003). Only 7% of the respondents reported having direct access to potable water in their homes. Conversely, the UN-ECLAC (2014) database reported that 74% of the population in the DR have access to safe water, which is contradictory to these findings. However, this significant gap between this study and the UN-ECLAC report may be explained by the target population selected by this study, which was the slum dwellers vulnerable to natural hazards, whilst the UN-ECLAC report’s sample represented the entire population of the DR.

Consequently, these findings raise intriguing questions regarding the achievement of the sixth Sustainable Development Goal concerning safe water and sanitation in respect to the Dominican informal settlements. The results show that 82% of participants have a toilet inside or outside their houses, whereas only 32% were connected to a sanitary sewer. These figures are similar to the UN-ECLAC (2014)

who report 84% and 40%. Also, 75% of the respondents reported that rubbish collection takes place at least once a week.

Transport Infrastructure, Quality of Housing and Residential Status

The lack of an accessible, safe and sustainable transportation system is typical in slums. Only 30% of the respondents said they have transport access to their homes. Interestingly, 49% of the respondents from “The Dique” have transport access to their home, whilst only 13% from “Gualey” can access their homes through a paved path. Over half of the sample, 53%, live close to public, recreational and green spaces. Surprisingly, 94% of the respondents from “The Dique” live nearby recreational spaces such as a basketball/ volleyball court, or a community centre, whilst in “The Barquita” there is no such a recreational space.

Slum housing is densely packed and poorly built with substandard materials. Moreover, houses built adjacent to hillsides are subject to landslides during heavy rain, and substandard buildings cause thousands of deaths from earthquakes (Unger and Riley, 2007). The results show that 41% do not have proper flooring and 44% of housing are built with substandard materials, which make them more vulnerable to natural hazards. Moreover, DiCaprio (2016) argues that climate change may make their situation even more vulnerable yet.

The lack of secure land or housing tenure forces residents to occupy unused or undesirable land (Unger and Riley, 2007). Only 2% of the participants possess formal title deeds to either land or residency. This finding broadly supports the work of other studies in this area linking slums with the lack of secure land and housing tenure. Making cities safe and sustainable involves investment in public transport, creating green public spaces, and improving urban planning and management in a manner that is both participatory and inclusive (UNDP, 2018).

Wellbeing of Slum Dwellers

As well as assessing the living conditions of the people in slums, this study also aimed to measure some aspects of their quality of life and wellbeing. The differences between these two indicators rely on that the former is focused on the circumstances of a household’s life such as the quality of the house, sanitation, and clean water whereby while the latter refers to the general well-being of the dwellers.

Previous studies and surveys (IDB, 2010; IDB, 2012) in Latin America and the Caribbean have shown that people’s satisfaction with their homes and cities in which they dwell is a determinant factor in their life satisfaction. The results show that 46% of those surveyed were satisfied with their living conditions, furthermore, the most single remarkable information observation to emerge from the data comparison between slums’ life satisfaction, was that 71% of respondents from “The Dique” have reported being satisfied with their living conditions in spite of the lack of basic services such as constant safe water, wastewater sewer system and transportation systems, whereas in other slums, this figure is only about a third. The results may be explained by the fact that “The Dique” slum has been favoured by an average of about twenty-one hours of electric energy per day, whilst other slums have roughly five hours a day.

Public Housing Resettlement Programme: “New Barquita” Findings

This section aimed to evaluate the overall satisfaction of the people who were resettled from slums to improved neighbourhoods through the public housing programmes, namely the “New Barquita” project which started in 2013 and was handed over in 2016. The project aimed to provide decent and safe shelter to people

who were vulnerable to flooding due to its proximity to the Ozama river. The participants were asked about the advantages, disadvantages and if amendments were necessary. Sachs (2012) argues that adequate resettlement of slum dwellers improves their living and environmental conditions. Nevertheless, Abebe and Hesselber, (2015) state that resettlement projects could disrupt people's social networks, also referred to as "uprooting". The advantages found in the survey were: flood protection, decent houses, potable water, cleanliness and constant electricity. The disadvantages highlighted were poor access to the public transportation system, no change in the level of delinquency, and a perceived lack of personal safety when walking alone at night. Some of the most vulnerable slum dwellers from the "Barquita" were provided with decent houses and basic services, however, the main issue is that people's livelihoods have been disrupted.

Housing Insufficiency in Slums as a Critical Issue in the DR

The interviews sought to determine if the housing deficit is a significant issue in the DR. When asked about housing with poor conditions in slums, interviewees were unanimous in the view of housing needs as a critical issue. R1 argues that "the housing variable in the context of poverty indicates that if people's housing conditions are not changed, they would not overcome the poverty line despite any endeavour" and R2 admitted that "it is one of the principal issues". In addition, R2 highlighted that the housing deficit exceeds the 2.1 million units according to the official sources. Similarly, R3 echoed the previous one in terms of the housing deficit figures, but also, added that "overcrowding is one of the biggest concerns within the housing issue". The fourth and fifth respondents simply agreed with the housing deficit as a critical concern.

Causes and Consequences of Inadequate Housing

The interviews also sought to understand the causes and consequences of inadequate housing. The results found that poor housing planning by the authorities, rapid urbanisation, and the rural-urban migration to city centres are the main causes that create slums. Interestingly, financial exclusion and inadequate public-private partnership were not observed in the literature review. The former indicates that a great proportion of slum dwellers do not have access to useful and affordable financial products and services to buy adequate houses, whereas the latter is deemed to the construction of economic houses that poor people in slums cannot afford. The third set of questions sought to understand the consequences and effects of inadequate housing. R1 alluded to the notion of the effects of inadequate housing would highly depend on the level of inadequacy, he said that "for example, if the inadequacy is the floor type, it would likely affect the health; if the issue is overcrowding, it might affect self-esteem, privacy, amongst other aspects". Again, the results show that overcrowding has the potential for detrimental effects of people's lives.

Housing Public Policies

Interviewees were also asked about housing policies. R1 said that he believed public policies had improved in recent years and also pointed out that these policies focus their attention on two branches: first, the public housing improvement programme, also known as the "New Barquita", and second, the private-public partnership, with its emblematic project "Juan Bosch City". R1 stated: "these two aforementioned projects are consequences of the new public policies towards housing; however, there is still too much to do to provide decent housing". R2 went on to state that such public policies do not include the provision of social housing within its scope; "the Dominican government has made huge endeavours for overcoming the houses deficit

but excluded the social housing aspects. Also, it prevails duplicity in functions when regulating the housing problem since there are many players undertaking it. In general, housing public policies could be more efficient and effective”. R3 agreed with this statement in terms of the housing public policies efficiency and effectiveness but also outlined that historically, these policies have “failed in regulating urban planning, land ownership, and safe residential status”. R4 mentioned that it is one the government policies dimensions that should be discussed, enlarged, driven and strengthen with adequate economic resources. R5 added that “the central government has made many efforts to overcome the housing issue, nevertheless, they need to articulate these efforts in a political declaration which allows maintaining a common goal”. Indeed, R1, R2 and R5 stated, the “Juan Bosch City” as a public-private partnership alongside with the “New Barquita”, and these are remarkable projects for adding dwellings to the Dominican housing system. However, non-governmental agencies are very critical of the new policies. For instance, Ciudad Alternativa (2018) demonstrated that the building costs of these blocks of flats in “Juan Bosch City” are not affordable for the poor people, whereas R3 argues that it is very expensive to duplicate the “New Barquita” and it is not sustainable in the long-term. Given the considerations above, these results would seem to suggest that housing public policies have been stagnated for a while, but recently, they have been changing for the common good.

Suggestions for Tackling Slum Issues

Table 3 shows the different answers from the respondents regarding the possible choices for overcoming the housing deficit in DR.

Table 3: Questionnaire survey number of participants

Respondent	Type
R1	A. Projects similar to 'Juan Bosch City' but at lower prices. Less than RD\$1 million pesos (£14,500 pounds). B. Better housing mortgages rates, conditions and loans. C. The application of acupuncture urbanism could be interesting. D. Social housing cooperatives E. Urban re-densification.
R2	A. Public policies including the norming of land, land-use, migration, safe occupancy. B. Instruments like social lease. C. A unique organism to regulate the housing sector in the DR. D. An adequate risk management programme.
R3	A. Law approach. B. Social production of the habitat. C. Benchmarking good practices from successful programmes in other countries.
R4	A. Elaboration of a housing deficit diagnosis. B. Design of a development programme within the country's goals and priorities. C. Economic management of the resources. D. Community collaboration involvement.
R5	A. Elaboration of a housing deficit diagnosis. B. Design of a development programme within the country's goals and priorities. C. Economic management of the resources. D. Community collaboration involvement.

With this in mind, the urban poor who earn the minimum salary would not be able to afford economic houses from the public-private partnerships due to low income, let alone to have access to financial sources. Therefore, the development of less expensive housing projects would not be enough to solve this dilemma, and thus, important changes in the whole economy would be necessary.

CONCLUSION

The research set out to assess the living conditions and quality of life of slum dwellers vulnerable to natural and man-made hazards. The results show that the predominant

housing structure in slums is the extended family model which contributes to overcrowding and often negatively influences inhabitant's well-being and quality of life. One of the most significant findings is that only seven per cent of slum dwellers surveyed have direct access to safe water which is contrary to previous reports. With regards to basic infrastructure, more than two-thirds do not have transport access to their homes and over half do not live close to recreational spaces. Almost half of the participants live in substandard houses, and virtually, none of them possesses formal title deeds to either land or residency.

The research also sought to evaluate the living improvements of former slum dwellers who were resettled to better housing conditions. Indeed, this study highlights that slum resettlements contribute to the enhancement of the overall quality of life and well-being of the urban poor. However, the option of slum relief has its drawbacks and can disrupt people's livelihood in some instances.

The final aim of the work was to explore different options to overcome the adverse conditions of slum dwellers. Despite the public policies towards housing being changing recently, this research found that it is not sufficient to overcome the cumulative issues. In the same vein, slum resettlements as part of housing public policy should be evaluated due to the very high transaction costs when compared to other solutions, such as slum upgrading. The key alternatives suggested by the specialists for overcoming slum issues are public-private partnerships but at lower prices, better financial conditions for house buyers, strengthening public policies in terms of land-use, migration and safe occupancy, benchmarking good practices from other countries and implementation of a state housing programme management.

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IMPLEMENTATION OF CIRCULARITY IN THE BUILDING PROCESS: A CASE STUDY RESEARCH INTO ORGANIZING THE ACTOR NETWORK AND DECISION-MAKING PROCESS

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Circularity aims to reduce waste by closing and narrowing resource loops and by extending the lifetime of materials and products. As a consequence of this fundamentally different approach to construction practices, implementation entails a different organization of the building process. The purpose of this research is to make recommendations with respect to the actor network and the decision-making process to facilitate implementation of circularity in construction practices. First, a theoretical framework is developed to structure and prioritize decision-making to implement circularity based on resource and value strategies. Second, this framework is applied to three circular building cases in the Netherlands, relying on stakeholder interviews and documentation. These cases include a renovation project, a newly built project, and a transformation project. Third, analysis of the case study data demonstrates the actor network and decision-making process including the following aspects: Actors, resources, relations, positions, influence, and decision rounds. It can be concluded that: i) some conventional actors have acquired knowledge on circularity; and ii) expert actors emerged who have specialized in circularity. Both types of actors are a prerequisite iii) to implement circular strategies for the beginning and end phase of the building's lifetime; and iv) should be involved early on (in the design-making processes) to influence decision-making on circularity, especially concerning the long-lived layers of a building.

Keywords: Actor network analysis, circular construction, life cycle, sustainability

INTRODUCTION

The building sector and its linear building process is responsible for a large share of the total waste production and CO₂ emissions globally. De Ridder (2018) illustrates that the building sector generates about 45% of the total waste in the Netherlands, whereas it only contributes for 10% to the GNP. This demonstrates the relevance to reduce waste and deal responsibly with materials and resources. Contrary to a linear building process, a circular building process helps to cut down production and consumption rates (Mulhall and Braungart 2010). By closing material cycles this approach aims to deal more consciously with resources by means of prevention,

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reusing, recycling, and decomposition; and generally, utilises waste (that is generated after demolition) as a resource (McDonough and Braungart 2009).

Although circularity seems to be a promising concept, some difficulties appear to arise during its implementation. Adams *et al.*, (2017) indicate several barriers inherent to the conventional organization of the building process. These are amongst others: lack of awareness and knowledge of circular building processes that designers and clients have, a fragmented supply chain, and lack of considerations and incentives at the start and end phase of the building's lifetime (Adams *et al.*, 2017). Additionally, Gorgolewski and Ergun (2013) explain that probably other actors should be involved, such as demolition or salvage companies that could aid in sourcing reused materials.

This research aims to analyse current circular practices and make recommendations for the actor network and the decision-making process to facilitate implementation of circularity in the building process. It is assumed that impact for circularity is maximized when circular strategies are already considered in the beginning of the building process. In accordance, the following research question is posed: "Which actors should be involved in design-making processes to ensure circularity throughout all phases in the building process?". A theoretical framework based on a literature study guides analysis of the actor network and decision-making process of the cases.

THEORETICAL FRAMEWORK

A circular building approach can be defined as "a life cycle approach that optimizes the buildings' useful lifetime, integrating the end-of-life phase in the design and uses new ownership models where materials are only temporarily stored in the building that acts as a material bank" (Leising, *et al.*, 2018:977). The conventional end-of-life phase (in this paper termed 'post-phase'), resulting in waste, should therefore be reconsidered and replaced by reduce, reuse or recycle. Preparations to guarantee dismantling and reuse or recycling at the end-of-life could already be made in the design-making processes (initiation, preparation and design phase). In this paper, these early on phases of the building process are termed 'pre-phase'.

Several authors have defined circular strategies (CSs) to guarantee reduction, reuse and recycling. In relation to materials and resources, some strategies are focused on dealing with waste at the end of life, others are focused on preventing waste upfront (Addis 2006). Although authors use different words and slightly different categorizations, there seems to be agreement that 'reduce' (including prevention and reduction) is the main aim for dealing with waste, followed by 'reuse' (including repair and maintenance, reuse and redistribution, and refurbishment and remanufacturing), and 'recycling' (including recycling, cascading and repurposing, and organic feedstock) (Lüdeke-Freund *et al.*, 2018; Kraaijenhagen *et al.*, 2018; Bocken *et al.*, 2014; and Ritala *et al.*, 2018). The following CSs are identified based on the framework established by Lüdeke-Freund *et al.*, (2018): (1) maximize material and energy efficiency and dematerialization, (2) functionality without ownership / product service system (PSS) and extending product value, and (3) extending resource value and industrial symbiosis, see Table 1.

The CSs (1) maximizing material and energy efficiency and de-materialization both focus on preventing waste upfront. Value is created by reducing components and material input and output. This results in using less materials and resources, thereby narrowing resource loops. In concrete terms this can be applied by means of evaluating the need for a (new) building, using less materials, using lightweight

materials, and obtaining efficient construction and manufacturing processes (Lüdeke-Freund *et al.*, 2018).

The aim reuse slows the resource loop down, since the lifetime is extended (Ness and Xing 2017). The accompanying CS (2) extending product value can be implemented by means of maintenance and repair or redistribution (Kraaijenhagen *et al.*, 2018). The CS (2) functionality without ownership, also known as a product service system (PSS), is aimed at providing a service instead of a physical product or component (Kraaijenhagen *et al.*, 2018). This strategy is based on the assumption that a product-oriented business is likely to increase the number of products sold, and thereby the materials used, whereas a service-oriented business is motivated to extend the product’s lifetime and minimize maintenance.

Table 1: Framework of circular strategies (CSs) and aims, patterns, design strategies, resource strategies, and value strategies, these can be applied as pre- and post-phase scenarios of a building's lifetime, based on and expanded from Lüdeke-Freund *et al.*, (2018); Kraaijenhagen *et al.*, (2018); Addis (2006); Ritala *et al.*, (2018); and Bocken *et al.*, (2016).

circular strategy (CS):	(1) maximize material and energy efficiency, dematerialization	(2) functionality without ownership / product service system (PSS), extending product value	(3) extending resource value, industrial symbiosis
aim:	reduce	reuse	recycle
pattern:	prevention and reduction	repair and maintenance	reuse and redistribution
design strategy:	resource efficiency	long-life, life extension	refurbishment and remanufacturing
resource strategy:	narrowing	slowing down	closing
value strategy:	reduce component and material input and output	retain component value	retain material value

The aim recycling requires processing of components into materials and subsequently into new components (Iacovidou and Purnell 2016). Since recycling often requires energy this option could not be considered entirely circular, especially if value is lost when components degrade in function (downcycling) (Lüdeke-Freund *et al.*, 2018; Adams *et al.*, 2017). According to McDonough and Braungart (2009) for biological nutrients the resource loop can be closed by means of decomposition. Therefore, biological and technical nutrients should be separated (McDonough and Braungart 2009). The CSs (3) extending resource value and industrial symbiosis both focus on aligning waste output from one industry as a valuable resource for another (Kraaijenhagen *et al.*, 2018).

Applying these strategies to buildings indicates differences in applicability for long-lived layers (site, structure, skin) and short-lived layers (services, space plan, stuff) (Brand 1994). According to De Ridder (2018) long-lived layers, with a lifetime that generally transcends the building’s lifetime, should be reused. And short-lived layers, with a lifetime shorter than the building’s lifetime, should be recycled with a minimum amount of energy (De Ridder 2018). For short-lived layers “suppliers can

take responsibility [...] via take back schemes” by means of leasing or buy back guarantee (Leising *et al.*, 2018:984). Components and materials with a long-lived life cycle can be reused which is facilitated via marketplaces (Leising *et al.*, 2018).

METHOD

By means of case study research, data is gathered to evaluate actor involvement and influence on decision-making in the building process with respect to circularity. The case study research evaluates three circular building cases in the Netherlands (Table 2). These cases were selected based on criteria to provide sufficient ground for comparison: their ambition for circularity, their recent realization, and their fairly similar context and comparable building process. The case study analysis is based on two main sources of data: documents, policies, (architectural) plans, and meetings notes (secondary data); and stakeholder interviews (primary data). The stakeholder interviews consisted of semi-structured interviews. In total 9 stakeholders were interviewed of which 3 interviewees were associated with each case (Table 2). The analysis, involving manual coding, proceeded according to a standard iterative process typically employed for qualitative data.

Table 2: Cases for case study research

case	type	year	location	standard	interviewees
Case I: Townhall Brummen	renovation	2013	Brummen	cradle-to-cradle certified	two contractors, designer
Case II: The Green House	newly built	2018	Utrecht	building circularity index	client, designer, project manager
Case III: EDGE Olympic	transformation	2018	Amsterdam	BREEAM Excellent	client, designer, dismantler

The semi-structured interview questions were formulated in line with relevant criteria gathered from theory on actor network and decision-making processes. Methods for studying the actor network can be found in the field of actor network theory. An actor is defined as “a social entity, person or organization, able to act on or exert influence on a decision” (Enserink *et al.*, 2010:80). An actor is involved, because he or she could offer something to construct the building. This offer is depicted as a ‘resource’, which is defined as “the practical means that actors have to realize their objectives” (Enserink *et al.*, 2010:81). A relation displays an indication of exchange of information or coordination between actors (Van Ruijven 2016). The positions of the actors in the actor network relate to their centrality in the network. Centrality is defined as “the number of connections between a node and other nodes” (Van Ruijven 2016:127). The actor with the highest number of relations is positioned centrally in the network. This actor can be defined as transformation agent, who acquires support from others and mobilizes the actor network (Kraaijenhagen *et al.*, 2018). Influence on decision-making is depicted by the size of the node.

The work of Teisman (2000) discusses models for unravelling complex decision-making processes. Its relevance for this study can be found in its identification of the decision-making process, including the involvement and roles of multiple actors and their influence on decision-making (Teisman 2000). Contributions to this work by Klijn and Koppenjan (2016) is utilized to visualize the decision-making process and identify rounds. A round is a moment in time when the most crucial decision(s) regarding a topic is/are made. The content of the decision-making process regarding circularity is identified by relating the rounds to certain CSs. These rounds are positioned on the x-axis. This helps to identify when decisions were made and to

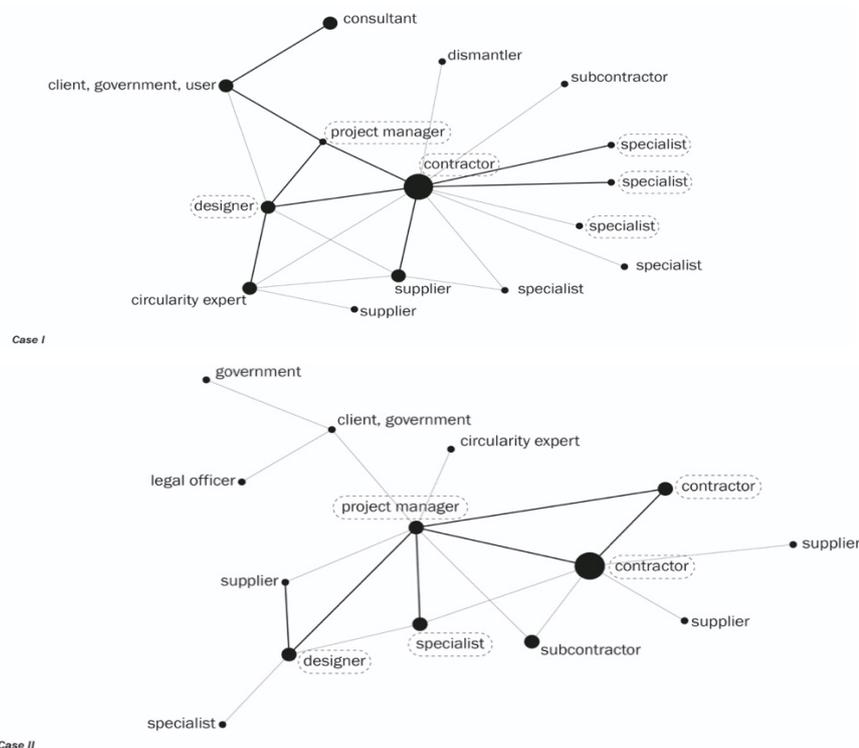
evaluate the relation between decisions made early on (in the pre-phase) and their subsequent implementation.

FINDINGS

Composition of Actor Network for Circular Building Processes

These three cases show that different types of actors are part of the actor network. Figure 1 shows the actor networks as concluded from the case study research. The three cases all involved, to some extent, experts with knowledge on circularity. In Case I these expert actors are: A circularity expert, consultant, and dismantler. In Case II this is a circularity expert. And in Case III these actors are: A circularity expert, dismantlers, an investor, and reclamation experts. In addition, these cases involved conventional actors who have acquired knowledge on circularity. In Case I this was a specialist, and supplier. In Case II this was a subcontractor, and suppliers. And in Case III this was a subcontractor. These actors exert moderate or little influence on decision-making for these cases.

Within the actor network some actors work in close collaboration, formally called 'project team'. From the cases, it can be concluded that the actors part of the project team have higher influence on decision-making. The project team, for each case, consisted mainly of conventional actors: clients, contractors, designers, project managers, and specialists regarding building technology and services and structural engineering. Besides, some actors who are not part of the project team do have moderate influence: in Case I a circularity expert, client, consultant, and a supplier; in Case II a subcontractor; and in Case III a dismantler. Interestingly, these actors consist of expert actors and conventional actors who have acquired knowledge on circularity. Thereby, these actors all provide circularity-related resources.



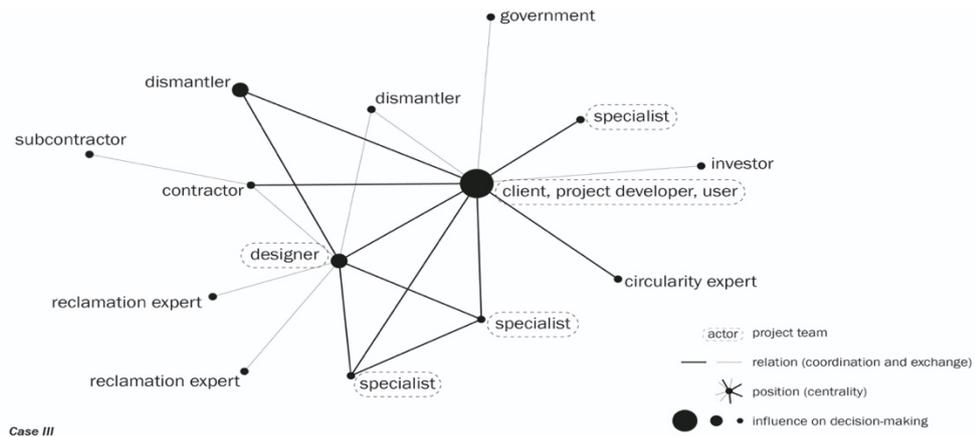


Figure 1: Actor network including involved actors, their relations, positions, and influence on decision-making, for Case I (Townhall Brummen), Case II (The Green House), and Case III (EDGE Olympic)

A high degree of coordination and exchange of information (thick lines) regarding circularity mainly occurs within the project team and to a lesser extent between the project team and surrounding actors. The following surrounding actors do coordinate frequently with project team actors (these do not all concern actors with resources to implement circularity): A circularity expert, client, consultant, and supplier (Case I); a supplier (Case II); a circularity expert, contractor, and dismantler (Case III). From these cases it remains uncertain whether already established relations are beneficial to implement circularity. Relations outside the actor network are established to facilitate in reuse of secondary components. This is facilitated, as occurs from these cases, by two aspects: 1) the proximity of secondary components in terms of distance, and 2) the external network of the involved actors. For all the three cases it appears that both contractors and designers facilitate in organizing reclamation of secondary components.

Actors positioned centrally, thus actors with the highest number of relations, are as follows: contractor (Case I), project manager (Case II), and client (Case III). For these cases, these actors act as transformation agents and fulfil a leading role. In Case I and III, the transformation agent also exerts the highest influence on decision-making. In Case II, the role of transformation agent and power to influence decision-making is separated and held by two actors; the project manager and contractor, respectively.

Decision-Making and Implementation of C_{ss} in the Building Process

Analysis of the decision-making process over time investigates the assumed benefit of early on decision-making with respect to circularity. Figure 2 shows the decision-making process over time as concluded from the cases. Several rounds have taken place to decide on beginning and end of life scenarios. Rounds are depicted by identifying decisions on CSs as determined by the theoretical framework. As can be seen in Figure 2, decisions to (1) maximize material and energy efficiency and dematerialization have been made for these cases relatively early on. These rounds are positioned in the pre-phase. However, different design strategies were applied in the three cases to reach this overarching goal of using less materials.

Decisions on the CSs (2) functionality without ownership and extending product value have been made for all three cases, although implementation differs.

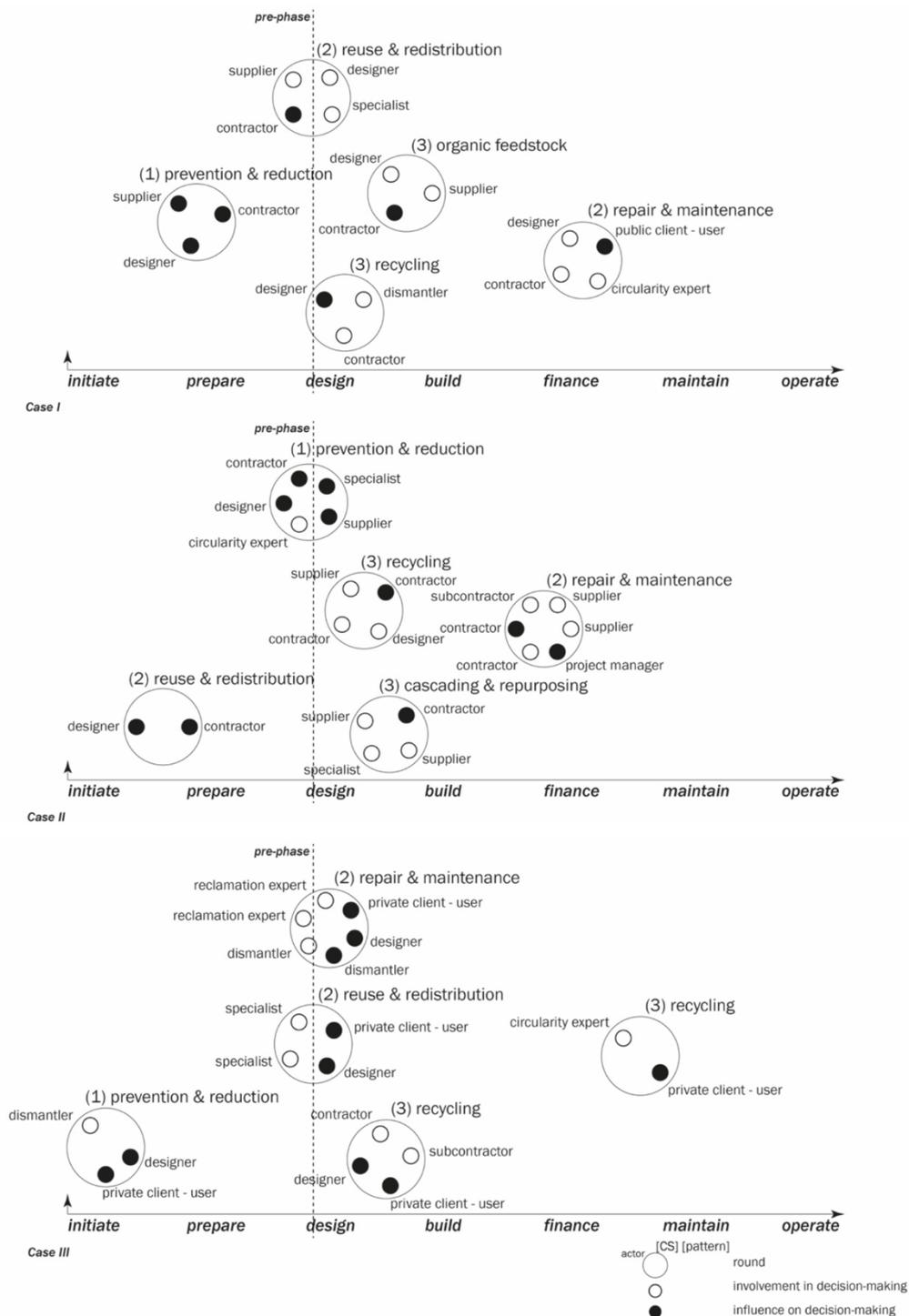


Figure 2: Decision-making process including involved actors, topics (CSs and accompanying pattern), and rounds positioned over time, for Case I (Townhall Brummen), Case II (The Green House), and Case III (EDGE Olympic)

Case I and Case II used the CS (2) to make agreements on delivery and take-back of components, determine end of life scenarios (i.e. securing demountability), and lay down ownership. Although, in the end this CS was not properly implemented in the case of Case I. Case III involved several expert actors to decide on CS (2) as a beginning of life scenario for the building, resulting in implementation of the design strategy long-life. The cases demonstrate that CS (2) was effectively implemented if the decision round took place early on. Later in the process, opportunities for

implementation of this strategy appeared limited due to risks experienced by non-traditional ownership structures.

Proper application of CSs (3) extending resource value and industrial symbiosis in the three cases is questionable, since its implementation mainly resulted in downcycling. In particular, in Case III the functioning of secondary materials was degraded after recycling. Regarding Case I, some materials were applied based on their ability to degrade biologically at the end of life. This resulted in use of bio-based materials. In Case II, decisions were made to separate biological and technical nutrients to facilitate recycling.

These cases show that in the pre-phase designers and contractors are involved. Besides, in Case I a specialist and supplier are early on involved. In Case II this concerns a circularity expert, specialist, and supplier. And in case of Case III a dismantler, reclamation expert, and specialist were involved early on. For all three cases the client initiated the project by proposing a circular or sustainability related vision, such as tendering a sustainable building, demanding a demountable building, or demanding closed resource loops.

Table 3 provides an overview of CSs that have been decided upon and were in most cases also implemented in relation to the building's layers. Some CSs have primarily been applied to short-lived layers and others primarily to long-lived layers. As can be seen CSs (1) and (2) with the aim to facilitate reduce and reuse have been mainly applied to long-lived layers. Whereas CSs (2) and (3) to facilitate reuse and recycling were decided upon and implemented for short-lived layers, although complete implementation of CSs (2) for short-lived layers proved to be difficult.

Table 3: Implementation of CSs for each case in relation to the building's layers

	site	structure	skin	services	space plan	stuff
case I	-	(1), (2)	(2)	(2)	(3)	(3)
case II	-	(1), (2)	(2), (3)	(2), (3)	(2), (3)	(2), (3)
case III	-	(1), (2)	(2)	(2)	(3)	-

These findings demonstrate that for these cases the pre-phase is important to secure circularity in design-making processes and make provisions for the beginning and end of life scenarios of the building. For these cases, it can be concluded that all rounds that took place early on have been implemented. Rounds that took place later on have not all been implemented. Rounds that took place later on in the building process and were implemented, mainly relate to financial or documentation aspects (such as a decomposition manual) in relation to the CSs and mainly concerned short-lived layers. Rounds regarding materials aspects (take-back management, and waste handling and processing) that took place later on, were not implemented thoroughly.

DISCUSSION

In addition to the current body of literature, the case study research identifies that some conventional actors acquired knowledge of circularity. These actors already developed to cope with renewed insights on how to deal with waste and facilitate implementation of circularity. This implies that when conventional actors will acquire in-depth knowledge to implement circularity themselves, instead of relying on expert actors, these experts become superfluous. Obviously, universities play a role in providing conventional actors (i.e. designers, contractor, specialists) with knowledge of circularity. Unfortunately, current state of practice is that conventional actors have

not (all) acquired knowledge about circularity yet while playing a crucial role as part of the project team. As the three cases clearly demonstrate, actors' part of the project team have higher influence on decision-making. In case these conventional actors lack expertise on circularity, expert actors should be involved in order to be able to implement CSs. In order to increase their influence on decision-making these actors should become part of the project team, or at least be able to influence decision-making. Moreover, these cases particularly demonstrate that contribution of their resources regarding circularity is enlarged, if these experts are involved early on.

With respect to the wider construction industry, this study generates insight into how to accelerate the transition process to move from a linear to a circular building process. As the three cases clearly demonstrate, (expert) actors could influence decision-making on circularity via their position in the project team, via their relations, or via actors with influential resources (i.e. building policy and legislation). Furthermore, this transition concerns a shift of attention to the end of life phase of a building. The end of life phase should be integrated in the pre-phase of the building process. Since early on decision-making on implementation of CSs could mitigate risks as perceived from involvement of unconventional actors (i.e. dismantler), non-traditional ownership structures (PSS), and secondary materials.

CONCLUSION

From the case analysis it can be concluded that the following actors should be involved and be influential in the design-making processes of circular building projects: i) conventional actors who have acquired knowledge on circularity; and ii) expert actors in the role of advisors, consultants, and assessors. Involvement of the following expert actors is, according to the cases, beneficial: circularity experts, dismantlers, investors, and reclamation experts. In addition, these cases demonstrate that implementation is facilitated when the following conventional actors are involved but only if they have knowledge of circularity: specialists, subcontractors, and suppliers. Furthermore, transformation agents could accelerate implementation of circularity by exploiting their central position to acquire support from others and mobilize the actor network.

Decisions-making regarding circularity is based on the following CSs: (1) maximize material and energy efficiency and dematerialization; (2) functionality without ownership / product service system (PSS) and extending product value; and (3) extending resource value and industrial symbiosis. Implementation of these CSs is benefited if decisions on CSs are made early on (preferably in the pre-phase). Subsequently, during the pre-phase these expert actors and other actors with expertise on circularity could help decide between the various beginning and end of life scenarios. This means that most decisions regarding reduce, reuse, and recycle with respect to short- and especially long-lived layers should be made early on in the process.

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INVESTIGATING THE MAJOR CAUSES OF MORPHOLOGICAL TRANSFORMATIONS IN THE CBD OF ACCRA AND THE IMPACT ON URBAN HEAT ISLAND INTENSITY

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Tropical urban sites are constantly under the threats of the adverse effects of urban heat island (UHI) - a situation which is aggravated by climate change. Urban morphology comprises a large set of factors that play an important role in modifying urban climate and, consequently, the potential energy demand and supply in cities. Ghana has since independence, experienced a rapid population growth, which has resulted in the urbanisation of many of its towns. The influx of people into the urban areas means there is a high demand for more housing, commercial and other infrastructural developments. For Accra however, this drive has resulted in drastic reduction in urban greenery. The aim of this study is to investigate the main causes of morphological transformations that have occurred in Accra over the past few decades, with the view to identifying possible measures for UHI mitigation. This study employs a mixed-methods research approach. First, to gain an in-depth understanding of the underlying causes of the morphological transformation the city has undergone, qualitative data are gathered through desktop studies and face-to-face semi-structured interviews with some experienced Ghanaian built environment professionals. The quantitative study involves the collection of weather data from selected monitoring points in the city. Upon analysing the qualitative data, other major causes of the morphological transformations that have emerged include poor enforcement of development control, non-adherence to building regulations; inadequacies in the existing building regulations; architects and building designers lacking the motivation for sustainable design etc. It is evident that areas with large expanse of hardscapes and significantly reduced greenery are experiencing high UHI intensities. Recommendations include measures which address the identified challenges as well as urban regeneration.

Keywords: urban heat island, urban morphology, morphological transformation

INTRODUCTION

In the course of history, cities have been developing, and their physical characteristics have undergone various transformations as a result of varying events (Aliakbari *et al.*, 2011). Sanders (2008) describes urban morphology as a way of investigating and designing urban form which takes into consideration both physical and spatial components of an urban setting, with particular reference to plots, streets, blocks,

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buildings and various open spaces, all of which are essential elements which shape the changing process of city development. Urban morphology establishes a link between urban spaces and physical elements which are shaped by socio-economic factors (Mirmoqtadaei *et al.*, 2006). High rate of urbanisation in the 21st century has had adverse effects on the microclimatic conditions, with resultant increase in urban air temperature (Karteris *et al.*, 2016; Salman and Baofeng, 2018). The influx of people into the urban areas means there is a high demand for more housing, commercial and other infrastructural developments. Unfortunately, this drive always results in drastic reduction in urban greenery. Constant changes to urban morphological characteristics, for example, the introduction of hard materials such as concrete and asphalt, have led to the storage and eventual release of large amount of solar radiation into the urban spaces. As a result, the air within the urban environment has become warmer (Rizwan, Dennis and Chunho, 2008; Gago *et al.*, 2013; Salman and Baofeng, 2018).

The population of Ghana has since independence, grown rapidly - a situation which has culminated in the rapid urbanisation of several towns across the country (GSS, 2014). This development was fuelled by policies put in place by the colonial masters, which have been sustained through the post-independence era, as well as consequences of rural-urban migration and natural population increase. The city has been experiencing increasing temperature which causes thermal discomfort for users of both indoor and outdoor environments. In effect, heat build-up in the city results in significant energy demand due to high dependence on artificial ventilation. Climate is attributed to its fast-growing population that has increased the demand for housing and other infrastructural developments.

Study Area

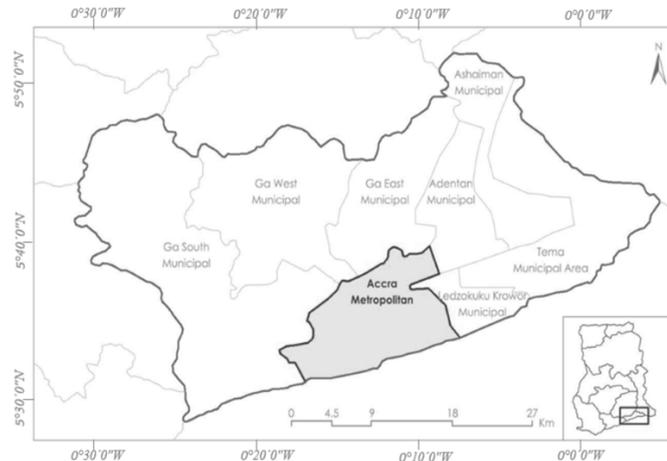


Figure 1: Map of Greater Accra Metropolitan Area showing the study area; Modified after Owusu (2013)

With findings from the study, proper mitigation measures and strategies could be developed that will ultimately culminate in effective long-term planning. This is against the backdrop that, "to help the urban dwellers cope with heat, it is extremely important to understand how cities have developed, and how they are to be redesigned for people to easily adapt to increased heat" (Hajat, O'Connor and Kosatsky, 2010).

The study aims at understanding the effect of the city's morphological transformations on its climate. The study employs a mixed-methods research approach by making use of both qualitative and quantitative data. First, it investigates the underlying causes of the city's morphological transformation using qualitative data. The impact of the

morphological transformations on the city's climate is explored by quantitatively assessing the city's historical temperature data as well as the urban heat island intensity dynamics that exist at present. To adequately assess the impact of the city's morphological changes on urban heat island, both quantitative and qualitative data are triangulated to ascertain the correlation between them.

Ghana has a total population of over 25 million (Ghana Statistical Service, 2014) and is found on the west coast of Africa. On the east, it shares a boundary with The Republic of Togo, and on the west and north, with La Cote D'Ivoire and Burkina Faso respectively. Ghana has 16 regions and 212 districts (GOG, 2019). The country basically experiences wet and dry seasons. In general, the country records average annual temperatures above 24 °C (GEPA, 2001). Figure 1 shows the location of the study area.

An obvious impact following the introduction of the liberalization program in the country during the 1990s was the boom in the establishment of multinational businesses in Accra. Currently, the city hosts the head offices of almost 700 companies (Grant, 2001). Accra has been experiencing substantial urban growth and globalization, and the associated increase in economic opportunities in the city has led to the potential for land cover and land use change (Lambin *et al.*, 2001; Auch, Taylor and Acevedo 2004).

Demography and Land Use

The Accra Metropolis has a population of about 1.7 million (Owusu 2013). The population is projected to be 10.5 million by 2040 (Ghana Statistical Service, 2012). The central and eastern parts of the CBD are characterized by formal buildings, dotted with civic and mixed-use (mainly civic-commercial) developments. In the west are extremely busy commercial areas with a major market, street shops and street vending points, though the latter has been officially outlawed. There are few residential buildings in the CBD, most of which are official. In the country, 80% of employment is informal (Baah-Boateng and Ewusi, 2013).

RESEARCH METHOD

Various researchers (Wei *et al.*, 2016 and Jin, Cui, Wong and Ignatius, 2018) have investigated the impact of urban morphology on climate urban areas of Shanghai and Jurong East (Singapore) by grouping selected sites in the respective study areas into distinct configurations, using morphological parameters such as sky view factor, building plot ratio and vegetation cover. Aiming at establishing the correlation between morphology and microclimate, such studies have often been carried out through field measurements. This study partly draws from the field measurement approach; however, to gain a deeper understanding of the phenomenon historically, it also investigates events that have culminated in the morphological changes that have occurred in Accra through desktop studies. This is an aspect which has hardly been considered by previous researchers. To fill this gap, this study employs both qualitative and quantitative research methods in a sequential manner.

The first stage involves the qualitative study, which involves a desktop investigation into the major factors that have contributed to the morphological transformation Accra has undergone since the post-colonial period. It includes descriptive analyses of historic land use changes in Accra. It also involves face-to-face semi-structured interviews with some Ghanaian built environment professionals, through which an in-depth understanding of the main causal factors of the recent changes to the city's land

use pattern and physical characteristics. The second phase of the study involves a weather measurement campaign across selected monitoring points within different local climatic zones in the CBD. Findings from both qualitative and quantitative data are then triangulated and discussed. For this study, the classification of the local climate zones (LCZs) has been done based on Stewart and Oke's (2012) method, which makes use of multiple observation data. It relies on current Landsat images and aerial photographic images. Table 1 shows a summary of the locations and the respective built types of the identified LCZs in the study area.

Table 1: LCZs identified in the study area - based on Stewart and Oke (2012)

LCZ	Locations	Built Types
LCZ1	Cedi House, National Theatre, Airport City	Compact high-rise
LCZ2	Shangri-La Hotel	Compact mid-rise
LCZ3	Awoshie, Baah-Yard, Kwashieman	Compact low-rise
LCZ4	Supreme Court-Public library, Attah Mills High Street, City Hotel, Novotel-Movenpick, Ministries-Ind. Square, Advantage Place, Jubilee House	Open high-rise
LCZ5	37 Military Hospital, PWD-Barnes Rd., Adabraka Polyclinic, Accra Ridge Hospital, Electoral Commission	Open mid-rise
LCZ6	Arko Agyei Interchange Anyaa	Open low-rise
LCZ9	Lands Commission, Anyaa NIC	Sparse low-rise

Consequently, a comparative analysis of the averaged weather measurements obtained at the study area and the historic weather data is done. There is a further analysis to ascertain possible correlations between the dynamics in both the historic weather and the historic land use/land cover characteristics and climate.

RESULTS

Secondary Data

Historical developments in the urbanisation of Accra

According to Songsore (2003), following the fall of the Western Sudan trade routes, a string of coastal towns including Accra, developed to handle the new trading activities that took place between West Africa and the Europeans across the Atlantic Ocean. Accra, being one of the major coastal towns at the heart of the booming trading activities, experienced a new urban system. The colonial administrators and the Europeans inhabited the well-planned low-density areas which were properly planned with provision for good sanitation, recreation and various spatial needs. Strict adherence to regulatory building standards were ensured and therefore, only buildings built of stone, concrete, brick and metal roofing were permitted (GSS, 2014). Due to the prevailing hot weather in Accra and Ghana in general, these well-planned low-density areas were made to have substantial greenery to make them cool and serene. Unfortunately, not much effort was made to accommodate the indigenous population in similar settlements. The indigenous population lived in unplanned areas with poor sanitation - areas described by Grant and Yankson (2002) as “mass thatched buildings arranged in a haphazard manner and separated by crooked streets. Over the years, the indigenous migrants from the rural areas also settled in the fringes or the peri-urban areas such as Nima and Accra New Town. Due to racial segregation policies by the colonial rulers, these areas fell outside the officially planned jurisdiction of Accra and as a result were unregulated. With time, these areas developed as squatter settlements which have been difficult to regulate.

Urban planning in Ghana and the major bottlenecks

A plethora of planning and urban management laws have been in place in the post-independence era. The absence of clearly defined policy direction on urban development has been the bane of the myriad of challenges that have confronted urban governance in post-colonial Ghana. The situation has further been worsened by poor institutional coordination by key government institutions such as the ministries, the metropolitan, municipal and district assemblies, coupled with the lack of enforcement planning regulations and laws. Consequently, Accra, just as several other towns and cities in Ghana, has experienced haphazard and unplanned developments, with certain precincts being fragmented (GSS, 2014).

Natural Increase

Natural population increase has undoubtedly accounted for the fast-urban growth Accra has experienced. The interplay between births and deaths determines the rate at which the population of any geographical area grows naturally such that, where births far exceed deaths, the population grows rapidly and in no time, may exceed the threshold population for an urban area (GSS, 2014). As it has been difficult to provide official residential accommodation and commercial spaces for the large number of poor in-migrants, several illegal structures such as squatter settlements, have emerged as interstices within certain parts of the city, thereby reducing green and open spaces.

Changes in land use pattern of Accra

A study by Addae and Natascha (2019) on land use pattern in the Accra area has revealed that built up areas have been expanding at an alarming rate, taking over most of the city’s open and green spaces. Through the study, it was discovered that the vegetative cover (grassland and forest) depleted substantially between 1991 and 2015. As shown in figure 2, grassland which used to be the most dominant land cover type changed from 50.5% in 1991 through 54.8% in 2000 and reduced to 46% in 2015. The same period saw the forest cover changing from 34.2% through 21.5% before reducing to drastically to 6%. It is evident from the figure that built-up areas virtually doubled from 11.8% to 20.6% between 1991 and 2000 and again from 20.6% to 44.4% between 2000 and 2015. The study further revealed that 733 ha (i.e. 0.5% of the land cover) of the bare land transformed into built-up spaces. Water bodies did not experience any significant change within the period.

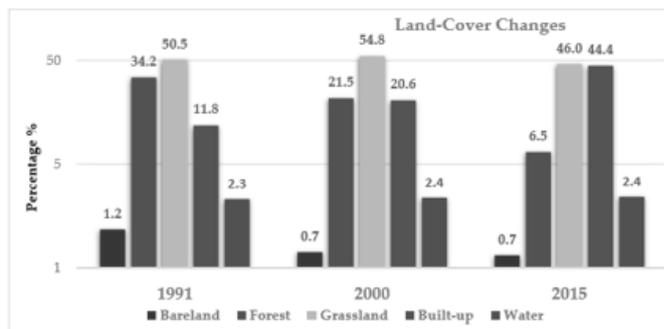


Figure 2: Land-use type percentage coverage from 1991 to 2015 Source: Addae and Natascha (2019)

Primary Data - Qualitative Findings

The qualitative data was gathered by purposively sampling local built environment professionals who are very knowledgeable in matters relating to the urbanization of

Accra as well as the research topic. All the interviewees are Ghanaians who have lived and worked in Accra for 15 to 25 years and are therefore very familiar with the city’s physical characteristics and historic land use issues. The qualitative study focused on the major causes of urban transformation in Accra in the past 3 to 4 decades. The description of each of the interviewees is presented in table 2.

Table 2: Detailed description of interviewees (Author generated)

Interviewee	Assigned code name	Years of experience	Profession	Location
01	RP/UP/01	25-30	Physical Planner	Accra
02	RP/AP/02	15-20	Architect Planner	Accra
03	RP/PP/03	15-20	Physical Planner	Accra
04	RP/ARC/04	25-30	Architect	Accra
05	RP/UP/05	15-20	Architect-Planner	Accra

The questions used were designed to allow the researcher to explore the major factors that have contributed to the transformation of the morphology of the city. The method of analysis used was “content analysis”. Findings from the qualitative study are presented under 4 main themes.

Factors contributing to rapid urban growth of Accra

This theme explored the main factors that have contributed to the rapid urban growth Accra has experienced over the past three to four decades. Whilst 50% of the participants further pointed to natural population, another 50% opined that booming economic activities of the city following the introduction of the Structural Adjustment Program in the 90’s and the discovery of oil. Interviewee RP/PP/03 added that people have just been building and the city keeps sprawling with developments which have no greenery, due to lack of development control.

Planning of Accra and its response to growth over time

This theme was meant to ascertain the effectiveness of the planning of Accra in response to the rate at which it has grown over the years. It became evident that half of the participants believed that to some extent, there were some planning policy provisions, but the pace of urbanisation and the associated developments were not well managed. While acknowledging that there are planning challenges, participant RP/UP/01 further indicated that, the transformation was an expected result of urbanisation, as there was a need for additional spaces to meet growing demands. Research participants RP/UP/01 and RP/ARC/04 opined that projections used in planning the city centre did not adequately cater for the rapidly expanding commercial activities, and in effect, the areas earmarked for residential developments had been engulfed by commercial developments. RP/AP/02 attributed the phenomenon to lack of implementation of concrete measures by the planning authorities to contain the growth of the city, subsequent to the exit of the colonial masters.

Causes of changes to green spaces in Accra

In interrogating the extent of changes to green spaces, all the interviewees were asked to shed more light on the main causes of the said changes. Research participant RP/UP/01 attributed the reduction in green spaces in the city to lack of awareness on the part of the public. He indicated that the level of ignorance among the public is so endemic that most people see trees as nuisances which should not stand in the way of developments. Interviewee RP/AP/02 on the other hand, identified the demand for mid to high-density housing as a major cause of reduction in green spaces in the core of Accra, particularly around Labone and Cantonments. This point was corroborated

by the view held by RP/PP/03. In the view of interviewee RP/ARC/04, migration of rural dwellers to Accra means that more spaces will be required for both economic activities and residential accommodation. He also pointed to the lack of implementation of planning policies as a major contributory factor to the continuous depletion of greenery in the city

Challenges with land use plan

The purpose of the question for this theme was to ascertain the main problems confronting the implementation of the existing land use of the city. Research participant RP/AP/02 indicated that various institutions that must be interested in the city's land use planning matters have over the years been working in isolation. He posited that the physical and spatial planning sector has not been working in collaboration with the road sector, and as a result, there is no harmony in the implementation of the city's land use map. He also averred that the planning authority has been developing good land use plans over the years, but implementation has always been a challenge. Interviewee RP/ARC/04 points to the phenomenon of developments done in inordinate manner as a major challenge to the implementation of land use plan in the city. He attributes the cause of the haphazard developments to lack of provision of housing for the urban poor in the planning of the city. Interviewee RP/ARC/04 further viewed the attitude of the citizenry as a big challenge, because most residents build without recourse to appropriate building materials, the adherence to building regulations, the use of qualified design and other built environment professionals.

FINDINGS

Analysis of Accra's Meteorological Data for 1987-2016

Climate data for Accra over the last 30 years (GMA, 2017) covering the Accra weather show that the period between November and early May is generally warm. Average maximum temperatures are usually above 30°C. Given that urban heat island is directly proportional to temperature, this study has focused on meteorological data from November to May. The data (GMA, 2017) for the period, January 1987 to December 1996 showed that the temperature range for November to May was 27°C to 34.5°C, while monthly maximum temperatures between 30 and 36.1 were recorded for the same months in the last decade (i.e. 2007 to 2017). It is evident that the temperature of Accra has been rising gradually over the years.

Mobile survey

For the mobile survey, important landmarks identified in the different LCZs were chosen as the monitoring points. Figure 3 shows a mapping of the routes used.

The mobile traverse covered several parts of the survey area. It started from a sparsely built area near Anyaa and moved through Awoshie, a compact low-rise area, then through Tetteh-Quarshie Interchange to Accra Airport City Park which is a compact high-rise area and various locations in the CBD. Figure 4 depicts mobile traverse measurements taken between the reference location and the CBD of Accra.

At Anyaa-NIC, which is the reference location (in LCZ9), the average air temperature and the relative humidity International were 29.5 °C and 61% respectively. The temperature increased by 0.5 °C whilst the relative humidity dropped by 3% after a ten-minute drive into Kwashieman (in LCZ3). The relative humidity further dropped by 10.5% upon reaching Shangri-La Hotel, which is within LCZ2 and in proximity to the Kotoka Airport.

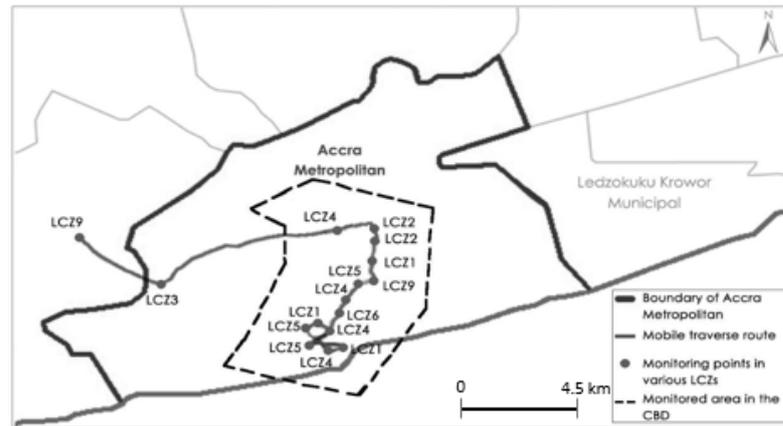


Figure 3: Map depicting traverse routes and monitoring points

At Shangri-La, the air temperature had increased to 33.5 °C, which meant that there was a significant increase of +3.5 °C from Kwashieman. The second phase of the mobile traverse covered monitoring points within the core of the CBD. The areas covered were: Airport City (LCZ1), Lands Commission (LCZ9), 37 Military Hospital (LCZ5), Jubilee House (LCZ4), Arko Agyei Interchange (LCZ6), Novotel Hotel (LCZ4), PWD (LCZ5), Supreme Court (LCZ4), Ministries (LCZ4), National Theatre (LCZ1), Advantage Place (LCZ4), Ridge Hospital (LCZ5) and the Electoral Commission Head Office (LCZ5). Using the average temperature recorded at the reference location (i.e. 29.5 °C), the urban heat island intensity (UHII) levels obtained for the various monitored locations have been plotted against the actual air temperature and relative humidity values, and these are depicted in Figure 4.

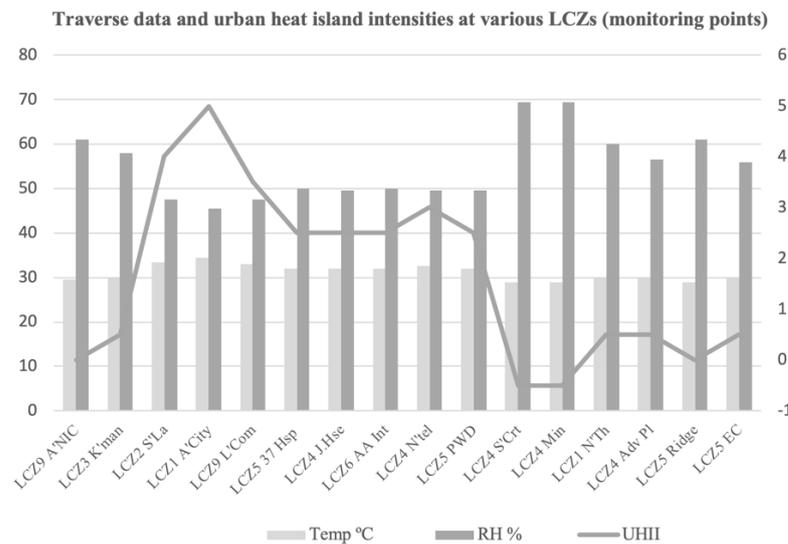


Figure 4: Graph of traverse data between Anyaa and the CBD of Accra. (Author generated)

DISCUSSION

Studies have shown that significant transformations to the physical characteristics of a city could ultimately affect its microclimate significantly. Sadly, researchers have hardly considered the chronology of events that can be attributed to such transformations. For researchers to gain in-depth understanding of the contexts they study and thus bridge research the gap, this study has assessed the phenomenon by considering both historical perspective and data from field measurements.

Although Accra has undergone significant morphological transformation, to date, most of the areas that were well-planned by the early Europeans still have green spaces which promote environmental cooling, while the peripheral areas that were abandoned created many challenges for successive governments. Findings from interviews identified a myriad of reasons accounting for the morphological transformation which include: earlier planning projections inadequately catering for expanded commercial activities; level of ignorance of public on benefits of green spaces; lack of coordination by institutions responsible for planning and developments; lack of provision of accommodation for the urban poor which has resulted in haphazard developments; inability of the planning authorities to effectively implement land use plans over the years. This clearly implies that there is a need for institutional reforms and a sustained public education on planning issues. It is evident from the studies by Addae and Natascha (2019) as well as the analysis of the 30-year climate data (GMA, 2017) that, due to continuous vegetative depletion, the climate of Accra has been changing over the years. The mobile traverse measurements showed how the effect of city's transformed morphology on the local climate. Areas with substantial greenery in most cases, recorded comparatively lower temperatures and higher humidity and the opposite was the case for areas with sparse or no vegetative cover. Consistent with Xiaofang *et al.*, (2012), mobile traverse carried out in the CBD of Accra revealed that the climate of each LCZ is significantly affected by its built-type and vegetative cover.

Due to the limited number of the weather sensors available, it was not possible to undertake stationary measurements in the different LCZs simultaneously to validate the mobile survey data. For future studies, additional sensors could be procured.

CONCLUSION

Using both secondary and primary sources, this study has revealed that factors that have contributed to the urbanization of Accra and the morphological transformations over time include: planning policies implemented during the colonial era, booming economic activities in the city, various challenges with the implementation of land use plan, others. The study has revealed that vegetative cover in Accra has depleted significantly and has mainly been taken over by built-up spaces. The quantitative study has highlighted the effect of urbanization on the local climate of the city. It is evident from the study that daytime temperatures of densely developed areas in the city (especially LCZ1 and LCZ2) are considerably higher in comparison with those of open and sparse low-rise areas (i.e. LCZ6 and LCZ9). The built-up spaces within the CBD which have substantial vegetative cover were found to be cooler than those with either little or no vegetation. There is therefore a clear indication that the transformed morphology of Accra has had a significant impact on the local climate.

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AN INTEGRATED MODEL FOR ENERGY-EFFICIENT BUILDING OPENING DESIGN

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The study uses system dynamics to develop a model that pinpoints the integration of a number of energy-efficient building practices that should be considered for building opening design. Examples are building commissioning, energy simulation, measurement and verification, carbon dioxide monitoring as well as automatic controllability. This may involve a compromise between aspects related to energy consumption, natural ventilation and lighting as well as noise control. In this regard, a stock and flow diagram are used to represent the integration of building opening design parameters, such as; orientation, window to wall ratio (WWR), glazing type and properties, cross-ventilation as well as applying daylighting controls using shading techniques. Hence, integration of design optimization techniques is performed for opening design of a residential building prototype in three different climate zones in Egypt; hot humid, moderate humid and hot arid-with 32 simulations for each location. The results indicate that the WWR provides an optimum solution while reducing energy consumption and emissions in all three climate zones. The results will assist practitioners in the proper selection of passive green building elements and techniques and the proper integration of energy-efficient practices.

Keywords: commissioning, simulation, verification, design, monitoring, control

INTRODUCTION

Any sustainable building process should aim at achieving 1) design optimization, 2) define measurement methods and benchmarks to compare performance against intended targets, 3) determine robust criteria for quality-verification as well as monitoring and feedback mechanisms to identify corrective actions (Muldavin, 2010). Hence, this study develops an integrated feedback stock and flow model to represent building-opening design parameters and their interrelations that reflect the complexity of the design problem; this includes building-opening design, orientation, material and any used shading device. This calls for an integrated view to the major role played by building-opening design in controlling indoor visual, thermal and acoustic comfort along with achieving energy efficiency and how it is practically impossible to act on one parameter without affecting others. (primary research objectives). Nevertheless, it is a challenging task for designers that necessitate viewing them as subcomponents of a larger system integration model to reach higher building performance targets as shown in Figure 1. Hence, this study uses system dynamic modelling tools to optimize building opening design using the interrelations of energy-efficient building practices (secondary research objectives). Examples are energy simulation, building

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commissioning (Cx), measurement and verification plan (M&V), carbon dioxide (CO₂) monitoring as well as automatic controllability.

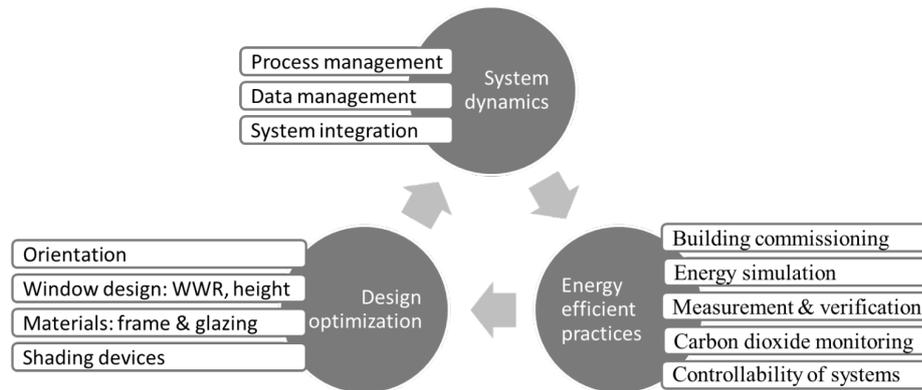


Figure 1: The conceptual approach of the research

LITERATURE REVIEW

This section presents the dual-tier objectives of the research. This includes discussing building-opening design optimization parameters on one hand and the interoperability of energy-efficient building practices for sustainable performance and data management on the other hand. Hence, an updated literature search was carried out using Science Direct database from 2010-2020. This included electronic books as well as peer-reviewed journal and conference publications. The search used the following keywords; building commissioning, energy simulation, measurement and verification process, opening design, monitoring and control systems. This outlined the different perspectives undertaken and identified relevant research gaps and limitations. It was noted that the number of relevant papers showed increased worldwide attention to the subject. It also indicated common areas with intelligent building application, daylighting and glare simulation and control as well as optimisation design for building-opening and façade designs to achieve energy efficiency.

Design Optimisation for Building-Opening Design

Previous studies pointed out the need for optimizing building-opening design to achieve a balance of multiple objectives; daylighting and visual comfort, thermal performance as well as energy savings. This included aspects associated with building-opening design as well as the ratio of window area to floor area, building location, orientation and surrounding obstructions as well as characteristics of the building envelope and glazing areas. Examples are the Solar Heat Gain Coefficient (SHGC), thermal resistance (u-value) and Visible Light Transmission (VLT); noting that high VLT and low SHGC should be achieved (Kirimtat *et al.*, 2016). Further considerations included the use of light shelves and shading devices (manual and automatic) for enhancing the efficiency of indoor light distribution and visual comfort. For measuring daylight, previous studies used Spatial Daylight Autonomy (SDA) and the Annual Sunlight Exposure (ASE) to assess visual comfort (Galatioto and Beccali, 2016).

A previous study investigated the ideal WWR for a southern facade window in an office building in Tehran through computational simulations. Then, the effect of horizontal solar shading was tested using the Ecotect and Radiance software programs. The results showed that a 5% increment in WWR of 15%, 20% and 25%

achieved a 10% incremental improvement in daylight efficient ratio and for a WWR of 30% and 60% only a 2% increase was achieved (Mahdavinejad *et al.*, 2011). Another experimental study by Choi, Lee, and Jo (2017) showed that buildings with movable shading devices stored up to 48% of the whole energy consumption.

System Thinking for Sustainable Project Management

The science of system thinking is emerging as a new approach for decision-making of issues related to sustainable buildings along their life cycle (Thompson and Bank, 2010). It allows the integration with BIM technologies and other advanced modelling software programs (Bank *et al.*, 2010). It has been used to discuss aspects related to energy efficiency. Nevertheless, the use of system thinking modelling approaches and calculation methods for building-opening design is considered a new field and the search for optimization techniques is still a work in progress.

The Interoperability of Energy-Efficient Building Practices

The use of advanced energy-efficient building practices is widely increasing in the international marketplace. These processes should not be looked upon in isolation because after all, they aim at achieving almost the same green goals but acting on different sustainable criteria or life stages. They can be applied for the whole building level or individual building elements (Ismaeel, 2020). For this research, they can be used for the process of building-opening design optimization.

Energy simulation is performed to support decisions taking place during the design stage to be able to manage the complexity of calculations and compare design alternatives. Performing the Cx process is also vital to support life cycle costs and long-term performance during building operation and management. The M&V plan provides performance feedback and adjustments. Moreover, the Post Occupancy Evaluation (POE) may also be used to consider the qualitative aspects that evaluate a buildings performance in defined time limits. CO₂ monitoring and automatic controllability are carried out during the operation stage. They may be associated with a centralized automatic control network to achieve energy efficiency while achieving indoor occupants' comfort by using real-time occupancy and activity (Muldavin, 2010).

The integration of energy-efficient building practices has been proposed by Ismaeel (2020) based on a set of criteria that have been defined by literature review and validated through an online questionnaire among local practitioners as shown in Table 1. The result showed that all energy-efficient practices are strongly related to the green building process, they are relatively easy to apply-provide the existence of proper guidelines. The study also showed that they may vary for capital cost and long-term savings; highest for energy simulation and least for M&V plans, and extra time is seen for the M&V plans. Furthermore, it showed that additional expertise is needed to carry energy simulations to develop the model and provide all necessary detailed input data, nevertheless, this process is associated with the greatest percentage error and this explains why it should be integrated with other energy-efficient practices for verification, control and feedback.

METHOD

This study aims at presenting a systemic approach for optimizing the building-opening design in terms of providing indoor visual, thermal and acoustic comfort as well as building energy efficiency as shown in Figure 2. This investigates different

parametric design variables based on previous literature; orientation, Window to Wall Ratio (WWR), glazing type and properties (light transmittance, G-value and U-value), cross-ventilation as well as applying daylighting controls using shading techniques.

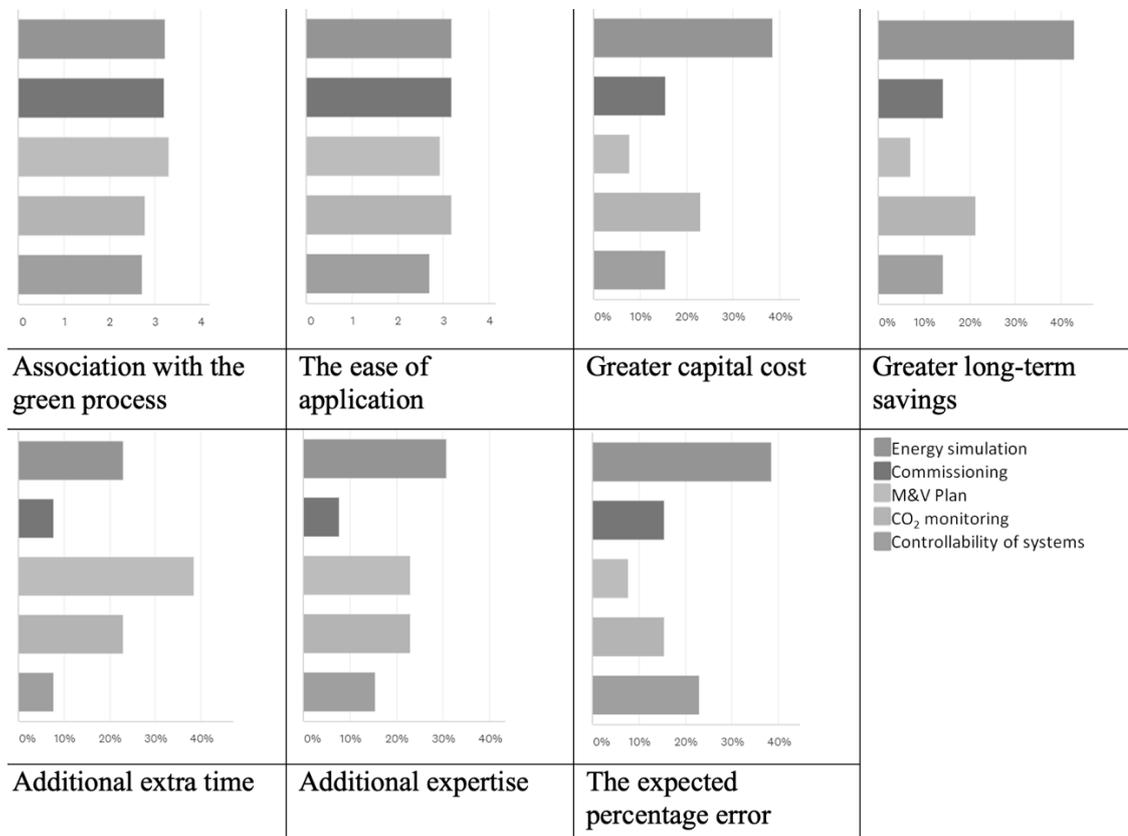


Table 1: Investigating the integration of energy-efficient practices (Ismaeel, 2020)

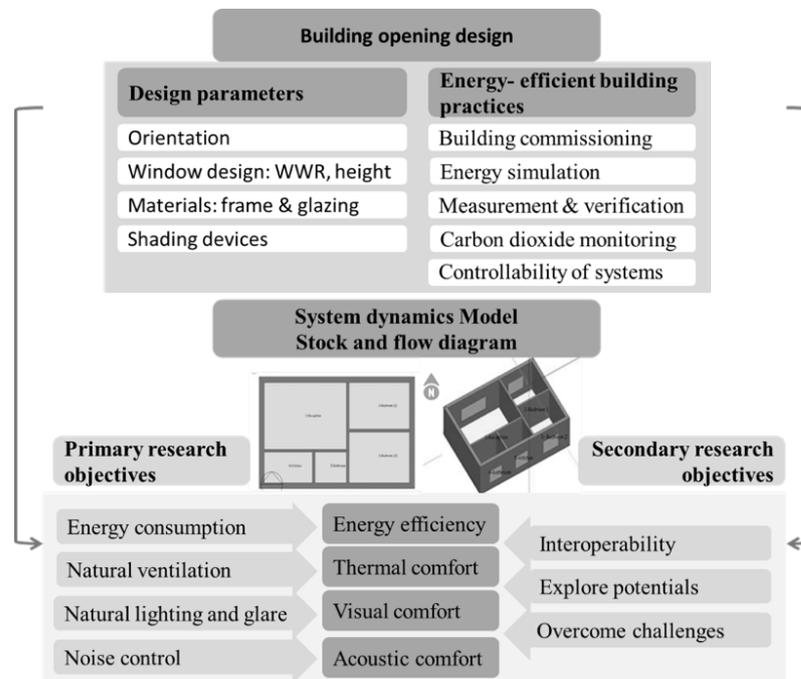


Figure 2: The research methodology

To calculate the total energy consumption (kWh) and indoor temperature (°C), the building simulation tool (Design Builder) is used which operates based on the Energy

Plus-version 7.2; noting that the latter is a validated simulation tool that performs heat-balance models to calculate buildings thermal performance.

It allows for an hourly-calculation of operative temperatures and space-heating demands based on accurate solar radiation analysis (DesignBuilder, 2020). Moreover, the DIVAs scripting interface was used for radiance analysis to be able to calculate the daylight factor, and annual SDA and ASE (Kröner *et al.*, 1990). Radiance software was developed in the Lawrence Berkeley national laboratories and validated against real measurement (Radiance, 2020). It is also noted that the rates of natural ventilation in non-air-conditioned residential buildings were calculated according to the Egyptian national code for improving energy efficiency in residential buildings. The simulation was repeated for three different climate zones (with 32 simulations in each location); hot humid (C1), moderate humid (C2) and hot arid (C3) to test the combination of different design parameter and indicate the optimised case scenario.

The building model is a typical example of a modern single-story family residential unit (according to national building codes and local building regulations). It is 3 m height (floor to floor) which includes one reception, two-bedroom, kitchen and bathroom with a total area of 50 m²; reception area 3.6x4.2 m, bedroom (1) 3.1x3.2m, bedroom (2) 3.2x3.6m, bathroom 1.8x1.5 m and kitchen 1.5x2.6m. It represents local materials and best practices. The 25 cm brick external wall is externally finished with 2 cm lightweight plaster and 2 cm cement mortar. It is internally finished with 2 cm cement mortar and 20 cm sandstone. A single glazing of 6 mm clear glass is used. Furthermore, the roof is composed of 12 cm reinforced concrete layer, 7 cm cement paste, insulated by 5 cm cork layer and 2 cm damp proof course (D.P.C.), covered by 10 cm sand, 2 cm mortar and 2 cm cement tiles. Also, the infiltration rate is set at 1.25 air changes per hour and the light power density is 21 W/m². Table 2 describes the model design parameters.

The results of the energy simulations require further checking using the Cx process to avoid common design errors, construction mistakes and defective equipment, as well as monitor its basic operation, and maintenance process. This raises the quality assurance process and provides better documentation for the performance of the building opening design and its contribution to the overall building performance. Then a more comprehensive check is provided as part of the M&V process to take any required amendment actions and provide continuous monitoring and feedback mechanisms.

The next step applies the science of system thinking to represent the complexity of optimising the building opening design process and the effect of interacting parameters. Hence, a stock and flow data-processing diagram is developed using Vensim PLE 7.1 software to act as an efficient method of defining the interrelations and problematic areas for the building model with the following deduced integrative index as shown in Table 3 referring to Ismaeel (2020).

This shows the limits of the study boundary, subsystems and causal effect interrelationships for an improved understanding of all associated design parameters. Putting them in a larger system model shows design complexities and their effect on the state of building opening design efficiency through feedback loops which rises as a result of their internal structures and governing decision rules.

This conveys information on the limits of the study and level of aggregation by showing the number and type of different sustainable parameters and provide a useful exploratory for viewing buildings as systems.

Table 2: Building model parameter variations

Parameter	Variations
WWR	20% and 40%
Glazing type	Single (u-value) Double (u-value)
Cross-ventilation	Single opening Double opening with the same heights Double opening with different heights
Shading type	Applying shading device No shading device applied
Orientation	North, South, East and West

Table 3: The deducted integrative index of each discussed green building practice, (Ismaeel, 2020)

Variables	Energy simulation	Cx	M&V	CO ₂ monitoring	Systems' control
Association with the green process	3.23	3.20	3.31	2.79	2.71
Ease of application	3.17	3.17	2.92	3.17	2.69
Long term savings	4.20	1.40	0.70	2.10	1.40
Capital cost	3.80	1.50	0.77	2.30	1.50
Extra time	2.30	0.77	3.80	2.30	0.77
Additional expertise	3.00	0.77	2.30	2.30	1.50
Expected error	3.80	1.50	0.77	1.50	2.30
Total integrative index*	0.31	1.46	0.40	0.60	0.74

$$* \text{Total integrative index } f(x) = \frac{\sum_{L3i=1}^n x_{L3i}}{n} - \frac{\sum_{L4i=1}^k x_{L4i}}{k}$$

RESULT

The study discussed the use of system dynamics to develop an optimization model for building opening design. This included energy-efficient processes and practices such as energy simulation, Cx, M&V plan, CO₂ monitoring and automatic controllability. The results showed a proposed optimization model exploring their interrelations through a stock and flow data-processing diagram to optimize building opening design as shown in Figure 3. The results showed dual-tier benefits for building-opening design parameters on one hand and the interoperability of energy-efficient practices on the other hand. The influence of modifying design parameters was discussed as follows;

The effect of changing the WWR

For visual environment and natural ventilation rates, daylight was directly proportional with the opening size in simple relation, hence, the duplication of the size leads to duplication in average daylight factor. For thermal performance, the average temperature increased by 1°C when duplicating the opening size. For energy consumption, it is found that duplicating the WWR from 20% to 40% lead to an increase in energy consumption. The east and west-oriented spaces were the greatest

in energy consumption, followed by the south and north ones. Hence, the results showed that changing the WWR from 50-20% did not significantly reduce the cooling loads but daylighting levels were significantly reduced.

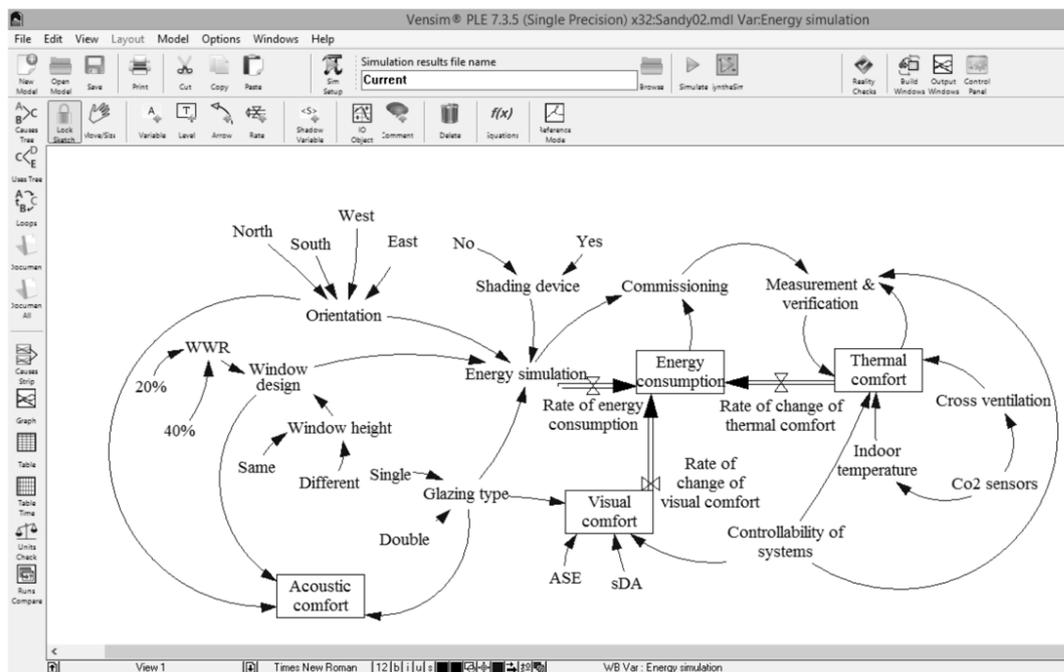


Figure 3: The Vensim model showing a stock and flow data-processing diagram to optimize building-opening design

Shading devices (overhangs, side fins and louvres)

the total cooling loads showed that side fins did not reduce cooling loads significantly but overhangs had a substantial impact of (18-20%) reduction for C2 and C3; and louvres had their greatest impact in C3 (14%) which was west-oriented, then C2 (11%) which was south-oriented and the case of using louvres recorded the largest impact reduction in daylight levels.

The glazing properties

The total cooling loads showed that double-glazing did not have an evident impact on load reduction. Using double low-E glazing had a greater impact on loads, especially in C2 and C3 (6-8%). Finally, using single glazing with low solar transmittance factor had the greatest impact on reducing loads, especially in C2 and C3 (14-15%).

Then, computer modelling, and simulation techniques were integrated with optimization methodologies to offer opportunities to evaluate multiple criteria design decisions. Nevertheless, the accuracy of energy simulation models was bound to the range of data input which may not be accurate at early design stages. This gives inaccurate indications concerning building performance. Thus, the Cx process is important to carry validation and verification checks and performance tests. This is in addition to creating archived O&M manuals and schedules as well as warranties and datasheets. Nevertheless, the expected risk arises from the lack of generally accepted industry guidelines and standards (Harmer and Henze, 2015).

The M&V process provides regular and long-term savings to the building; nevertheless, this may require installing building automation systems. Some of the problems with applying the M&V plan include lack of past utility data, building-level

utility meters or other means of following-up after project completion, this is in addition to the lack of energy management control systems (Harmer and Henze, 2015; Granderson *et al.*, 2016). The result indicates great commonalities between the aforementioned practices; in sharing system-energy data and engineering-saving assessments; noting that the data collected for the Cx process may act as input data for the M&V plan and provide a reference to check the operational verification and energy saving calculations of the energy model.

The M&V should optimally begin during the Cx process to validate its procedure. The Cx process requires performing trend-analysis to test equipment functional operation after they are installed and including CO₂ sensors calibration in both the Cx and M&V plans. This is associated with the M&V operational verification requirements and indicates that applying system integration is the key to attain better performance targets (Komínek, Weyr and Hirš, 2017).

DISCUSSION

The role played by building opening design is significant to achieve energy efficiency as well as occupants' comfort and productivity. The study discussed its complexity for a residential building- which accounts for 60% of building stock in Egypt (ElGohary and Khashaba, 2018). The result provides dual-tier benefit; it can be incorporated in local building laws and codes, furthermore, it may assist practitioners for the proper selection of passive green building elements and techniques. This stresses the need to develop practitioner's knowledge concerning system thinking and application.

CONCLUSION

The study applies system thinking and modelling approach as a basis for providing an integrated approach. It develops a stock and flow data-processing diagram to optimize building opening design. Design parameters included WWR, orientation, glazing type and properties, cross-ventilation as well as applying daylighting controls using shading techniques. The model was applied on a case study-residential building-in three climate zones in Egypt- showing that changing the WWR provided an optimum solution while reducing energy consumption and carbon emissions in all three climatic zones.

This put forward a systemic approach to achieve energy efficiency as well as thermal, visual and acoustic comfort. Nevertheless, it is a challenging process particularly with the several variables in hand and their dynamic and implicit interactions. Hence, the author presented fresh perspectives and insights of using system integration of several green building processes and practices that shared a common aim of maximizing energy savings and showed the interoperability of these practices in wider building management plans and applications, these include building commissioning, energy simulation, measurement and verification, carbon dioxide monitoring as well as automatic controllability. This should be considered during early project stages to create an iterative process of joint-inquiry and develop novel comprehension of the dynamic complexity of its interrelations.

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EXPLORING THE IMPACT OF ALCOHOL ABUSE ON CONSTRUCTION SITES IN SANTO DOMINGO, DOMINICAN REPUBLIC

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The construction industry in Santo Domingo, Dominican Republic grapples with problems of unregulated and harmful alcohol consumption by workers and this directly have an impact on workplace safety. This study fills the gap in literature related to the harmful consumption of alcohol by construction workers and the need for policies to be implemented that could regulate harmful alcohol consumption amongst construction workers in Santo Domingo. A qualitative approach using purposeful sampling was adopted to evaluate the perception of workers in the construction sector. A total of 12 in-depth semi-structured, open-ended interviews with workers undertaking different roles were conducted until saturation. The initial findings suggest that alcohol is used as a coping mechanism by workers to deal with situations related to financial, emotional and personal difficulties. It also indicated that heavy drinking is not considered as an addiction, but as part of the cultural norms, habits and way of living. Although instances of harmful alcohol use link with incidences within the workplace; there are no formal regulations in place to encourage, mitigate and educate workers within the industry. Rather, offenders are casually dismissed off site only for them to get back on to the project next day. To achieve meaningful change, adopting formal policies and procedures, involving stakeholder collaboration, education and raising the awareness and the impact of harmful alcohol consumption should be considered. The limitation of this study was the lack of access to a more diverse participant base due to the sensitive nature of the topic. This initial study is a precursor for further in-depth investigation.

Keywords: Alcohol, health and wellbeing, safety, Santo Domingo, safe working

INTRODUCTION

The economy of Dominican Republic (DR) mainly relies on free trade zone industry, tourism and construction (Nowak, 2018). The construction sector experienced major growth in the 1990s and over the years, it has remained consistent, dynamic and with high retention of migrant workforce (Petrozziello, 2012). The consumption of alcohol in the DR is perceived as a normal way of life with resulting consequences of the alcohol-influenced behaviour sometimes overlooked and this is also analogous to other Latin American regions, (Pan American Health Organization, 2007).

The construction industry in DR is perceived to adopt a similar ‘not much of a problem’ approach around issues involving alcohol misuse and this can have

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detrimental impact; irrespective of geographical location of workers this often lead to irregular working schedules, mental health of workers, lack of workforce engagement and work-related accidents (Roche, *et al.*, 2012; Ntili, *et al.*, 2015; Shield *et al.*, 2015; Lawani *et al.*, 2019). Issues related to global excessive consumption of alcohol which often result in significant risk to the health of individuals has been at the forefront of The World Health Report (Monteiro, 2007). The work of Sherratt (2018) indicated that the levels of stress, the occupational norms and workplace issues could translate into high levels of alcohol abuse, smoking, overeating and drug use. These aforementioned characteristics coupled with availability of substances; a significant time and distance working away from families; and economic concerns place construction workers in a cycle with these unique risks (Roche *et al.*, 2012; Ntili *et al.*, 2015).

In the Americas, the excessive consumption of alcohol is significant for countries ranked as low and middle income. For developing countries such as the DR, the perilous volume of alcohol consumed and the harmful patterns of use has become a health and safety related burden, with minimal or non-existing legal enforcement (Monteiro, 2007). However, the UK that previously adopted rigorous enforcement-based safety approaches on construction sites is gradually moving towards safety-culture programmes (Sherratt *et al.*, 2013) as well as management systems designed to mitigate hazards in the workplace; whilst in developing countries, safety implementation and initiatives are not always a top priority (Dorji and Hadikusumo 2006). Putting Santo Domingo into context, there are still some unknowns in terms of the worker's perception regarding the need for treatment for alcohol misuse; and there is a dearth of studies conducted in the Americas and DR regarding the impact of harmful alcohol consumption and the workplace (Cherpitel, *et al.*, 2013; Edlund, *et al.*, 2009).

The Blurred Line Regarding Alcohol Misuse in the Dr Construction Sector

Alcohol and illicit drug use have formed part of people's lives as an alternative to alter mood and as well as being part of certain customs or cultures (Mushi and Manege, 2018). The construction industry has consistently and statistically significantly ranked very high for illicit drug and alcohol use when compared to other industries (Tan and Lloyd, 2016), with male-dominated industries presenting the highest levels of alcohol misuse. Additionally, alcohol represents the most used and abused psychoactive substance by construction workers, with the sector having one of the highest rates of heavy alcohol use (Bush and Lipari, 2015; Rajeshkannan, *et al.*, 2018). Mushi and Manege (2018) identified motives behind the consumption of alcohol and drugs and that these are directly or indirectly related to the workers themselves. The construction site is considered as a high-pressured, high-hazard work environment and any likelihood of worker impairment can have significant consequences on the worker and those involved on the project site. The very nature and pressure of construction work, including coming in contact with hazards on a daily basis (Biggs and Williamson 2012), are some of the resultant factors that could trigger workers getting involved in excessive alcohol consumption.

Although Ntili, *et al.*, (2015) highlight that alcohol abuse can be swayed by attitudes, beliefs, social patterns, affordability, acceptability, advertisements and its availability; the World Health Organization (WHO) identified that harmful consumption or use, can damage the health and social environment of the drinker and those around, such as family, friends, and co-workers (Flannery, *et al.*, 2019). In the Americas, drinking is linked to social-cultural activities like social gatherings, and alcohol consumption is

also vital to closing out deals with profound cultural roots, beliefs and customs (Japal and Benoit, 2017). McIlwaine and Moser (2004) revealed that the level of acceptance of alcohol in Colombia mirrors the common trend in Latin America, where it forms part of the life of individuals and the social activities of communities. This is however in stark contrast with the use of drugs which is seen as shameful, whilst heavy drinking in large quantities in short periods or binge drinking is interpreted as a norm.

The adult per capita consumption of pure alcohol in the Latin American region has been on the increase since 1961; an average of 7.14 litres over a calendar year above the world average of 6.1 litres, (Cherpitel, *et al.*, 2013; Shield, *et al.*, 2015). The health burdens related to excessive use of alcohol or illicit drug use affect all stages of life; resulting in multiple ill-health conditions, violence and risky health and safety behaviours (Delker, *et al.*, 2016). Alcohol consumption is considered as significantly problematic in Latin America, accounting for an incremental rise in the number of early death and disabilities; and with over 200 diseases and disabling conditions (Dohn, *et al.*, 2014; Japal and Benoit, 2017). However, the trend of alcohol intake has not been extensively investigated for the DR; where levels of consumption over a calendar year (94% beer and spirits) has seen a sharp rise from an average per capita of 1.18 litres in 1961 to 6.70 litres in 2010 and 6.90 litres of pure alcohol in 2016 according to WHO. The World Health Organization (WHO) and the Pan American Health Organization (PAHO) indicate that the DR has higher number of men experiencing long-term risk associated with alcohol consumption as well as being one of the countries with the highest percentages for women in the Americas. Also, DR has no national policy or action plan regarding mitigating the use of alcohol; no restriction for on or off-premise sale of alcoholic beverages; no legally binding regulations on alcohol advertising or product placement and no legally binding regulations on alcohol sponsorship or sales promotion. Therefore, work-related pressure resulting from extended and long working hours, long commute to job sites, meeting tight deadlines, lack of job control or autonomy, excessive and conflicting demands, inadequate training, poor working conditions, and the temporary nature of projects and employment all impact on construction workers based on the ever-changing and rising levels of work-related stress in the sector (Dohn *et al.*, 2014; Japal and Benoit, 2017; Flannery *et al.*, 2019).

Ntili *et al.*, (2015) shows that although there are multiple root-causes regarding alcohol abuse, the consumption of alcohol by construction workers is often as a substitute for coping with the challenges of their work environment. Flannery *et al.*, (2019) also identified how the workplace can influence alcohol use as a coping mechanism and concluded that one in three men traced their poor mental health to the stress and pressure related to the workplace and the 'macho' attitude in the work environment. Sherratt *et al.* (2017) evidenced that construction workers have a tendency to smoke, use illicit drugs and harmful use of alcohol with higher than average rates compared to other industries, and these can be directly related to absenteeism, presentism, interpersonal conflicts, job turnover, poor performance and reduced productivity (Kenley *et al.*, 2012). The consequences of excessive alcohol consumption can result in short-term behavioural, cognitive and physical changes; including symptoms like slurring, diminished hand-eye coordination and reaction time, lack of consciousness, reduced perception, lack of attention and coordination and all these factors can increase the possibility of workplace injury for the individual, work colleagues or the public (Foster and Dissanaik, 2014). Despite the possible link between alcohol abuse and the risk of injury on worksite, studies intended to reaffirm

this relationship using samples from multiple nations have posited no relevant connection between substance use and traumatic injuries in the workplace, (Veazie and Smith 2000). However, global policies such as the Sustainable Development Goals of 2030 and the World Health Organisation's Global Target strategy intends to confront the harmful use of alcohol by increasing the prevention and mitigation of alcohol abuse through the following objectives - incorporate increasing taxes on beverages, enforcement of restrictions on marketing and promotion, the implementation of restrictions on the availability of liquor and advocating for policies by the respective society.

Rationale

The construction industry is among the top three contributors to the DR's economic growth with 10.6% in 2018. Santo Domingo (capital of the DR) is a thriving city, with the construction sector being one of the net employers of labour and currently boosting the country's economy. However, construction work in Santo Domingo as in other developing countries is very much unsafe and unregulated coupled with other inherent health and safety risks associated with construction projects. Despite studies alluding to the possible harmful effects of alcohol in terms of health and safety in the construction sector, the levels of liquor consumption per capita in the DR exceeds the average global standards and research is needed to address this paramount issue in construction. This study explores the impact of alcohol consumption on daily tasks on construction sites in Santo Domingo and the initiatives in place to mitigate against the effects. Therefore, this study addresses the following objectives: investigating the leading indicators of harmful alcohol consumption and impact on construction sites; evaluating the effects of alcohol and safety on construction sites; and examining policies or strategies in place to mitigate the consequences on construction sites.

METHODOLOGY

To adequately contextualize this study, it was ideal to address it through the lens of the construction workers (different job roles) based on their perception of the industry and the impact on job site safety. The study adopted qualitative phenomenological approach focusing on how participants understand and attribute meaning to specific events (Creswell, 2014; Creswell and Poth, 2017; Creswell and Creswell, 2018). The phenomenological interpretive approach was implemented to collect the data necessary to explain the phenomena of alcohol consumption of construction workers from the viewpoint of the workers. This approach describes the lived experiences of a phenomenon for single or several individuals (Creswell, 2013) by conducting interviews with workers in Santo Domingo regarding harmful consumption of alcohol. This type of description concludes in the core of the experiences of the workers that have experienced the phenomenon of alcohol abuse. A qualitative approach was adopted by collecting data within an informal setting within the workplace. The study readapted and used the World Health Organisation Alcohol Use Disorders Identification Test (AUDIT) questions and the work of Ntili, *et al.*, (2015) on the impact of substance abuse in construction to develop a semi-structured interview for workers in Santo Domingo.

Sampling

Qualitative research method was employed to research the causes, effects and strategies in place regarding harmful alcohol consumption in the construction industry. Purposive non-probability sampling strategy was adopted as the most appropriate to ensure standardized job profile for participants working in Santo

Domingo construction sector and also due to the sensitive nature of the topic under consideration (Creswell, 2014; Creswell and Poth, 2017). Access to participants was facilitated through industry contacts, adopting convenience sampling. It was important not just to identify individuals that work in the construction industry, but those willing to share their perception on the issues of harmful alcohol consumption in Santo Domingo as well as proffer insight into the current measures in place to mitigate substance misuse in the industry. The participants held management and technical positions and their understanding of the subject matter, perspective of the causes, impact and sensitivity of the issue made them ideal participants. Getting labourers involved in this study proved difficult as employers were not willing and committed to free up time for the labourers to participate.

Semi-Structured Interviews and Data Collection

The adoption of the phenomenological study involves different data collection strategies predetermined by either the type of interview or the use of non-numeric data analysis (Creswell, 2014; Creswell and Poth, 2017). The study collected information based on the perception of the individuals regarding harmful alcohol use. The in-depth semi-structured, non-leading open-ended interview was the most suitable approach to enable the gathering of relevant information on the issue and to allow the exploration of a sensitive topic through the eyes of the participants. The interview was developed and implemented following a logical order to enable participants offer their perceptions on the issue. It is important to state that the native speaking language in the DR is Spanish and the interviews were all conducted in this language as participants felt more comfortable being engaged in their native language. The interview questions were translated from plain English to Spanish, while the interview responses were transcribed and translated verbatim from Spanish to plain English by the researcher who is bilingual. The interviews involved participants within the technical and managerial positions, such as foremen, supervisors and field engineers with a minimum of two-years construction site experience in Santo Domingo. A total of 12 in-depth interviews were conducted with the participants until saturation (Charmaz, 2014). At this point in the interview process, no new information emerged from the interviews, and responses led to the same conclusions with recurring keywords. The interviews lasted from 20 to 35 minutes, with each individual interview an average of 25min of which harmful alcohol consumption was the main subject. Each participant was requested to willingly review the transcribed texts for accuracy after the interview phase.

FINDINGS

Harmful alcohol consumption is widespread in the Latin American countries and there is dearth of studies specific to the DR, and in particular to workers in Santo Domingo construction industry. This exploratory study acquired primary data using interviews with participants having between two and 30-years hands-on construction site experience in Santo Domingo, see Table 1.

The interviews related to the causes of harmful alcohol consumption revealed that workers rationalised their consumption of alcohol stating that it helps them forget their financial, emotional and family issues. Other responses from workers identified issues associated to the amount of work-related pressure and stress, and Ntili *et al.* (2015) alluded to this same idea that workers use substances such as sedatives to deal with the high levels of stress, financial situations or past traumas.

Table 1: Role and years of experience of participants

Job Role	Experiences in Years
2 Site Project Manager/Civil engineers	4 and 3
2 Foremen	21 and 8
1 Plumber	25
1 Floor polisher and cleaner	10
3 Project supervisors	6, 3, and 3
1 Project Inspector	2
1 Civil Engineer/ Supervisor	3
1 Civil Engineer	30

Leading Indicators of Harmful Alcohol Consumption and Impact on Construction Sites

The interviews indicated that workers use alcohol as an alternative ‘to clear their minds’ while some consume harmful alcohol to deal with workplace resentments, to relieve work-related stress, and for general relaxation. It was also clear that not all participants identified alcohol consumption as harmful or negative, by highlighting that people drink ‘to have a good time or simply because they like the taste’, and most importantly, it is part of their culture. The workers associated alcohol consumption as part of the custom of DR and personal lifestyle choice, which ties with the work of Mushi and Manege (2018) regarding the direct causes for alcohol consumption, relating it to traditions, customs, lifestyle or peer pressure. The participants acknowledged that heavy or harmful drinking is a common occurrence in the construction industry, however, majority of the participants overwhelmingly do not consider if heavy drinking represents or should be classed as an addiction problem that needs intervention.

...the consumption of alcohol is an acceptable part of the lives of workers after work hours, which means that as long as this activity is done outside work hours, it is not a matter of concern for employers.

The feedback from the interviews revealed that issues around accident causation, worker performance and productivity impairment, and physical wellbeing resulting from harmful alcohol consumption was not considered as managements responsibilities because workers indulge in such activities outside of the work environment. Also, the growing evidence over the consumption of alcohol amongst construction workers in Santo Domingo and its impact on site safety are not particularly considered as managements primary responsibilities. The consequences of this in-action could pave way for management to blame workers for wider issues related to job site management failures, but this could also indicate the lack of genuine benevolence from management (Frederick and Lessin, 2000; Lawani *et al.*, 2018).

Evaluating the Effects of Alcohol and Safety on Construction Sites

Participants agreed that consistently overindulging in harmful alcohol consumption could impact on the safety and health of construction workers, with consequences on cognitive performance related to issues that affect productivity and site safety. Ntili *et al.*, (2015) identified that substance misuse can potentially lead to health hazards and a danger to the lives of other construction workers which is similar to the case of harmful alcohol consumption.

...fainting during working hours due to dehydration caused by excess alcohol intake”, was an example cited by a project supervisor as a condition that is quite common with some particular set of workers.

A few days ago I had a worker who was vomiting, although the reality is that he usually gets to work under the influence of alcohol and because of this, he puts the job/the company in a bad position because he fails to fulfil his requirements on the necessary amount of days and delay the general schedule. The truth is, he works well, and he's mostly a Monday drunk.

Some of the participants indicated that the recurrence of this type of case is often overlooked mostly when it involves a worker that is exceptionally skilled in specific craft and executes quality work. Such actions from a worker could potentially jeopardise on-site safety and productivity, and such intoxicated workers are simply told to “come back to job site the next day” and then pressured to complete their task to maximise lost time and to meet deadlines. Participants also identified that workers that are hung-over often display signs associated with difficulties in task completion and this could result in even more complex social consequences, like the increased probability of making mistakes and exposing other workers to harm, (Schofield *et al.*, 2013).

Examining Policies or Strategies to Mitigate the Consequences of Harmful Alcohol Consumption

The participants identified the lack of adequate strategy, and the inconsistency in terms of policies and enforcement on construction sites regarding addressing alcohol and drugs related issues.

Although it is not a mandatory practice, some companies do random testing to check for alcohol consumption; however, most testing usually occur when there is already a case of intoxication and not as a measure for prevention.

There is conflicting evidence regarding alcohol testing, e.g., the British Medical Association identify that despite random testing becoming a common practice in the United Kingdom and the United States, its benefits in terms of reducing occupational injuries are still uncertain.

Some project sites in Santo Domingo adopt an approach where:

Every foreman, before work begins visually assess their workers so that none of them enter the construction zone under any apparent influence of alcohol.

This policy of assessing workers acts as a deterrent to those under the influence of alcohol from entering the job sites and not exclusively leading to sanctioning or dismissal. There are no regulatory or legal limit regarding alcohol consumption in DR, but with the influx of migrant construction workers from Haiti, the participants agreed that they have experienced fewer cases of worker intoxication on site which they associated to the migrant workers' culture or religion. The participants established that there are currently no unified formal management measures or procedures adopted by the industry to curtail or control the misuse of alcohol by construction workers. However, very few companies are beginning to independently implement random use of breathalysers or random blood testing to ensure that workers enter the site sober, and that a system of consequences or penalties for the individuals that violate the regulations should be in place whilst raising awareness and providing education.

First, raise the worker's awareness of the danger of working under the influence of alcohol and give them workshops on the negative effects of alcohol on the work area...

Behavioural-based safety initiatives (Frederick and Lessin 2000) or programmes that can educate or raise the awareness of the impact and consequences of harmful alcohol consumption should be introduced in a number of ways during pre-employment (proactive), post-accident (reactive and lessons learned), randomly, or because of reasonable suspicion, (Schofield *et al.*, 2013), with the aim of mitigating harmful alcohol use for current and future workers.

CONCLUSION

Research on the theme of alcohol abuse by construction workers in Santo Domingo is rare. Although the consumption of alcohol is considered as part of the culture and customs of DR, the introduction of higher taxation or minimum pricing unit for alcohol and tighter availability restriction measures like limiting alcohol sale outlets and their opening times and minimising prime time advertisements are measures capable of influencing consumer behavioural change. The consumption of alcohol in DR is generally seen as a social way to relax or for people to psychologically escape from their personal issues. However, harmful consumption behaviour comes with burden of disease and introducing policy options such as increasing the minimum age to legally buy and consume alcohol might be an effective way to minimise long-term health, wellbeing and safety impact. Working under the influence of alcohol can affect task quality, reduce performance and potentially increase the likelihood of an accident happening within the workplace. Therefore, the management should reassess their safety and engagement practices that encourage and grant unhindered access to job site without penalties just because workers under the influence have valuable trade skills. Such actions could pose a major safety risk to other workers and the cost of alcohol-related accident far outweigh the cost of getting the job done. There are no formal alcohol policies regarding alcohol misuse for construction companies to adopt and even if there are, such policies take time to develop and to be unanimously adopted. Few organisations have measures in place to assess workers for alcohol consumption at the start of a shift and to prevent unsafe behaviours and improve site safety; these type of screening measures being introduced have no immediate intervention actions for workers considered as needing treatment for alcohol dependence or harmful use. Also, construction workers rarely undergo any form of education or training on health, site safety and psychological wellbeing and the introduction of initiatives that could promote these would be immensely beneficial to workers. The limitation of this study is that the findings cannot be generalised and may not represent the entire Santo Domingo. However, the findings could serve as a roadmap to further initiate a holistic and more extensive set of participants from multiple jobsite across DR. The sensitive nature of the topic being investigated could also lead to particular bias or reservations from participants involved in the study.

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CONCEPTUAL MODEL FOR MANAGING MENTAL HEALTH IN THE CULTURALLY DIVERSE CONSTRUCTION WORKFORCE

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Construction workers are exposed to a plethora of stressors which may cause psychological problems. Meanwhile, in the context of globalization, there is a growing trend of diverse culture within the construction industry which may aggravate the mental health issues of construction workforce. Therefore, to better address the mental health issues in a multicultural workplace, the impact of cultural-related factor should be considered. However, how construction workers' mental health is influenced in a multicultural context remains unclear. Thus, there's a need to investigate the major determinants of mental health so as to reduce workers' psychological issues in the culturally diverse worksite. The aim of this research is to develop a conceptual framework of mental health for the multicultural construction workforce. Literature review was adopted as the research method to lay a solid theoretical foundation for the development of the conceptual framework. This study was grounded in the transactional theory of stress and coping. Cultural coping models were employed to justify the incorporation of cultural-related factors. Conceptualisation of intercultural coping was based on the tripartite model of attitude and intercultural competence model. The occupational stress model identified the sub-dimensions of personal and work stressors. Hypotheses regarding the relationships between the main factors were proposed and measurements of each items were determined. The conceptual model may contribute to the knowledge of mental health management in a multicultural construction workplace and provide an effective framework for workers to manage their mental health.

Keywords: workforce, coping, cultural diversity, mental health, stressor

INTRODUCTION

The construction industry is acknowledged as a stressful, challenging, and risky work environment (Loosemore *et al.*, 2010). Against the background, construction workers have constantly experienced a variety of mental health problems, such as anxiety, stress and depression (Lingard and Turner 2017). In the UK construction industry, around 70% of construction professionals were reported to have suffered from job-related stress, anxiety or depression (CIOB 2006). Similarly, about 55% of the UK construction labours in the worksite were found to have undergone mental health disorders, and 42% of the mental illnesses were work-related (Alderson 2017). Accordingly, the mental health issues have brought about a series of severe consequences in the construction industry. Construction workers' suicide rate was 3-7

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times of the industry average rate during 2011-2015 in the UK (Burki 2018). The project productivity and company profit would also be affected (Wong *et al.*, 2010). In the UK, there are £40 billion losses of the organizations and £25 billion losses for the government per year resulted from the mental health issues (Stevenson 2017). Given the prevalence of mental health problems and the severe consequences they bring, it is of great significance to develop effective coping measures to improve mental health in the construction industry.

In the context of globalization, there is a growing trend of workforce diversity in the construction industry where numerous transnational conglomerates emerge with migrate construction workers from various cultural backgrounds in the worksite (Findler *et al.*, 2007). For instance, in the UK, non-UK nationals accounted for 40% (70,000) of the construction of buildings workforce in London (Office for National Statistics 2018). The construction industry has thus become one of the most culturally diverse workplaces (Wong *et al.*, 2010). However, the increasing trend of cultural diversity in the construction workforce brings about new and complex challenges in terms of accommodating workers' requirements, interests and habits in the work environment, thus may lead to a variety of mental health problems (Pasca and Wagner 2011). The Hofstede model indicated that how construction workers manage their mental health issues is influenced by their national culture (Hofstede 2001). Besides, the cultural differences derived from national culture have a significant impact on an individual's perceptions and reactions to mental health problems, and the coping measures adopted by construction workers (Wong *et al.*, 2010). Furthermore, Torres and Taknint (2015) suggested that stressful events resulted from cultural diversity may cause more critical psychological illnesses if not managed correctly. Therefore, in order to develop effective coping strategies to ameliorate the mental health of construction workers, the impact of cultural diversity should be considered. However, currently there is a paucity of work on improving construction workers' mental health in a multicultural construction workplace. Therefore, it is imperative to investigate the major determinants of mental health in a culturally diverse construction workforce so as to reduce workers' psychological issues. The aim of this research is to develop a conceptual framework of mental health for the multicultural construction workforce.

LITERATURE REVIEW

Coping theory

The transactional theory of stress and coping developed by Lazarus and Folkman (1984) is the most prevalent and frequently adopted theoretical approach to studying psychological stress and coping across multiple fields (Nel and Spies 2019). It has been modified and evolved by Lazarus and his colleagues over a long period of time. This theory depicts the entire cognitive process of stressors-coping-adaptational outcomes, including the antecedents (personal and situational stressors), mediator variables (appraisal and coping) and outcomes (immediate and long-term physical and psychological consequences). In this model, psychological stress refers to “a relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being” (Lazarus and Folkman 1984: 21). Coping is defined as “the person’s constantly changing cognitive and behavioural efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the person’s resources” (Lazarus and Folkman 1984: 141). Therefore, when the stress is appraised as exceeding the individual's resources and adverse to his or her well-being, coping is needed to

address the stressful events. Coping thus plays a crucial role in moderating the relationship between negative events and psychological health issues in a particular person-environment transaction (Folkman *et al.*, 1986). Coping is divided into two categories: problem-focused coping and emotion-focused coping. Problem-focused coping attempts to change the problematic person-situation relationship involved with mental health issues. In contrast, emotion-focused coping aims to regulate negative emotions of an individual and maintain moderate levels of arousal.

In the construction industry, a few efforts have been made to examine the relationships between coping behaviours and psychological issues. Langdon and Sawang (2018) explored the stressors, coping mechanism, and mental health for the construction labour workforce. They found that construction workers who adopted maladaptive coping strategies such as acceptance, self-blame, and disengagement when facing stressors had increased feelings of mental distress. Enshassi *et al.*, (2018) investigated the two main coping measures of problem-focused and emotion-focused coping used by construction professionals. In terms of problem-focused coping, planned and constructive review problem-solving, need for social contributory support and confronted coping were found to be the three most frequently used ones. In relation to emotion-focused coping, the principal strategies were identified to be accepting responsibility, avoidance and seeking emotional support. Chan *et al.*, (2018) developed a stressor-coping-stress model based on the expectancy theory in stress management for Hong Kong expatriate construction professionals. This research revealed the lack of attentions on the significant role of cultural stress on the expatriate construction professionals in the construction industry. Yip *et al.*, (2008) examined the degree to which the different types of coping strategies (e.g. rational problem solving, resigned distancing, and passive wishful thinking) moderate the relationship between role overload and burnout among professional construction engineers. Rational problem solving were discovered to be the most significant one among all the coping strategies.

The existing literature review shows that the stress-coping research in the construction industry generally adopted the traditional coping strategies: problem-focused coping and emotion-focused coping based on the transactional theory of stress and coping (Lazarus and Folkman 1984). However, since the transactional theory has been criticised to have a clear lack of research in cultural context which neglects cultural-related factor, it may be insufficient to address the mental health issues in a culturally diverse construction workplace. Therefore, it is imperative to expand current stress-coping theories and frameworks by integrating cultural and multicultural contexts, as well as developing intercultural coping strategies.

Theoretical models of cultural coping

In a culturally diverse environment, cultural adaptation is an inevitable process an individual undertakes to manage and cope with stressors and diversities brought upon by being in an extended contact with new cultures (Berry 1997). Even though the transactional model of stress and coping laid a solid foundation in studying psychological coping, it has displayed a clear lack of research in cultural context. It concentrates on problem- focused and emotional-focused coping strategies rather than on cultural-specific coping behaviours (Wong and Wong 2006). Therefore, cultural coping models have been developed to fill in this gap of stress-coping theories.

Based on Lazarus and Folkman's (1984) transactional model of stress and coping, the resource-congruence model of coping (Wong 1993) posits that adaptive coping can be

achieved where appropriate resources are available and congruent coping strategies are employed. In particular, this model emphasizes the significant role of culture plays on effective coping and its impact on all aspects of coping-well-being process, including potential stressors, primary and secondary appraisal, coping behaviors and outcomes. Coping is classified into three categories: creative coping, reactive coping and protective coping, among which creative coping specifically relates to cultural factors. The multi-axial model of coping postulates that cultural can impact on the coping process through factors of individual precise interpreting, culturally shared biases, family norms and illusions depended on personal, familial and cultural biases (Kuo 2011). Likewise, Chun *et al.*, (2006) developed a transactional model of cultural stress and coping to clarify the interaction between culture and coping process. It depicts that culture is embodied in the whole process of stress and coping, as well as imposes effects on five systems (environmental systems, personal systems, transitory conditions, appraisal and coping skills, health and well-being). In addition, Aldwin (2007) proposed a sociocultural model of stress, coping, and adaptation which highlights the cultural context of the stress and coping process. This model also illustrates the influence of culture on the entire process of stress and coping.

The review of these cultural coping models demonstrated the significant impact of culture on the entire process of stressor-coping-well-being and the necessity to incorporate culture into coping research so as to better investigate mental health problems in a multicultural context. However, although these cultural coping models confirm the essential role of culture on coping process, they mainly consider the impact of national culture on the perception and management of mental health but fail to illustrate the impact of diverse culture derived from different cultural backgrounds. Further theoretical study is needed to investigate the impact of diverse culture on the coping-mental health process. Therefore, this research attempts to develop a conceptual framework incorporating cultural-related factors in a multicultural construction workforce based on the transactional model of stress and coping, in order to ameliorate the mental health of construction workers in this sector.

CONCEPTUAL MODEL

Conceptualising intercultural coping

The existing research on coping of mental health issues mainly adopted problem-focused and emotion-focused coping strategies based on the transactional model of stress and coping. Nevertheless, this culture-absent coping may not be applicable to the multicultural work environment. Moreover, research in the construction industry has found out inconsistent findings in regard with the efficacy of these two coping behaviours. Most studies demonstrated that problem-focused coping is more adaptive in enhancing the mental health of construction workers/professionals than emotion-focused coping, while other research indicated that some of the problem-focused coping strategies fail to improve mental health of them (e.g. Langdon and Sawang 2018; Yip *et al.*, 2008). Thus, effective coping should be developed to better address mental health problems in a multicultural workplace.

The tripartite model of attitude (also called ABC model of attitudes) (Rosenberg and Hovland 1960) identified three components of evaluative response, which are the affective, behavioural, and cognitive components of attitude. In this model, “attitude is defined as a response to an antecedent stimulus or attitude object, which may or may not be observable. And the three components are three classes of responses to that stimulus” (Breckler 1984). The affective component is focused on feelings or

emotions, such as sympathetic nervous responses and verbal statements of affect. The behavioural component is focused on behavioural intentions, including overt actions and verbal statements concerning behaviours. The cognitive component is targeted on beliefs containing the perceptual responses and verbal statements of beliefs (Ostrom 1969). This 'ABC' model of attitude has become an essential component of the general body of knowledge in the areas of psychology and organizational behaviour (e.g. Eagly and Chaiken 1998; Greenberg *et al.*, 1993). Meanwhile, coping is also recognized as evaluative response which manages specific stressful stimulus (Lazarus and Folkman 1984). Comparing with the implication of attitude from ABC model and coping from transaction theory, it can be referred that coping can be classified into three dimensions, including affective, behavioural, and cognitive components.

Intercultural competence is acknowledged as effective ability to manage mental health stress in a culturally diverse work environment (Starren *et al.*, 2013). It was defined as "the ability to develop targeted knowledge, skills and attitudes that lead to visible behaviour and communication that are both effective and appropriate in intercultural interactions." (Deardorff 2006). The intercultural competence model identified three constituent elements of intercultural competence: knowledge, skills and attitudes (Deardorff 2006). Knowledge mainly focuses on the cognitive aspect, including cultural self-awareness, culture specific knowledge, socio-linguistic awareness, grasp of global issues and trends. Attitude targeted at the emotional reaction which is constituted by respect (valuing other cultures); openness (withholding judgement); curiosity (viewing difference as a learning opportunity); discovery (tolerance for ambiguity). Additionally, skills embody the behavioural responses that is composed of listening, observing, evaluating; analysing, interpreting and relating. In view of the crucial role of intercultural competence in enhancing mental health, it is regarded as effective coping in multicultural workplace (Starren *et al.*, 2013). Therefore, to improve the mental health of multicultural construction workforce, intercultural competence should be integrated into the development of effective coping. This research thus proposes the term of "intercultural coping" as effective coping to manage mental health issues in a multicultural construction workplace, and it can be identified as three dimensions, including affective intercultural coping, behavioural intercultural coping and cognitive intercultural coping.

Djebarni (1996) suggested that different types of coping behaviours are needed to tackle with specific types of stressors. Thus, it is essential to develop effective coping strategies specifically targeted at different stressors for construction workers. The measurement scale of intercultural coping was developed based on the intercultural competencies. Based on the intercultural competencies classification system (Lloyd and Hartel 2010), affective intercultural competencies were classified into dissimilarity openness, tolerance for ambiguity and cultural empathy; behavioural intercultural competencies had the dimensions of intercultural communication competence, emotion management skills and conflict management skills; cognitive intercultural competencies could be categorised as cognitive complexity and goal orientation. After adapting and modifying the measurement items of all the intercultural competence constructs, 24 measurement items were eventually developed to measure the concept of intercultural coping. Based on the discussion aforementioned, the first hypothesis is set out:

Hypothesis 1 - (Affective/Behavioural/ Cognitive) Intercultural coping has a positive impact on mental health.

Stressors of mental health in a culturally diverse construction workplace

Identifying the determinants of mental health is of significant in the stress-coping process. A better understanding of the determinants that have essential impacts on psychological well-being can contribute to the development of effective coping measures (Murphy 2000). Personal and situational stressors are identified as the main determinants in the transactional theory of stress and coping. Likewise, the occupational stress model of Cooper and Marshall (1976) postulated that the interactions of the individual characteristics and potential sources of stress in the workplace had crucial impacts on either coping behaviours or psychological illnesses. Besides, extra-organizational stressor was also recognized as a type of stressful situation which affected an individual's psychological well-being at work.

The occupational stress model identified five work-related stressors: factors intrinsic to a job, role in organization, career development, relationships at work, organizational structure and climate (Cooper and Marshall 1976: 14-22). Previous studies demonstrated that most of the occupational stressors in the construction industry were fitted well in the job-related factors as in the model (Johnson *et al.*, 2005; Motowidlo *et al.*, 1986; Rahman *et al.*, 2014). The measurable items of work stressors were adapted from previous research works of Leung *et al.*, (2017), Leung *et al.*, (2005), and Fye and Staton (1981). Personal characteristics play an essential role in stress-coping process (Hendrix *et al.*, 1985). Two of the most prevalent and frequently employed factors of personal characteristics in the psychological wellbeing are the behaviour pattern of an individual (Type A and Type B behaviours) and locus of control (external and internal locus of control) (Cooper 1972; Leung and Chan 2012). The extra-organizational stressors such as family problems and financial difficulties are found to be the most significant ones in regard with mental health issues in a workplace (Cooper and Marshall 1976; Hendrix *et al.*, 1985). Since these elements are derived from the individual themselves, they are classified into the personal stressors. The personal stressors were measured by the Speed and Impatience construct (Friedman and Rosenman 1959), Introversion-Extraversion (I-E) Scale (Rotter's 1966), home-family relationships scale (Fye and Staton 1981), and Life Events Checklist (LEC), respectively.

Despite the valuable insights of person-work stressors provided by transactional theory of stress and coping and occupational stress model, these models viewed the transactions of stressors and coping in a mono-cultural background, which displayed a clear lack of focus on cultural and multicultural context (Wong and Wong 2006). However, given the essential role of culture plays and the absence of research on the impact of cultural diversity on the coping-well-being process, it is imperative to incorporate the cultural-related factor in the present framework. Cultural stressors are recognized as the conflicts and difficulties that originated from the process of intercultural contacts (Pan *et al.*, 2007). Interactions with different cultures generally bring about a set of negative status, such as mental health symptoms (anxiety, depression, stress), feelings of isolation and marginality, and confusion of self-identity (Berry, *et al.*, 1987). Currently only a limited number of studies have explored the cultural barriers in the construction industry. From the findings of extant studies, racial discrimination, language barriers and cultural value conflicts have been identified as the most prevalent cultural stressors in the multicultural construction workplace. Four items of racial discrimination in the construction workplace were adopted from Wong and Lin (2014). Three questionnaire items of language barriers were adapted from Leung *et al.*, (2017). Two items of national cultural conflicts were

adapted from Al-Bayati *et al.*, (2017). Therefore, Hypothesis 2 is proposed in accordance with previous literature review:

Hypothesis 2 - (Personal/Work/Cultural) Stressors have a negative impact on mental health

As has illustrated above, stress-coping theories and literature review have illustrated the significant role of coping plays in moderating the relationships between stressors and psychological outcomes. Furthermore, in this study, the intercultural coping refers to effective coping strategies to alleviate stressful states and ameliorate mental health of construction workers in a culturally diverse workplace. Thus, the following hypotheses are proposed:

Hypothesis 3 - Effects of (Personal/Work/Cultural) stressors on mental health are moderated by (Affective/Behavioural/Cognitive) intercultural coping.

Based on the hypotheses mentioned above, a conceptual framework for managing mental health of multicultural construction workforce is proposed (Figure 1).

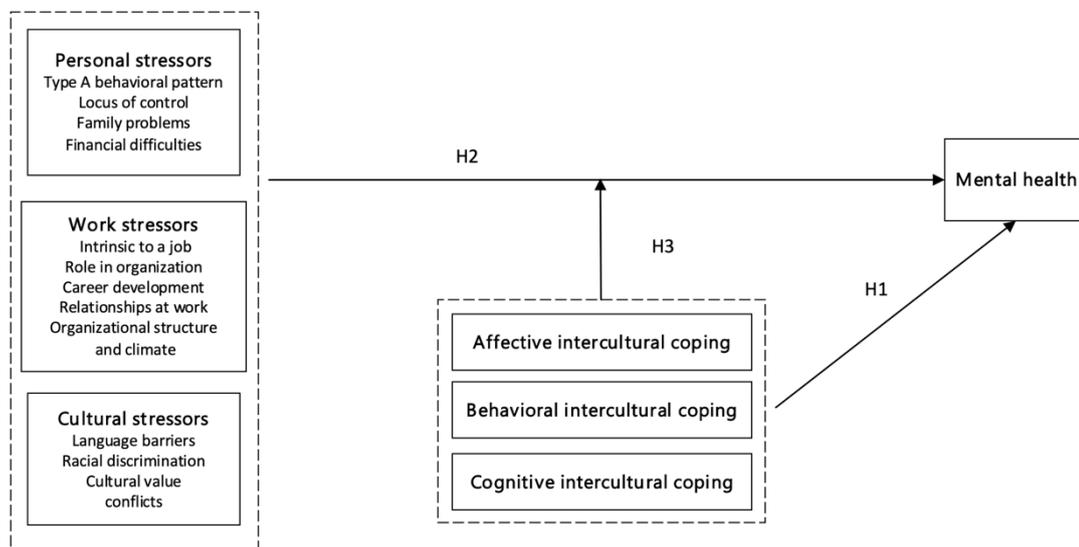


Figure: 1 Conceptual model for managing mental health in the culturally diverse construction workforce

CONCLUSION

This research developed a conceptual model for managing mental health in the culturally diverse construction workforce. Literature review method was employed as the research approach. The transactional theory of stress and coping was adopted as the theoretical basis. The incorporation of cultural-specific factor into the framework was justified with cultural coping models. Based on the tripartite model of attitude and intercultural competence model, the term “intercultural coping” and its three dimensions (affective/behavioural/cognitive) were developed. In accordance with the occupational stress model, three stressors (personal/work/cultural) of mental health were identified. Three hypotheses were proposed and measurements for each item were determined. This research is of significance both theoretically and practically. Theoretically, it may contribute to the knowledge of mental health management in the field of multicultural construction work environment. Particularly, the present study might be the first research which emphasizes the significance of multicultural context on mental health by incorporating cultural-specific factor, providing theoretical

development of intercultural coping and clarifying the associations of stressors, coping and mental health in the context of the construction industry. In practical, this study provides a framework for construction workers to manage their mental health problems in the multicultural workplace. Next step of the research is to collect data via questionnaire survey method and analyse the collected data. To avoid the effect of cultural segregation, the screening questions (e.g. working with team members from different cultural backgrounds) for potential respondents will be used. Only the respondents who pass the screening questions will get access to the official questionnaire. Moreover, the moderating effect of intercultural coping on relationships between stressors and mental health will be examined by the Structural equation modelling (SEM). Effective coping strategies will be developed based on the findings.

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LOSING GROUND: ADAPTING CONSTRUCTION MANAGEMENT APPROACHES TO PERMAFROST RETREAT

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A significant amount of critical energy and resource infrastructure rests on permafrost. As the global climate changes, more areas of permafrost are becoming affected by seasonal thawing, leading to changing ground conditions which were unforeseen during design and construction. As the untapped energy and resource potential of the northern icefields becomes more accessible, construction in these environments is only set to increase. In this paper, recent literature on design and construction in areas of retreating permafrost is examined, and a mixed-methods approach is described which includes a survey of experienced construction managers, and interviews with industry experts whose primary work is in geo-technical research and development of structures in Arctic regions. It seeks to identify the construction challenges faced by the changing ground conditions, and to establish how existing approaches and practices to construction in permafrost need to be adapted for the future. The study confirms that existing practices generally work well, and the challenges are well defined. But it identifies several interlocked areas which must be further understood for the success of both existing and future projects in permafrost and Arctic regions. These include expanding survey ranges, improved risk tracking and management, milestone mapping, adaptive design, and intensive logistics management. The research makes it clear that for a successful project, the ground conditions and their interaction with the project design must be fully understood, and stakeholders must be brought on board with improved approaches and convinced of the criticality of complete understanding before proceeding with construction.

Keywords: Permafrost, construction methods, infrastructure, climate change

INTRODUCTION

This paper reviews the current practices for establishing infrastructure on areas of permanently frozen ground - permafrost - and examines how these will need to adapt to account for climate-change-induced instability of the permafrost ground.

Permafrost is ground which remains completely frozen. Found mainly in the Arctic, Antarctic and high alpine zones, permafrost represents one of the most challenging yet critical construction environments on earth (Oswell 2011). Continuous permafrost is a sheet of frozen material which lies under the sub-surface of an area and maintains a maximum surface temperature of 0°C. It is often present in layers around 100m thick,

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and may reach over 1,500 m in thickness, (Vincent *et al.*, 2017). The main zones of interest in this paper are located across Alaska, Siberia, and the Tibetan Plateau.

In the last half century, significant infrastructure has been established in permafrost regions. Major projects include the China-Russia Crude Oil Pipeline (CRCOP), the Baikal-Amal Mainline (BAM) in northern Siberia, and the Trans-Alaska Pipeline System (Hjort *et al.*, 2018). The Chinese Qinghai-Tibet Corridor (QTC) contains several projects under construction or repair including 470 km of railway and the Qinghai-Tibet Highway, (Lin *et al.*, 2011; Sun *et al.*, 2018). This infrastructure represents an enormous investment with Streletskiy *et al.* (2014) estimating the potential cost of hard-standing structures in Russia alone at \$80 billion.

Permafrost is sensitive to climatic changes. Projections for the next fifty years show a retreating permafrost layer as the arctic zones contract in response to global warming (IPCC 2014). In a hallmark study, Hjort *et al.* (2018) found that approximately 3.6 million people and 70% of the current infrastructure on permafrost is located in areas with a high potential for thaw by 2050.

This represents one third of all pan-Arctic construction and an estimated 45% of the hydrocarbon extraction fields in the Russian, American, Canadian and Norwegian Arctic (Yumashev *et al.*, 2019). Risks are mostly due to thaw-related ground instability, (Wu and Niu 2013), and estimates for addressing this are placed at upwards of \$15 billion (USD) in direct impacts, excluding knock-on effects on transport, trade and the global energy supply.

Existing infrastructure built on permafrost must be assessed and safeguarded to prevent damage in the wake of rapid thawing of the continuous permafrost layer (Yumashev *et al.*, 2019). Many projects in permafrost areas are undergoing testing and remedial work in an attempt to future proof them. Serious changes have been found in the ground regime and bearing capacity in Central Asian and Eurasian mountainous regions, possibly from the effect of seismic activity on ground stability (Sun *et al.*, 2018; and Liu *et al.*, 2019). The cost to existing infrastructure in the coming three decades in Alaska from remedial works is estimated at \$5.6 - \$7.6 billion (USD), under the Regional Climate Projection, (Larsen *et al.*, 2008), and \$570 million (USD) has been set aside for research and mitigation of the damage retreating permafrost will cause in Canadian permafrost regions over the next decade (Anthony 2019).

Howard (2009) notes that the Arctic and Antarctic regions house around 25% of the world's untapped energy and resource reserves. These areas will become more accessible as the ice retreats, implying that the operational tempo of construction projects will only increase (Shur and Goering 2009). As existing Arctic permafrost zones contract and new avenues open for energy and trade, demand for supporting infrastructure and utilities will increase (Sun *et al.*, 2018). This will include communication, energy conduits, supply depots and emergency provision (Farré *et al.*, 2014). The renewed interest in this 'untapped economic potential' emphasises the importance of understanding the changing conditions, (Farré *et al.*, 2014).

Aims of the study

The main concern for construction is the impact of retreating permafrost on the load-bearing capacity of the ground. Although the engineering methods for establishing projects on permafrost are extensively documented, construction management techniques have been given little direct focus in literature.

The aim of this study is to review the existing construction management practices for building on permafrost and establish a preliminary view on how these needs adapted for the projected changes in climate. The hypothesis is that while existing procedures and practices are effective, they no longer fully address the changing risks. Three questions were set for the study:

- What are the existing approaches to construction on permafrost?
- What challenges do these practices face and what shortcomings do they cause for projects?
- How can these existing approaches be adapted for the future?

METHODOLOGY

Literature on permafrost construction was reviewed, including accounts of specific projects in permafrost regions. Very little literature was found dealing specifically with construction management for projects on permafrost, suggesting that more input from experts and practitioners in the field is needed.

To supplement the literature review with up to date opinion and analysis, a mixed methods approach was adopted. Quantitative data was collected via an on-line questionnaire sent to a range of project managers, site engineers, designers and subcontractors, in order to construct a picture of how projects are presently conducted in permafrost regions. 73 responses were received mostly from practitioners working in permafrost regions. Given the limitation of this relatively niche field, 73 is considered a reasonably significant sample, and acceptable for a preliminary survey, (Sue and Ritter 2012). The survey was analysed using several statistical tools, but the detailed statistical analysis is not relevant to this paper and is not described here.

Qualitative data was collected from interviews conducted on-line with three industry experts whose primary area of work is in geo-technical research and development of structures on permafrost. One is based in Alaska, the other in St Petersburg and the third in Vancouver, and together they bring a wide geographic scope to the study.

The interviews were carried out in a semi-structured format, centered around a set of key questions but allowing for follow-up to elucidate particular points. The responses were transcribed for coding and analysis using NVivo. Nodal cluster analysis was conducted (Edwards-Jones 2014). Nine nodes and eight clusters were identified. The qualitative and quantitative data were assessed separately which allowed some of the shortfalls of each data collection method to be assessed, improving its reliability.

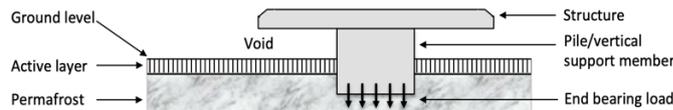
LITERATURE REVIEW

Several techniques are used for construction on permafrost, (Li *et al.*, 2016). A general rule is that what is frozen should be kept frozen and vice versa (Charles 1959). This means avoiding deepening the active layer - the thin surface layer which thaws and re-freezes seasonally. For structures on permafrost, the goal is to prevent direct contact with this layer, both to reduce thermal transference and avoid putting direct pressure on the ground, therefore overcoming the problem of differential thaw settlement (Doré *et al.*, 2016). A common method is to use space frames to help distribute the load and leave a self-regulating airgap (Oswell and Nixon 2015), see Figure 1. Piles may be installed at unstable areas to bypass the sub-surface and anchor directly to bedrock.

Structures may be elevated above the ground to prevent degradation of the active layer by the combined effects of reduced ablation, thermal insulation and increased moisture

retention (Van der Sluijs *et al.*, 2018). One example of this is seen in the Qinghai-Tibet Railway (QTR), (Wu *et al.*, 2007), which uses raised bridges over the permafrost to prevent rail operations affecting the sub-base. This method prevents damage from passive thermal transmission from the rails but does not address the impact of climate change-induced permafrost retreat, (Lv *et al.*, 2019). For metaled surfaces, a common method is to lay soil under the gravel sub-base and geotextile to allow better water drainage and reduce the load-signature (Ma *et al.*, 2016). However, Hjort *et al.* (2018) reports that this method has proven inadequate, as the active layer often continues to deepen or else the permafrost has receded outright.

Figure 1: Avoiding load on the active layer



Approaches to construction in permafrost can be categorised as active or passive. Passive measures include elevating the structures sufficiently to prevent a heat-bloom affecting the active layer. Tundra vegetation can be used as a passive biological insulator, for example on the original embankment of the QTR, where a raised embankment was used to reduce the thermal transmission from the rail-lines (Wu and Niu 2013). Passive methods were originally deemed sufficient to safeguard the infrastructure from ground instability while mitigating the risk of thaw. Hjort *et al.* (2018) conclude that these traditional methods will not be adequate to counteract the shift ground stability due to rapid permafrost retreat.

Active measures are less commonly used on permafrost projects, as it is costly and difficult to seat a structure in excess of 100 km long into bedrock (Hauck and Geistauts 1982). Active measures can include the use of thermosyphons to redirect unwanted heat from the active layer, the instalment of temporary embankments, artificial freezing of the soils via liquid nitrogen, or the construction of frozen geocylinders - i.e., cylinders composed of bored frozen soils - to act as an insulating layer, primarily for oil pipelines, Ma *et al.* (2016). Vermiculite powder may also be injected into the asphalt mix to increase its ablation and decrease the quantity of insolation it retains (Oswell 2011; Li *et al.*, 2016).

Piling is also common (Doré *et al.*, 2016). Some authors have begun investigating the utility of quicklime energy piles, an approach which accepts that the ground will thaw so its purpose is not to serve as structural support but to accelerate the thawing, allowing the design and construction to progress as if building on swampland. This may be more economic than boring through the ice. However, this approach is only truly effective in shallow permafrost and can create other problems in terms of increased local instability or releasing previously trapped gasses (Liu *et al.*, 2019). While it may be an option for static structures on the Tibetan Plateau, it is not a long-term solution for regions such as Siberia and Alaska and would be unlikely to pass the feasibility stage due to rapid cost escalation (Van der Sluijs *et al.*, 2018; Liu *et al.*, 2019). Active methods require intensive engineering works and tend to be used where the risk of permafrost degradation is too high for passive methods to be an acceptable form of mitigation (Hjort *et al.*, 2018).

Adapting Construction Management Practices

A wide-ranging review of the literature has revealed several critical areas which will require more intensive management in areas of potential permafrost retreat.

1. Defining the project scope and requirements with stakeholder engagement

Project feasibility must be more thoroughly assessed and will likely occur over a more protracted period (Greenslade and Nixon 2000; Oswell and Nixon 2014). This is because factors such as the total ice-content, ground and surface temperature, confining pressure and strain rate, frost-heave and slope stability must be more carefully considered before groundworks can commence (Lv *et al.*, 2019). These factors were neglected in the Norman Wells Canol Pipeline. Although constructed between 1943 and 1944 (Oswell 2011), it nevertheless serves as a useful example of where ground conditions were poorly understood, the construction methods untested and the pipeline was insufficient to meet the demand. Its throughput only ever reached 25m³ of oil per day before the project was abandoned early (MacNaughton *et al.*, 2007).

2. Long-term project-planning

Kokelj *et al.* (2010) suggest that long-term management plans should be established for the monitoring, mitigation and reclamation of the permafrost ps. Greenslade and Nixon (2000) take this further in their evaluation of the TAPS. They consider that its success was largely due to proactive project management and high levels of innovation in the design. The TAPS cost a total of \$8 billion USD in 1977, making it the most expensive privately developed construction project at that time (Van der Sluijs 2018).

3. EFMI and ECI for Operability and Buildability

The TAPS pipeline project is managed from the operations control centre in Anchorage and has three separate leakage monitoring stations to provide effective early warning of breakages (Streletskiy *et al.*, 2012). This project helps demonstrate the need for early contractor involvement (ECI) and the early facilities managers involvement (EFMI) (Oswell and Nixon 2014;). With such projects, considerable thought is required on how to adapt the system to a changing environment and increasing demand over its lifetime (Hauck and Geistauts 1982). Likewise, the project complexity and the specialised construction techniques required involving the contractor(s) early in the project design to ensure buildability.

In the long term, EFMI is critical for infrastructure on permafrost (Greenslade and Nixon 2000). Wu *et al.* (2007) and Lin *et al.* (2011) cite poor integration of facilities management in the early stages of highway and railway engineering in the Qinghai-Tibet permafrost region as causing otherwise avoidable issues down the line. For example, Lin *et al.* (2011), point out that the poor provision of monitoring stations across the Qinghai-Tibet Highway meant that lateral and transverse stress fractures caused by frost heaving near the road embankment and metaled surface were undetected until inspection units found the tears weeks after they occurred. Likewise, Kin (2015) points out how poor monitoring provision and a de-centralised maintenance network across the Soviet boundaries of the old Baikal pipeline network led to its eventual failure and breakdown. In this instance, there was no early involvement of the facilities management team.

4. Increased scientific research

Large scale infrastructure projects in permafrost regions require the extensive involvement of scientific research teams, both for determining ground suitability and monitoring of the permafrost conditions (Oswell and Nixon 2014). The initial BAM project was considered a failure, and poor survey work and a weak knowledge base was touted as a key factor (Kin 2015). Projects such as CRCOP and the TAPS demonstrate scientific involvement on a level not seen in any other construction sector (Oswell 2011 and Sun *et al.*, 2018). Conversely, where this is absent, projects have

been riddled with issues correlating to poor design, poor long-term management and inadequate maintenance provision, Kin (2015). From the perspective of managing a project in permafrost conditions, the implication may be drawn that there is no ‘gold-plated’ design approach with each project needing its own data-driven, bespoke approach, (Dore *et al.*, 2016).

5. *Recognising the Logistical Challenge*

Any infrastructure project spread over hundreds of miles of varying terrain is a logistical challenge and can require establishment of temporary roads, supply depots, workforce accommodation, helicopter landing sites and temporary airstrips, (Hjort *et al.*, 2018). In permafrost, these challenges are redoubled, as construction will be seasonal depending upon the climatic conditions, with a restricted window for operations, meaning there is often a longer lead-time for the manufacturing and delivery of materials. Permafrost regions are remote, with little supporting facilities and infrastructure for the physical workforce, (Hauck and Geistauts, 1982), and for a project to be successful, extensive enabling works may be needed, often months prior to the main construction phase (Hjort *et al.*, 2018), with temporary works subject to the same design issues as the permanent facilities (Kin 2015).

RESULTS

From an analysis of the literature, surveys and interviews, several elements have emerged relating to the further efforts needed to adapt existing construction management approaches to future needs.

1. *Improve the Setting of Project Milestones*

The responses suggested a strong need to improve milestone planning. This is surprising, as planning is considered a well-managed facet of construction. However, older approaches have been unable to protect both the infrastructure and the permafrost, and as the end-state of projects becomes less clear, milestones have become harder to map, (Hjort *et al.*, 2018).

Assigning milestones involves looking at operational windows and against the need move materials (McFadden and Barnett 1991). Efforts are ongoing to establish new shipping lanes and oil-extraction fields in the Arctic as the ice retreats and accessibility increases (Farre *et al.*, 2014). As the working season lengthens, increased movement should be possible via sea lanes (Ma *et al.*, 2016). This combination of factors may revive the role of logistics managers and replace the ad hoc approach often taken in such projects (Streletskiy *et al.*, 2012).

2. *Design Flexibility and Improving Survey Procedures*

Until the 1990s, survey data was reviewed in 1km sections to establish construction methods appropriate to the geology (Farre *et al.*, 2014). This led to the application of one or two ‘catchall’ designs applied to the different ground conditions (Liu *et al.*, 2011; Doré *et al.*, 2016), but this ased that ground conditions were contiguous and would respond consistently to one or two design approaches. To address this, modular designs may be used, which can be adjusted to the conditions (Van der Sluijs 2018), although non-modular designs which can be relatively easily adjusted to the conditions, may also be used. This is being tested in the QTR where two designs are employed, which both vent excess thermal energy away from the permafrost but do so in two different ways and across different ground conditions.

3. Better Communication of Uncertainty and Risk

On permafrost projects, the risk of ground thaw causing shear damage to structures is difficult to predict (Yumashev *et al.*, 2019). To better manage risk, improved communication on permafrost projects is needed, especially as new approaches and unfamiliar designs come into play (Dore *et al.*, 2016). In the interviews, 3D imaging was suggested as one means of doing this, especially for discussions with clients. 3D imaging is used in the energy industry and the evolution of 4D BIM can better help clients and contractors understand and mitigate potential hazards (Zhang *et al.*, 2013). For permafrost, using software along with land survey data could help clients and designers better manage the risks and adapt the design for the conditions.

4. Improved Logistics Management

Logistics planning will change significantly over the coming decades. McFadden and Bennett (1991) explain how during the construction of the TAPS in Alaska's oilfields, all material and personnel had to be transported via air or barge during a narrow seasonal window, with materials sitting in storage months ahead of transport. With the retreat of the underlying ice, logistical planning can be adapted. It may be possible to establish storage facilities closer to construction sites, ahead of the operations window (Oswell and Nixon 2015), as seen in the ongoing effort of the Russian Navy to establish new naval depots in the Arctic, (Staalesen 2019).

For the future of construction in inland regions, the practice of establishing temporary roads may need to continue. However, as Ma *et al.* (2016) have pointed out, the design of the roads themselves will need to adjust to cope with the relatively rapid thaw observed in Permafrost. With the scale of construction on permafrost regions set to increase, there will be more users, larger facilities and more supporting facilities.

5. A New Generation of Research, Operation and Maintenance

The approach taken for the feasibility phase for the Baffin Island Mary River Iron Mines Project demonstrates the level of research required before construction commences, especially over the complex permafrost terrain (Zhang *et al.*, 2013). A survey was conducted across nearly 108 km of track in need of re-alignment (Vladislav *et al.*, 2010), in order to identify the main permafrost-related features in the ground and, rather than find new ways to build on them, bypass them completely. Wu *et al.* (2007) suggests this is the preferred approach, although the option is often not feasible, especially where access is restricted such as on the Tibetan Plateau.

Another key aspect is the question of operation and maintenance of structures placed on permafrost. One of the key environmental lobby's concerns with the proposed Enbridge Pipeline extension was the risk of shearing in the pipeline and the subsequent environmental impact (Yumashev *et al.*, 2019). A similar concern for the new road and rail networks of the QTR, is the need to track damage to the roads due to heave-thaw-related instability (Oswell and Nixon 2015).

Several methods have been proposed for this, including the use of autonomous civil aviation units to track key sections of road, rail and pipeline networks (Mitchell 2019). Another is the establishment of sensor networks in the pipelines (Zhang *et al.*, 2013), although this relies on sensors which may become faulty or inaccurate and only inform the operators of problems after they have occurred.

CONCLUSION

The research findings suggest a strong positive sentiment towards the effectiveness of existing construction management procedures, but an equally strong sentiment

supporting the need to adapt these approaches in the near future. One conclusion from the survey responses and interviews is the need for stronger emphasis on adapting construction techniques and methods, rather than adapting the infrastructure itself, implying that at present, the design and suitability of the infrastructure less a concern than the construction techniques.

The challenge of permafrost is well-defined, and the industry's understanding is improving rapidly. Efforts are being made to understand how working in this climatically sensitive environment will change and how the interplay between the air-temperature, seasonality and the frozen ground will affect the infrastructure founded on it. Ongoing ground research will expand the level of detail available to construction managers and their design teams. However, innovation and new approaches are also needed in the planning and management of the construction process. With this, significant up-front investment will be needed, and future investors will need to be well informed of the short-term costs and long-term viability and have a complete understanding of the risks and mitigating measures needed.

Wider Implications for Climate Change Mitigation and Adaptation

Although this topic was not addressed in the research, technical discussions on opening up the Arctic regions cannot be held without reference to the wider political and ethical issues raised. Political economists sometimes criticise the asption that climate-change-inducing economic development for the good of the 'global economy' inevitably requires the measures needed to address the resulting problems to be applied at a local and community level, (see Nightingale *et al.*, 2019)

In this case, the indigenous people of the Arctic region, already vulnerable to climate change effects, will be further impacted by induced effects arising from development of their own region. Behl (2016) points out the ethical dilemma of this and notes that it is 'important to gain a better understanding of the nature of climate vulnerabilities faced by Arctic people, explore options that increase resiliency and help indigenous peoples adapt to climate change'. Since no construction occurs without the acquiescence and participation of local communities, this is an issue that construction professionals will need to be increasingly aware of as these previously frozen regions open up.

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CHALLENGES FOR IMPLEMENTING THE SUSTAINABLE DEVELOPMENT GOALS IN THE DANISH CONSTRUCTION INDUSTRY: BUILDING OWNERS' PERSPECTIVE

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The construction sector holds great potential and responsibility in achieving the United Nation's 17 Sustainable Development Goals (SDGs). The aim of this study is to investigate how the SDGs can be implemented in construction projects in a Danish context, and which challenges building owners face working with the SDGs. A focus group workshop was held with 22 professional building owners to investigate which challenges they encounter and what is needed to support successful implementation, along with a survey focusing on their current implementation of the SDGs. The results showed that the five SDGs with the highest prioritization among the building owners were Goal 7 (affordable and clean energy), Goal 11 (sustainable cities and communities), Goal 13 (climate action), Goal 8 (decent work and economic growth), and Goal 12 (responsible consumption and production). 94% of the building owners had implemented, or wished to implement, the SDGs in various degrees. The main challenges experienced by the building owners were a lack of local indicators, tools and methods to support the implementation of the SDGs in construction, knowledge regarding the SDGs among the building owners, and extra costs related to the implementation of the SDGs. The main solutions suggested to overcome the challenges were the development of new tools and methods supporting the practical application of the SDGs in construction, e.g., dialogue tools for goal setting and prioritisation and for measuring performance regarding the SDG in construction, along with practical examples and knowledge aimed towards the actors within the construction industry. This study provides valuable insights of the challenges experienced by professional building owners regarding the implementation of the SDGs, as a point of departure for future research and developing practical solutions to support the implementation of the SDGs.

Keywords: sustainability, SDGs, prioritisation, barriers, Agenda 2030

INTRODUCTION

In 2015, the 193 United Nations member states agreed on the 2030 Agenda for sustainable development, marking a global milestone in the field of sustainability and sustainable development (United Nations, 2015). The 2030 Agenda included 17 goals

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for sustainable development (SDGs), supported by 169 targets and 231 global indicators, dedicating equal attention to the environmental, social and economic dimensions of sustainability (Diaz-Sarachaga *et al.*, 2018; United Nations, 2015). The construction industry holds a great potential and responsibility for contributing to the realisation of the 2030 Agenda. About 40% of energy use and one third of greenhouse gas emissions world-wide is related to the built environment, which entails increasing attention on sustainable development within the construction industry (Nielsen *et al.*, 2016). While the environmental focus is urgent, a holistic approach to sustainable development is necessary to ensure healthy, high quality buildings, without compromising the environmental and economic aspects (Kamari *et al.*, 2017). To establish a common ground for sustainable development within the building industry, the global and stable definition of sustainability provided by the 2030 Agenda can be valuable (Goubran and Cucuzzella, 2019).

As stated in the 2030 Agenda, the SDGs should be translated to the local and project-specific levels to become operational (Caiado *et al.*, 2018; Ike *et al.*, 2019; United Nations, 2015). In Denmark, an action plan towards 2030 has been developed and presented by the government in 2017 (The Danish Government, 2017), and currently local SDG indicators are being developed to establish a baseline for the Danish implementation of the SDGs (expected in 2020). Meanwhile, to ensure successful adaption and implementation of the SDGs in construction, the professional building owners plays an important part in setting goals for sustainability in construction projects, to push the ambitions towards the 2030 Agenda. Therefore, new methods and tools are needed to support the building owners in operationalising and implementing the SDGs. To focus this task, exploring the challenges/barriers experienced by the professional building owners is an important first step to further develop solutions towards overcoming these challenges. This paper therefore presents the results of an explorative study investigating the challenges/barriers of implementing the SDGs for professional Danish building owners, both on a strategic level and in individual construction projects. Along with the challenges, possible solutions are proposed.

LITTERATURE REVIEW

While sustainable building design has gained increasing attention in recent years, the academic literature investigating how the construction industry can contribute to the 2030 Agenda is still limited, partially due to the recency of the SDGs. A literature review from 2019, Goubran and Cucuzzella (2019) provide a state-of-the-art overview on how the 2030 Agenda and the SDGs have been utilized in sustainable building design. Furthermore, they propose two analytical mapping tools which can be applied to track the integration of SDGs in building projects (Goubran and Cucuzzella, 2019). Thuesen and Opoku (2018) suggested a research agenda for addressing the SDGs in construction, specifying four research areas to include; (1) an understanding of the relationships between the goals, (2) developing measures for evaluating progress, (3) addressing the target with specific projects and (4) the facilitation of knowledge transfer. Opoku (2016) investigated the built environment's role in achieving the SDGs, and highlights that the sustainable built environment in particular can contribute to socio-economic development and well-being of society. Additionally, Goubran (2019) identified SDG targets that depend directly or indirectly on construction activities, concluding that 17% of the SDG targets depend directly on the construction sector's activities, and 27% of the targets depend indirectly. A number of frameworks to support achieving the SDGs exist (e.g. the SDG compass (GRI *et al.*,

2016), SDG Capture (Niras, 2019) and the SDG impact assessment tool (Ramboll, 2018)). Also, Grainger-Brown *et al.* (2019) reviewed existing tools and frameworks for strategic implementation in organisations. However, the existing tools and frameworks are mainly conceptual and not adapted to the specific needs related to construction and building projects (Caiado *et al.*, 2018; Goubran and Cucuzzella, 2019). While the SDGs suggest a global framework for sustainable development, assessment frameworks for sustainable construction exist and have been adapted to local contexts. Therefore, these frameworks can potentially support the operationalization of the SDGs in construction. The link between the SDGs and existing sustainability assessment frameworks in construction has been explored in several studies.

Alawneh *et al.* (2018) explored the link between a number of LEED credits and the SDGs, followed by an investigation of a broader contribution of six rating system (LEED, BREEAM, CASBEE, Green Star, Green Mark and GBI) to the SDGs (Alawneh *et al.*, 2019). The link between CASBEE and the SDGs has been elaborated by Miyazaki *et al.* (2019), and the Danish Green Building Council (2018) mapped how the DGNB-DK criteria contribute to the SDGs. The barriers/challenges of operationalising and monitoring the implementation of the SDGs in general have been investigated e.g., in a literature review by Caiado *et al.* (2018) along with proposals of frameworks for strategic implementation of the SDGs (Allen *et al.*, 2019; GRI *et al.*, 2016). Also, Stafford-Smith *et al.* (2017) provided suggestions to how the SDGs can be implemented in an integrated way, and Jaiyesimi (2016) investigated the challenge of implementing the SDGs in Africa. However, there is a gap in the academic literature on the barriers and challenges for implementing the SDGs within the construction industry, including perspectives from the building owner. Several studies have explored the barriers and challenges of sustainable building design, e.g., (Häkkinen and Belloni, 2011; Opoku *et al.*, 2019; Tokbolat *et al.*, 2019), and while these results can provide valuable knowledge regarding the barriers for designing sustainable buildings, there is a need for research focusing explicitly on the implementation of the SDGs in construction projects, the authors argue.

METHODS

This explorative study seeks to investigate the barriers/challenges of professional Danish building owners in implementing the SDGs, and to suggest possible solutions to move forward. A focus group workshop was held with 22 building professionals representing both public and private building owner organisations, including four building owner advisors. The focus group method was chosen to ensure interactive discussions at this explorative stage of the study, and at the same time to enable knowledge sharing among the participants. The workshop participants were purposefully selected based on their interest in implementing the SDGs in construction projects. Prior to the workshop an online survey was sent to the participants, to investigate to which extent they were implementing the SDGs on both a strategic and a project specific level, and which SDGs and targets they had implemented. The survey consisted of close and open-ended questions, and the response rate was 91% of the workshop participants. The focus group workshop was facilitated by four academics and was divided in two main parts; a session focusing on barriers and a session focusing on possible solutions. The participants were organised in four groups and placed at four round tables. In the first session, the groups were given the task of discussing the challenges and barriers they encountered in relation to implementing the SDGs in their organisations and in individual construction projects.

After the discussion, each group agreed on the three biggest challenges representing the group discussions and presented them to the other groups. In the second workshop session, the same process was repeated with the focus on possible solutions to the challenges. Qualitative data was collected through audio recordings at each of the four tables and the written outputs of the workshop sessions in the form of post-it and notes. The data was analysed by first transcribing the audio recordings and post-it notes, followed by identifying and coding the themes emerging from the data (Brinkmann, 2014).

RESULTS

In this section, the results of the survey and focus group workshop are presented and discussed. The results are structured based on the themes which emerged from the data and includes a presentation of the main challenges experienced by the building owners and possible solutions to overcome these challenges.

Building owners' current implementation of the SDGs in construction

The results of the survey showed that 39% of the respondents currently work strategically with the SDGs within their organisation to some extent, 28% to a large extent, 22% to a minor extent, while only 6% respectively to a very large extent or not at all. This means that 94% of the respondents do work strategically with the SDGs to a varying degree. A majority, 78%, of the respondents answer that they have a strategy for sustainability within their organisation as a point of departure for implementing the SDGs, where 22% do not. Furthermore, the respondents were asked to which extent their organisations currently implement the SDGs in individual construction projects. To this question 50% answered to some extent, 28% to a minor extent, 17% not at all and 6% to a very great extent. Additionally, the respondents were asked to specify what their greatest motivation for working with the SDGs were. The answers varied from wanting to improve the built environment and the surroundings, contribute to sustainable development and be responsible for future generations, improve the climate and execute global responsibility. Other motivations were to improve the workplace and branding of the organisation.

SDG prioritisation

Should all the 17 goals be implemented in individual construction projects to contribute to the SDGs? On one hand, the SDGs should be viewed as a whole, in order to ensure the holistic approach to sustainable development (United Nations, 2015; Weitz *et al.*, 2018). The goals are intimately interconnected, and a failure to appreciate this will perpetuate an approach which is non-aligned at best, and highly ineffective at worst, according to Morton *et al.* (2017). On the other hand, some of the 17 goals are more relevant for the built environment than others (Opoku, 2016; Thuesen and Opoku, 2018). There has been some critique of the approach of focusing only on a few SDGs, with the risk of forgetting the interlinked nature of the SDGs (Morton *et al.*, 2017). According to Morton *et al.* (2017), addressing the SDGs, and thereby all three dimensions of sustainability, collaboratively, will yield greatest benefits, while the alternative - addressing them separately and in competitive isolation will deliver much less and induce greater risks. There is a danger that individual goals may be prioritized without an understanding of the potential positive interactions between the goals (Morton *et al.*, 2017). But should the built environment focus on e.g., stopping hunger and poverty (Goal 1 and 2 respectively), or should the emphasis be on contributing to the goals which are directly linked to the built environment? In the survey sent to the workshop participants, the answers surprisingly

showed that the participants had (or wish to) applied all 17 goals in building project - some more often than others (see Figure 1). A majority, 82%, of the respondents specify that they implement Goal 7 (affordable and clean energy), followed by Goal 11 (sustainable cities and communities) with 76%, and, third, Goal 13 (climate action) which 65% of the respondents have implemented. 59% have implemented Goal 8 (decent work and economic growth), Goal 12 (responsible consumption and production), and Goal 17 (partnerships for the goals). Goal 3 (good health and well-being) is the 7th highest prioritized goal, implemented by 53% of the respondents. 12% were unsure of which goals they have or will implement in future projects.

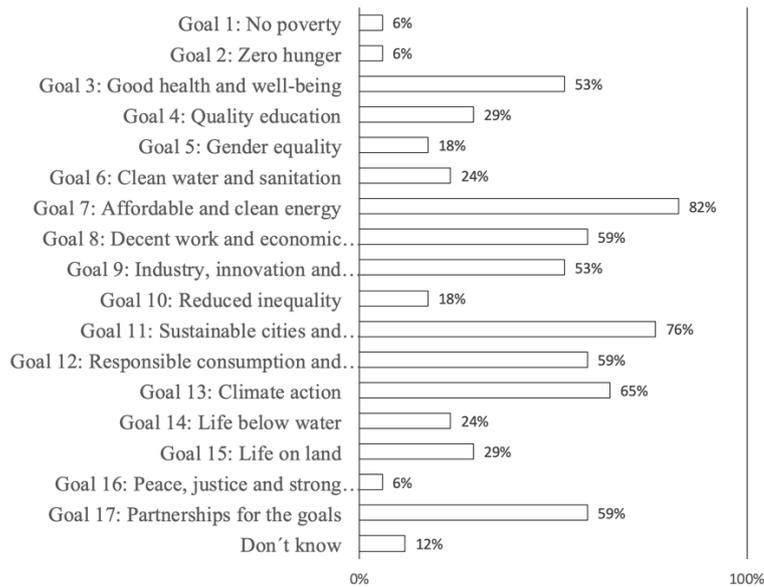


Figure 1: SDGs implemented in construction projects by the building owners

In the study by Opoku (2016), Goal 3 (good health and well-being), Goal 6 (clean water and sanitation), Goal 7 (affordable and clean energy), Goal 9 (innovation and infrastructure) and Goal 11 (sustainable cities and communities) were rated as highly impacted by the (sustainable) built environment. This aligns to some extent with the prioritisations of the professional building owners, with exception of Goal 6 which was only implemented by 24% of the respondents. Also, the building owners indicated that Goal 12 (responsible consumption and production), Goal 13 (Climate action), and Goal 17 (Partnerships for the goals) were prioritised, differing from the results from Opoku (2016)). Also, the prioritisation of the building owners aligns broadly with the suggestion on how buildings can contribute to the SDGs according to the World Green Building Council (2017).

Challenges for implementing the SDGs

The respondents were asked in the survey if they had experienced one or more barriers regarding the implementation of the SDGs and were given the options of choosing among the following categories; costs, time, collaboration/organisation, lack of knowledge, legislation and other. The categories were adopted from the barriers for sustainable building identified by Häkkinen and Belloni (2011) Figure 2 shows the responses. The two main barriers experienced by the building owners were related to costs and lack of knowledge, both categories selected by 76% of the respondents. A lack of available tools and methods were chosen by 65%, followed by barriers related to time 47%, and cooperation/organisation, 24%. Only 6% indicated that legislation

was a barrier. 12% ticked the "other" category and clarified that a barrier was that the SDGs are not necessarily explicit in the individual construction project.

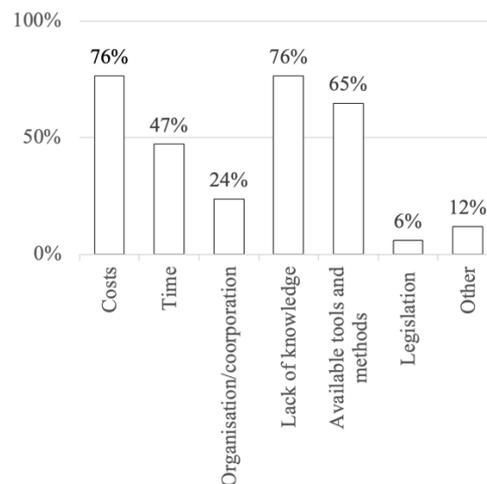


Figure 2: Challenges and barriers for implementing the SDGs

Also, it was elaborated that the SDGs are not tangible enough, and therefore requires specific tools and methods to implement in construction. A majority of the themes of barriers and challenges suggested in the survey were brought up and elaborated by the participants during the workshop discussions, and new themes emerged from the discussions. The main barriers highlighted by the groups during the workshop were "measurability and adaption to local context", "time and costs", "limited knowledge and information", and "process, tools and methods". The emerging themes are discussed in the rest of the section;

Measurability and adaption to local context

As the global indicators have not yet been fully adapted to Danish conditions, obviously this would be perceived as a barrier for implementing the goals in Denmark. The workshop participants expressed that the lack of Danish indicators make it hard to set specific goals and requirements in construction projects explicitly linked to the SDGs. Furthermore, the participants expressed that the global nature of the goals is far from the challenges they experience in a Danish context, and therefore it can be challenging to fully commit to the SDGs. The building owners add that the interpretation of the SDGs can differ a lot within different organisations and that even when the local indicators will be presented, they will still need to be adapted specifically to the construction context. Along these lines, the measurability of the SDGs was also highlighted as a barrier. To be able to set goals regarding the SDGs, the building owners need to be able to measure the performance within individual construction projects. Also, it is easy to say that you adapt the SDGs when there is no baseline and local indicators, and there is a risk of greenwashing, the participants expressed. Along these lines, it was stated that there is a need for a Danish baseline, and, as mentioned in the introduction, a Danish baseline has only been developed for goal 11 (sustainable cities and societies) so far (Dansk Arkitektur Center and Rambøll Management Consulting, 2019).

Solutions to these challenges were suggested by the participants as developing new tools that can support the measurement of the goals and make them tangible. It also suggested that a common ground and language within the industry regarding sustainable building design and the SDGs should be established, including the

prioritisation of the SDGs in construction. As the Danish building industry has already chosen DGNB-DK as a framework for sustainable building design, the SDGs should be integrated or aligned with DGNB-DK to not introduce a new, different framework. The Danish Green Building Council has already integrated the SDGs in a new manual which is currently under development. Also, political initiatives and requirements for implementing the SDGs were suggested to motivate the implementation. New requirements based on the SDGs should be added to the building regulations, the participants suggested. The public building owners added that political prioritisation of the SDGs is a prerequisite for their adaption and engagement.

Tools for measuring performance in relation to the SDGs and making the SDGs tangible would be an aid in implementing the goals, according to the participants. Along these lines, a common tool to track measures and ranking the effort towards the SDGs in construction was suggested (e.g. inspired by the SDG index (Sustainable Development Solutions Network and Bertelsmann Stiftung, 2019)). A shared platform which connects the different certification systems applicable in a Danish context could also be useful, argued by the participants.

Time and costs

In relation to time and costs, the participants expressed that extra time is spent on getting to know the SDGs, before being able to implement them, and that is an extra cost for the organization. Also, if certification is needed for the SDGs on individual projects in the future, extra time spent on certification would be expected, as the building owners currently experience with creating documentation for DGNB-DK assessment. The participants argue that the occupants need to understand the SDGs and their importance, to be able to prioritise them. This is especially relevant for Danish housing associations, as the occupants are the decision makers regarding major renovation projects. Along these lines, the total costs perspective was also highlighted as important, to show the potential value of sustainable solutions to the decision makers. To overcome the barrier of time and costs it was suggested to clearly communicate the value of the SDGs to create commitment among the building owners, end-users, and other decision makers, such as politicians. Economic incentives were also suggested as a motivational factor.

Limited knowledge and information

The participants expressed that limited knowledge about the SDGs and their application in the Danish construction industry was perceived as a barrier for implementation. The building owners also miss practical examples and solutions of successful SDG implementation for inspiration, and they need the professional and industrial organisations to lead the way and commit to the 2030 Agenda. The building owners suggested that information should be made accessible to the actors within the construction industry, to support the adoption of the SDGs. This indicates that knowledge regarding the implementation of the SDGs in construction is needed on a local level, and that existing information need to be aimed more specifically towards the different actors within the construction industry, including the building owners, to become operational.

Process and the need for new tools

The participants expressed that it is challenging to adapt all 17 goals, and thereby all three dimensions of sustainability equally, and that, in their experience, the SDGs was often used as a retrospective checklist, and not as goals towards 2030. Also, the fact

that the actors change throughout the process of a building project is a challenge, as knowledge and decision rationale might not always be sufficiently transferred between the actors. The participants suggested that increased collaboration across the value chains within the construction industry, e.g., to create new products and business models, could improve collaboration and thereby support the implementation of the SDGs. Furthermore, it was expressed that the SDGs should be a part of the early goal setting in a construction projects, and that the involved actors, such as the architects, should include the SDGs in their proposals. The SDGs should be an explicit part of the agreement and negotiation from the beginning of a project.

The participants expressed that support is needed in prioritizing the goals and targets, as different interests within the organisations entails different prioritisations. Especially tools to support the implementation of the SDGs in the early stages of a construction project for goal setting was expressed as a need. A dialogue tool for building owners and advisors to provide requirements in the individual construction project could be a solution. Also, a dialogue tool to communicate important aspects with politicians regarding the SDGs was suggested (e.g. inspired by the REDIS tool (Gade *et al.*, 2018)). A framework to support planning on how to implement the SDGs in the construction industry and single projects could be beneficial.

CONCLUSION

This study investigated the challenges/barriers for the implementation of the SDGs for Danish building owners, and possible solutions to these challenges, based on a focus group and a survey with 22 professional building owners and advisors. The results showed that the five SDGs with the highest prioritisation among the building owners were Goal 7 (affordable and clean energy), Goal 11 (sustainable cities and communities), Goal 13 (climate action), Goal 8 (decent work and economic growth), and Goal 12 (responsible consumption and production). 94% of the building owners had implemented, or wished to implement, the SDGs in various degrees. However, they experienced multiple challenges; apart from the need for local SDG indicators the main challenges were: 1) lack of tools and methods to support the implementation of the SDGs in construction, 2) lack of knowledge regarding the SDGs among the building owners, 3) extra costs related to the implementation of the SDGs, including time spent on extra documentation. The main solutions suggested by the building owners to overcome the challenges were 1) development of new tools and methods supporting the practical application of the SDGs in construction, e.g., dialogue tools for goal setting and prioritisation and for measuring performance regarding the SDG in construction, 2) existing information should be aimed towards the actors within the construction industry, e.g., the building owners, along with practical examples for inspiration. The results presented in this paper fill a gap in the academic literature by providing valuable insights of the challenges experienced by professional building owners regarding the implementation of the SDGs, as a point of departure for future research and developing practical solutions to support the implementation of the SDGs. However, a limitation to the study is on the research participants which only involve 22 participants. Based on the results, the authors suggest that future research focus on developing tools and frameworks supporting the implementation of the SDGs aimed towards professional building owners.

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ARCHITECTURAL DESIGN OF VERTICAL EXTENSIONS OF BUILDINGS: A RISK PERSPECTIVE ON COMPLEXITY

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In Sweden, urban densification by vertical extension (VE) of buildings is one contemporary movement to meet the increasing urbanisation. The aim of this research is to increase the understanding of the complexity in architectural design (AD) of VE by applying a risk perspective. The proposition is that the uncertainties in the existing building (the host) create a demand for design adaptability of the extension and that this dependency, together with the inflexibilities in the extension, contributes to the complexity of VE. Empirical material was collected by in-depth interviews with eight experienced architects and followed by a theoretical analysis. The main contribution of this research is that it uses the complexity-uncertainty-risk interconnectivity to visualise the effect complexities in VE have on AD. The vertical interface is shown to be ambidextrous, both a difficulty and a solution. This adds managerial coordination complexity in the Swedish AD context that further the double-edged complexity of the vertical interface.

Keywords: Architectural design, complexity, retrofitting, sustainability, urban

INTRODUCTION

This paper addresses architectural design of vertical extensions of existing buildings. The issue is that existing buildings put additional constraints on the extension. Developing heritage and urban form while being technically sound and cost efficient thus involves risks that usually are not managed in the early phases of new-build projects. The background is that Sweden is facing increased urbanisation in a time where sustainable urbanisation is a priority, e.g., in the 11th goal of the 17 Sustainable Development Goals (UNDP 2020) which concerns sustainable cities. Of the current urban planning and design issues, urban sprawl (e.g. increased city area) is recognised as the one of the most urgent problems to solve (COM 2004). Nabielek (2011) argues that the focus rather should be on urban densification, as a strategy for sustainable development of cities. Urban densification is shown to reduce ethnic and socio-economic segregation (Nabielek 2011). In addition, Dodman (2009) discerns benefits with urban densification through lower per capita emissions. Bolund and Hunhammar (1999) underpin opposing arguments to urban density by stating that urban ecosystems are threatened and (Jim 2004; Fuller and Gaston 2009) that green areas might be reduced by densification. There is a conflict between densification, land use and environmental impacts of densification. Campbell (2007: 307) writes: "Though we live in a three-dimensional world, land is a limited resource with essentially two

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dimensions” and that the potential for balance between economic and environmental interests exists in design itself.

In Sweden, urban densification by vertical extension (VE) of buildings is one contemporary movement to meet the increasing urbanisation without additional land usage. This is valid for both commercial and residential projects, including hybrids. Industrialised house building (IHB) is a commonly used option for the additional, new part of the extension, partly because of the light-weight structure and as a solution for logistics in constricted urban spaces.

In this research, VE is defined as: A vertical addition of a host building that creates new or extends existing functions, both technical and operational.

With this definition, vertical extension can be related to retrofitting as one of three options (Figure 1) to add functions (dotted lines) to a host building (solid lines). This research addresses only Vertical Extension (1), which is different from Horizontal Extension (2) and Renovation (3).



Figure 1: Three types of retrofitting, horizontal view

From an Architectural Design (AD) stance, retrofitting allows for the preservation of the morphological and architectural identity of the existing building and urban setting (Nilsson *et al.*, 2014). However, retrofitting projects are considered as more complex and uncertain when compared to new build (Ali 2014; Nibbelink *et al.*, 2017) and a retrofit will mean more unknowns and greater risks (Abdou 1996). Decisions made at the early stage of design have major influence on the overall design performance such as cost and time (Ali *et al.*, 2008). Poor decisions made early in the design phase might explain problems encountered in the construction or maintenance phase (Emmitt 2014). The early decisions and perceived values in house building projects are often influenced by an architect’s design visions. Emmitt (2014) further states that the risks and uncertainties should be identified and managed to avoid compromising the projects’ value. However, Uher and Toakley (1999) found that application of risk management in the conceptual design phase was relatively low, accounted to various structural and cultural factors. These studies point to a motivation for, but also lack of, early risk management generally in AD and specifically in high complexity and uncertainty situations. The aim of this exploratory study is to increase understanding of the complexity in architectural design of vertical extensions by applying a risk perspective.

Architectural Design

Alharbi *et al.*, (2015) describe an architect’s three core areas as: design, technology and management, and how these interrelated areas depend on communication. However, the role and responsibilities of an architect is contingent on the specifics of each national building conditions and sector culture. Grange (2005) believes that Swedish architects wish for a stronger role. Emmitt *et al.*, (2009) mention that in the Swedish context the architects are quite invisible. Arguably, compared to other European architects, Swedish architects generally have much less managing responsibilities over parameters as economy and technology. In Sweden, the roles of the architect and the project manager are two different professions. A Swedish architect is more concerned with quality parameters such as the aesthetical and the

functional perspective whereas the project manager has the overarching responsibility with primary control over project objectives, like time and cost, on behalf of the client. This separation of roles has developed over time with the increasing demand for niche knowledge (Hansson *et al.*, 2015), resulting in the two professions becoming more specialists than generalist. This research follows the Swedish approach to the architects' profession (Figure 2). Based on management of the majority of Swedish house building construction project in all types of stages in design and with any contract, this interpretation defines the role of the project manager and the architect. Technology expertise lies with consultants e.g., structural or HVAC designers.

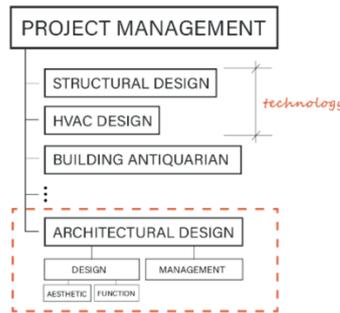


Figure 2: Scoping this research by defining architectural design in the Swedish context

Complexity, Uncertainty and Risk

As defined above, VE is a vertical addition of a building volume that creates new or extends existing functions, both technical and operational. Following the argumentation of Kivelson and Kivelson (2018), VEs can be considered complex systems since at least two parts interact dynamically to function as a whole and the parts are interconnected. Therefore, a complexity perspective is adopted, to portray and position vertical extension projects among other retrofitting or new built projects. Qazi *et al.*, (2016) agree that it is not only important to understand and evaluate project complexity but also to visualise the complex interaction between project complexity and complexity-induced risks. Chapman (2016: 938) argues for a link between complexity and risk and proposes that “a complex project is one which exhibits a high degree of uncertainty and unpredictability, emanating from both the project itself and its context”. Abdou (1996) characterizes a complex project as when new approaches paves for uncertainty. In addition, Botchkarev and Finnigan (2015) characterize it as when interactions of structural and dynamic elements occur across the broad categories of technical, organisational and environmental domains. Finally, Baccarini (1996) considers a complex project to be when many interrelated parts can be described as their degree of differentiation and interdependency. The construct in Figure 3 is used in this research to address complexity as an integrated component in the risk-uncertainty interconnectivity.

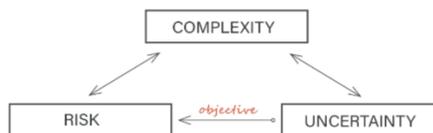


Figure 3: The complexity-uncertainty-risk interconnectivity

A risk is an effect of uncertainty on objectives (ISO 2018). In the context of projects, risk is associated with an uncertain event or condition that if it occurs possibly has an effect on the project’s objectives (Chapman 2001; Zou *et al.*, 2007; Ayyub 2014).

These objectives can be described by fixed measurable terms often as cost, time and quality (Hillson 2002). Consequently, risk cannot be defined without a relation to an objective. Furthermore, if objectives are flexible rather than fixed, and if objectives could be varied to cope with the effects of uncertainty, then risks wouldn't exist (Hillson and Murray-Webster 2017). This indicates that the possibility for flexibility or adaptability of objectives could affect risk management.

Uncertainties in risk analysis are often divided into two types; (1) aleatory (random) uncertainty and (2) subjective, epistemic uncertainty (Ayyub 2014). Epistemic uncertainties arise from lack of knowledge or understanding (Hillson 2004) while aleatory variability are not dependent on knowledge. Epistemic uncertainty is the most dominant type in risk analysis (Ayyub 2014) and the one that this research focuses on.

Vertical Extensions - A Matter of Adaptability?

Uncertainties in Retrofitting

In terms of the interconnectivity between complexity-uncertainties-risk, retrofitting stands out regarding the AD compared to new build. For example: “The development of design for refurbishment most likely depends on designer’s endeavours to gather information from the existing building” (CIRA 1994 as cited in Ali *et al.*, 2008: 390). Factors that contribute to complexity and uncertainty in retrofitting are identified by Ali (2014) to be e.g., unforeseen site conditions and lack of information during design stage, low quality of information feeding into the design process (Nibbelink *et al.*, 2017) and the fervently changing time-design equation (Abdou 1996). Consistently, Ali *et al.*, (2008) states that the uncertain conditions of the existing building limits in the available design information that consequently creates uncertainties in the design process causing high risk in decisions.

Inflexibilities in Industrialised House Building

Industrialised House Building (IHB) firms in Sweden organise their operations around total deliveries, structured into platforms. Their platforms use high degrees of both prefabrication and standardisation of components, and processes for building and logistics (Lessing *et al.*, 2015). IHB is the pre-dominant choice in Sweden for the extension part of the VE, partly because of the lightweight structure, partly because of the logistics solution offered. Arguably, the IHB solution offers predictability concerning delivery speed and dependability.

Based on the Swedish context, the position taken in this research is to consider VE as a retrofit with an extension of a pre-constructed (IHB) structure. Consequently, the inflexibilities of IHB must be considered. The level of flexibility in design adaptation to building specifications decreases with a high level of predefinition (e.g. Jansson *et al.*, 2014). IHB platforms do not support generality, while host buildings cannot be controlled to suit IHB platforms. Here is a possible conflict that this research addresses. The reduced design flexibility inherent in IHB can increase risks when confronted with functional and technical requirements and conditions of the host. The complexity-uncertainty-risk interconnectivity can increase even further because of the difficulties to determine the host conditions, in turn caused by lack of as-built information of the host. In the VE setting, the balance between prefabrication and standardization imposed by IHB limits the adaptability of the extension in relation to a required adaptability to the host.

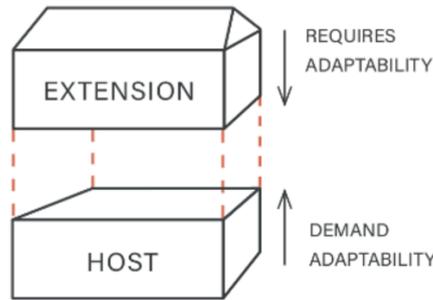


Figure 4: The adaptability dependency between a host and an extension

The proposition that this research intends to evaluate is that there is demand for design adaptability of the extension which generates a design adaptability dependency, and that this dependency contributes to the complexity of VE (Figure 4).

METHOD

Context-specific data collection from VE-projects was considered essential to increase understanding of the complexity from an AD point of view. This speaks in favour of a qualitative method since the intention was to study the phenomena in its real-life context (Yin 2011). To address the aim and specifically how adaptability contributes to the complexity of VE, an exploratory and qualitative design was considered suitable. To gather deep empirical material the method of qualitative in-depth interviews was preferred, an approach that aims to depict a complex phenomenon by the respondent's viewpoint (Yin 2011). These were conducted with an open approach where there was only an outline of subjects prepared. Supplementary questions emerged along the interview and thus varied based on respondent's story. The interviews were held March-May 2019 with eight architects from different companies, all with experience of recently completed VE projects in Sweden. The selection of respondents was made so that their projects' character varied based on place (urban density), function/operation and material for the extension (Figure 5). Large variety was important, from the representative projects, to be able to characterise complexity in AD of VE in general, regardless of these variations. The respondents' involvement in the design phase narrate what content this research is based on.

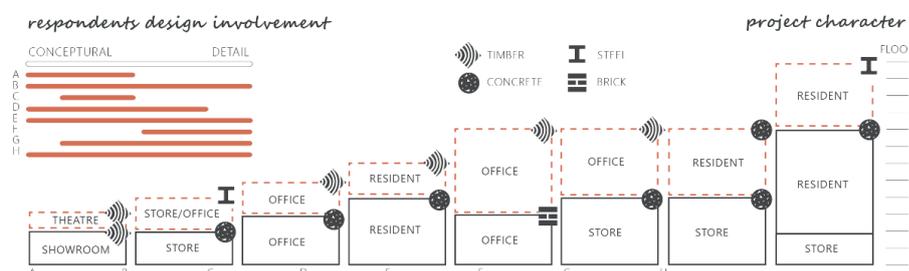


Figure 5: Respondent overview

Based on the complexity-uncertainty-risk interconnectivity (Figure 3) the interview subjects were centred on the quality objective related to AD (Figure 2). Design issues or problems that occurred in real projects were identified, relating to risks as an uncertainty that has effect of objectives, a risk that has happened (Hillson 2017). The interview subjects were put together in a two-dimensional logic: first about positive insights covering AD issues from the real projects, second zooming out to vision

opportunities and obstacles for vertical extensions in general to detect opportunities for sustainability drivers of VE and for insights into further research.

The interviews lasted 70-150 minutes and were all recorded and transcribed. Data analysis was done in two steps. The first step was thematic coding, which can provide a rich and complex data and generate unanticipated insights (Braun and Clarke 2006). The codes used to filter the data originated from the theory presented above and are listed in Figure 6. Braun and Clarke (2006) argue that this theoretical thematic analysis is driven by the researchers' analytical interest and tends to generate less description on the overall data. The choice between data-driven or analysis-driven coding depends on the question. Since the question here is to investigate complexity in AD of VE by adding a risk perspective the logical choice is to begin with risk-theory and then look at risk-theory in the context of retrofitting and IHB. The second step in the analysis was interpretation, which is essential when aiming to understand the data (Flick, 2014), by adding the complexity-uncertainty-risk interconnectivity (Figure 3) when viewing the data.

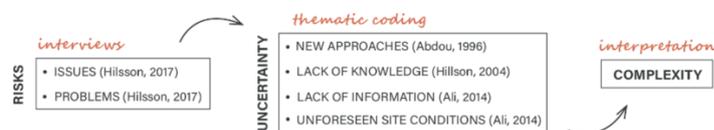


Figure 6: Research approach

Architectural Design of Vertical Extension as a Complex System of Components

The following findings are the main take away from the interviews. They are presented to illustrate the complexity in AD of VE projects. The intention in all eight VE projects was to extend or create new functions. In all eight projects IHB was used for the extension. Here the findings from occurred issues (risk) regarding uncertainty are themed as derived from different components in VE-projects, altogether leading to complexity by interpretation (Figure 6).

The Host / Extension Adaptability Dependency

Many of the uncertainties in the VE projects studied originated from lack of information about the host's condition. ["It is a never-ending detective work and some guesswork if the information is correct"]. Due to this, late changes were imposed when updated information of the host was provided. When conditions in the host became known, the new frame of requirements sometimes largely changed the AD possibilities that also needed to correspond to the IHB extension adaptability requirement to accommodate changes in layout. In many projects, due to lack of knowledge or/and information regarding the host condition or the IHB extensions adaptability requirements, the structural designers underestimated the task for proper structural design and thereby gave the architect incorrect information for the possibilities in AD. ["They promised a little too much in the beginning, and then they realized that there were some limitations."]. It was also brought up that new building approaches like IHB timber structures added problems, ["Few structural designers know how to deal with timber"] which according to Abdou (1996) generates uncertainty that contributes to complexity. In some cases, the updated information of technical or functional requirements of the host demanded that adaptation of the IHB extension to the new conditions. The host / extension dependability illustrated above adheres to the complexity-uncertainty-risk interconnectivity in Figure 3, the interdependency as a factor for complexity described by Baccharini (1996) and that lack of knowledge adds to complexity and uncertainty in projects (Hilsson 2004; and

Ayyub 2014). Consequently, flexibility and adaptability are essential characteristics of the extension (cf. Figure 4).

In summary: The combination between lack of information and knowledge (uncertainty) and constantly changing information of conditions in the host requires adaptive visions (objective) and a flexible design of the extension to prevent the system from locking. The factors leading to uncertainty do all contribute to complexity of AD in the case of VE.

The Vertical Interface - a Possible Solution

Figure 7 conceptualises the architectural design risks in the form of interacting components (host, interface and extension) that together generate complexity. The main uncertainty factors are the uncertainties in the host that combined with the adaptability dependency in the interface generate large risks. Many of the AD challenges originated from what can be called the interface between the host and the extension consisting of a technical and a design dimension.

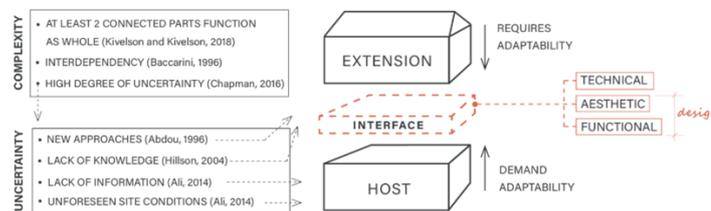


Figure 7: Architectural design of vertical extension as a complex system of components

The Technical Interface

The technical interface includes demands for connecting the structural systems of the host and the IHB extension and services systems (e.g. HVAC). In some projects specific physical interface structures were designed, called a waist by the architects. [“We had a waist, as we call it, an installation floor of about a meter high that is in the transition between the existing and new building where we can distribute installations horizontally”]. This interconnected solution loosened flexibility requirements on the IHB extension and opened for AD, e.g., more freedom in the layouts. The waist can be viewed as an adaptability zone that minimized the interdependency between the extension and the host. However, the waist led to increased total building height. Since the detailed development plan often have restrictions on maximum building height (meters) based on standard floor height this creates a problem. Consequently, this not only added technical complexity to the VE project but also created a time-consuming iterative process with the municipality and within the design team. However, flexibility in the development plan objectives could reduce risks emanating from the vertical interface, as described by Hillson and Murray-Webster (2017).

The Functional and Aesthetical Design Interfaces

The functional interface regards the communication service as well as the intersections of the layouts. Earlier functional standards utilized for the host are not compatible with the accessibility requirements needed for the VE which sometimes led to design changes in the host to meet contemporary requirements of communication and fire safety. [“The challenges are always communication; can you use the same stairwell? The elevator is outdated, does not meet today's requirements for accessibility and it may not be so easy to extend the stairwell”]. Issues also arose in some VE projects with multi-functional purposes, which entail heterogeneous functional interfaces. One example of incompatibility was when apartments in the

extensions were placed on top of an office host building ["When the existing building was not intended for housing, there are divisions of the supporting structure that can pose problems. The dimensions were not equivalent to what we have as IHB housing module measures."].

The challenges in the aesthetical interface were mainly concerned with bringing the two facades together aesthetically. Proportions were mentioned as one of the main concerns from the municipality (the local planning authority) and spoken of as a great challenge for the architects. ["I think the proportions are very difficult.", "It was very much the municipality that wanted three distinct bodies to break up the scale."] This can be managed by working with the waist, or using tools like colour, shape and material to contrast or integrate. One example was to let materials converge in the waist. ["The idea was to be able to respect the existing tile through this waist and at the same time disconnect these two building parts from each other."].

In summary, the interface, not the host and extension per se, induces the most architectural design complexity to the system of components. The extent of the challenges in the aesthetical and functional interface seems mostly to be linked to the rationality of the technical interface, thus a possible solution for AD complexity. However, the design of the technical interface is not traditionally the (procured) responsibility for architect in the Swedish AD context which then required a lot of coordination and information management by the architects (Figure 2). ["Formally, it falls to the project management, but we had many visible installations and suddenly it became an issue of aesthetics, so we tried to manage those issues as well"] The importance of managing the risks in the interface reoccurred in many interviews. ["We have seemingly a lot of responsibility in the coordination, but we have no power over the consultants."]. Arguably, the possibilities for architects to manage AD risks lie in taking on a complex coordination and communication task between technical consultants, the municipality (as the local planning authority) and the IHB system supplier.

CONCLUSION

The aim of this research is to increase understanding of the complexity in architectural design of vertical extensions by applying a risk perspective. In this paper, this has been met by viewing VE as a system of uncertain components and by highlighting the adaptability dependability concentrated in the interface between the host and the extension as the main complexity. The vertical interface is ambidextrous since it is both a unique AD difficulty in VE and a possible solution for the adaptability dependency. Flexibility in architectural design in VE is dependent on technical solutions of the interface that in the Swedish AD context adds managerial coordination complexity which in turn further the double-edged linkage complexity of the vertical interface. The research also points out that there potentially is a gap in the Swedish architect's authorised management responsibilities and those unofficially taken on.

Moreover, in VE projects, sustainability goals for urban densification imposes additional complexity-uncertainty-risk interconnectivity. To reach such goals, it is important to understand and manage this interconnectivity. Consequently, future research will investigate those risks further, using risk identification techniques.

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DECISION-MAKING PROCESS TO SELECT ENERGY-EFFICIENT RENOVATION ALTERNATIVES FOR RESIDENTIAL BUILDINGS: TWO CASE STUDIES

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In the EU, buildings consume 40% of the final energy and are responsible for one-third of the CO₂ emissions. Since new buildings account just for 1% of the stock, the largest opportunity to implement energy efficiency comes from the renovation of existing buildings. However, renovation projects address particularities that make the selection of suitable options a complex process. Developing tools to support this process requires to get a better understanding of who participates, what criteria stakeholders consider, how they assess alternatives, and what methods they implement. Therefore, this paper studies how the decision-making process was performed in two residential case studies: An apartment building in Spain, and a set of dwellings in The Netherlands. The main goal is to identify stakeholders, objectives, criteria, alternatives assessment methods, and the sequence of the decision-making process. Findings are contrasted with concepts presented in the related literature. Results show that not only energy-related activities are considered in the decision-making process, but also additional renovation tasks that are performed simultaneously. Social criteria play an important role in the process. Moreover, renovation deals with stakeholders' interactions related not only to the landlord/tenant dilemma, which may impact the process and final solution.

Keywords: building renovation, decision-making, energy efficiency, sustainability

INTRODUCTION

Buildings account for 40% of the EU's energy consumption, 36% of its CO₂ emissions and 55% of its electricity consumption. The rate at which new buildings either replace the old stock or expand the total stock, is about 1% a year (Artola *et al.*, 2016). This implies that the renovation of existing buildings is key for achieving sustainability at the urban level. According to Artola *et al.* (2016), renovation rates should increase from 1% to almost 3% to accomplish the energy-saving targets of the 2030 Agenda. In this context, building owners, investors and other stakeholders need proper support and tools to choose suitable renovation options. A renovation alternative may include a single measure such as façade insulation, or packages of measures such as window replacement, façade and roof insulation, and mechanical ventilation units. While stakeholders, alternatives design, and other aspects in new construction are well established, renovation encounters specific conditions that may impact the way the final solution is selected. Ferreira *et al.* (2013) show that most of the decision-making tools have been developed for new buildings and renovation, just a few of them focus only on renovation projects. While decisions in new buildings

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involve only a few stakeholders such as designers, architects and investors, one of the particular elements in renovation projects is the involvement of tenants and building managers (Jensen and Maslesa, 2015). These additional stakeholders may define different criteria to choose the final renovation solution. Moreover, existing conditions of the building may call for objectives and renovation options that cover not only building energy performance and comfort issues but structural, accessibility and other aspects.

A closer study of the decision-making process in real renovation cases may contribute to understanding who participates, what procedures the stakeholders follow, what criteria they consider, how they assess alternatives, and which decision-making methods they implement to choose the solution. Therefore, the main goal of this paper is to study how the decision-making process is conducted in real residential renovation projects. To this end, two real cases are studied to map common practices, identify stakeholders, objectives and criteria, and methods to assess the renovation options. A sequence chart of the decision-making process is developed for one of the cases. These elements are contrasted with the related literature to identify gaps that may be covered by decision-making tools addressing renovation projects. This analysis may support the development of decision-making tools aligned with common practices of stakeholders, the information they have access to, and strategies that allow considering their preferences. The paper is structured as follows: First, the background and motivation are presented. Second, the methodology to capture and analyse the data is summarised. Third, the two case studies and results are introduced. Finally, the discussion and conclusions are synthesized. In this paper, *renovation* will be used as a general term comprising improvements in the form of refurbishing or retrofitting.

Background and Research Motivation

The steps often considered in decision-making processes can be described as defining the problem and objectives, identifying criteria and alternatives, criteria weighting, aggregation of weights and alternatives performance, and final decision (Majumder, 2015). All this process is carried out by the stakeholders involved in the decision-making process. In renovation projects, there are multiple stakeholders with different interests, but except for the landlord/tenant dilemma, these interests are not contradictory (Jensen and Maslesa, 2015). However, decision-making tools should enable the active participation of the different stakeholders since their preferences are relevant along the process. In countries such as Denmark, the law demands that tenants vote to approve the renovation project, while in Spain the regulation asks the owners to vote on the project. Nevertheless, most of the decision-making tools presented in the related literature are based on literature reviews, researchers' suggestions or certification schemes and do not include directly practitioners, users, investors and other stakeholders in their development.

According to a review conducted by Nielsen *et al.* (2016), most of the tools developed for decision-making in renovation focus only on specific aspects such as performing simulations or criteria weighting, but elements such as goal setting and the integration of weights and alternatives are considered in fewer studies. One of the main steps in the decision-making process is to define the objectives, they are the starting point to identify criteria and characteristics of alternatives. In the literature, a few tools as the proposed by Jensen and Maslesa (2015) rely explicitly on the discussion of objectives with stakeholders, other tools include choosing goals but do not mention how to do it

(Nielsen *et al.*, 2016). According to Jafari and Valentin (2018), reducing Life-cycle cost is the most frequent objective in decision-making tools for optimal building renovation, other objectives comprise reducing energy consumption, increasing energy savings, reducing CO₂ emissions, and increasing thermal comfort. Once the objectives are established, alternatives to accomplish them should be identified. Pombo *et al.* (2015) conducted a review of renovation measures applied to different kind of houses, showing that envelope insulation, windows replacement and air sealing are the most common strategies. Other measures comprise the renovation of heating, cooling, and lighting systems. A renovation alternative may include one single measure or a package of measures. Evaluating the multiple possible combinations of these elements considering materials, dimensions, configurations and other parameters may represent thousands of options. The high number of alternatives and multiple variations of each one makes the analysis and decision-making process for renovation very complicated (Jafari and Valentin, 2017).

To assess how alternatives fulfil the objectives, it is necessary to define a set of criteria which quantify directly how the alternatives perform on the objectives. These criteria may be quantitative or qualitative. Kylili *et al.* (2016) identified eight generic categories to classify criteria for renovations, including conventional categories such as environmental and economic, and other groups such as technological, time, and disputes. However, most of the studies follow the traditional triple bottom line integrating environmental, economic and social criteria (Taillandier *et al.*, 2016; Kamari *et al.*, 2017; Li and Froese, 2017; Jafari and Valentin, 2018). Criteria considered on those tools comprise energy efficiency improvement, investment cost, acoustic, thermal and visual comfort, and among others. Pombo *et al.* (2015) show that economic and environmental criteria are included in most of the studies, while social aspects are barely considered. Other studies such as (Dodd *et al.*, 2017) follow environmental and life-cycle cost principles, including global warming potential, construction and demolition waste or materials, and cost.

After defining the criteria, approaches such as the Analytic Hierarchy Process (AHP) assign weights to them to capture the stakeholders' preferences. The selection of the weighting method and the weights themselves have repercussions on the final rank of alternatives. Weighting methods can be subjective, objective or a combination of them. In subjective methods, criteria weights are derived from the stakeholders' judgment, while in objective methods, the weights are obtained from mathematical models (Zardari *et al.*, 2015). According to Nielsen *et al.* (2016), AHP is the most used weighting method in decision-making tools for renovation. Other approaches include Direct raking, SMART, and Entropy method. After defining weights, they and alternatives performance are integrated to obtain the final ranking. Integration approaches include methods such as Additive Aggregation, AHP and ELECTRE. Dirutigliano *et al.* (2018) use the PROMETHEE method to rank different renovation alternatives, while Taillandier *et al.* (2016) incorporate ELECTRE III to their tool.

The fragmentation of the process, the large number of proposed criteria and the small number of studies regarding the stakeholders' interactions may reflect the complexity of the decision-making process in renovations. Some studies have focused on understanding it better, Gohardani *et al.* (2013) examined the decision-making process to identify the drivers of energy renovations, analysing three case studies through semi-structured interviews and questionnaires. Kim *et al.* (2019) analysed a renovation project at an education institution, using semi-structured interviews and general data to study the factors considered when making a decision. As the best of

our knowledge, such a study has not been conducted in the residential field. Therefore, it is required to understand better how the decision-making process is conducted in practical residential renovations to explore aspects that have not been studied in detail, map common practices, identify stakeholders' perspectives, and identify gaps between theoretical and practical approaches.

RESEARCH APPROACH

The research approach focuses on studying how the decision-making process to select renovation alternatives for residential buildings is executed in practice. The main goal is two-fold: 1) To identify key aspects including objectives, stakeholders, alternatives and criteria, and process; 2) To contrast the findings with concepts from the related literature to identify gaps and elements that should be addressed by decision-making tools in this field. To this end, we analyse two real case studies: A twelve multi-family apartment building in Spain, and a 79-unit dwelling, in a district in The Netherlands.

We collect general information from the two cases and conducted semi-structured interviews with the project's supervisor from the case in Spain and an architect, who monitored the case in The Netherlands. The former has experience in renovating different types of buildings, while the latter leads a firm in the renovation industry. A sample of the questions that guided the interviews is shown in Table 1. They were developed based on a grand tour approach and the queries presented by Gohardani *et al.* (2013) and Kim *et al.* (2019). The main goal is to address objectives, stakeholders, alternatives, criteria, weighting and integration methods, restrictions and tools. The interviews lasted around 60 minutes and were conducted in January and March 2020.

Transcripts of the interviews were coded and analysed individually using a deductive approach, the concept-driven content analysis was assisted by the qualitative data analysis tool ATLAS.ti. The initial categories correspond to objectives, stakeholders, alternatives, criteria, tools and methods, and restrictions. The codes gathered in each category are used to identify the main elements of the decision-making process, then we present a descriptive narrative. Finally, we contrast these elements with some of the concepts presented in the related literature.

Table 1: Interview questions

Topic	Question
General	- Could you make a brief description of the renovation project?
Objectives	- Could you describe the expectations you had from the renovation project?
Stakeholders	- Which stakeholders did you work with to select the final alternative? Were there any other stakeholder that should have been included? - Could you describe the process to select the alternative that will be implemented?
Alternatives	- Could you describe the renovation alternative that will be implemented?
Criteria	- Could you list the criteria that were used to assess these alternatives? - Which criteria were important for you? which were important for other stakeholders?
Tools and methods	- Could you describe the process to select the solution that will be implemented? - What kind of tool did you use to assess the alternatives and rank them? - Are you familiarized with decision-making tools or methods such as AHP?
Restrictions	- What kind of external restrictions (e.g. fire regulation, contract requirements, construction licenses) did you encounter during the decision-making process?

RESULTS

Table 2 summarizes the main aspects of the decision-making process extracted through the coding process of the interviews. The following sections analyse these aspects in detail, italicized texts correspond to quotes from the interviewees.

Table 2: Main aspects of the decision-making process in the two case studies

	Spain	The Netherlands
Main objectives	To reduce CO ₂ emissions and dependency from fossil fuels. To improve quality of life.	To improve energy performance. To improve comfort.
Main stakeholders	Owners, supervisor, design architect. Tenants had voice but not vote.	Owner, contractor, energy consultants, architects.
Decision-maker	Owners, at least 60% agreement.	Single owner.
Alternatives	Initially by combining insulation for façade options and windows types. Then, other aspects such as the refurbishment of terraces and internal pipelines were added.	Prefabricated façade, five scenarios considering different materials, windows sizes, insulation thickness and image.
Criteria	Main: Minimum technical requirements, investment cost and aesthetics. Secondary: comfort, operational energy cost, safety.	Main: Energy performance, energy savings, investment, comfort. Secondary: durability, endurance, and aesthetics.
Weighting and integration methods	No specific methods.	No specific methods.
Restrictions	Requirements imposed by funding entities, external renovations going on, fire regulation, conflicts between owners.	Façade building limits, regulation on the quality of prefabricated façade.

Case Studies and Objectives

The first case study is a building with twelve apartments and two commercial units, it is a typical case in Spain. It was constructed in 1950 and does not have any insulation on the façade nor the roof, and the energy performance is low. The local government and a European project are executing also a renovation at the neighbourhood level, which is out of the scope of this analysis. However, it is important to mention that these institutions provided funds for the building renovation and defined the connection to the district heating and insulation of the envelope as mandatory tasks. The public society representing the government would like to improve the quality of life of people. This goal is integrated with the aim of the general project: to reduce the CO₂ emissions and reduce the dependency from fossil fuels.

The second case study is a 79-unit dwelling, in The Netherlands. The dwellings were built in 1975 and are owned by a social housing corporation and occupied by tenants. According to the local regulation, the energy label was G, the houses were old, they had moist issues and low comfort level. The renovation was conducted in the context of a European project that looked for the implementation of innovative renovation elements. The interviewee mentioned that the social housing company was really ambitious with the project and wanted to renovate almost to zero energy. They also aimed at very comfortable new dwellings and building wise.

Alternatives

In the Spanish case, different options for the thickness, materials and technologies for the façade insulation were analysed including ETICS or just a ventilated cavity air façade... with mineral wool and with polystyrene. In a similar fashion, for the windows, two alternatives, aluminium with thermal bridge cut and PVC were analysed. Once the owners were engaged with the main renovation tasks, additional activities such as the replacement of terraces and internal pipelines were included in the options as a result of a building inspection that must be performed according to the Spanish regulation. The final solution includes the insulation of the envelope, roof and a ventilated façade, second external windows, the insulation of the first-ground floor slab, terraces, pipelines and boiler replacement, and heating exchanger installation.

In the Dutch case, the renovation alternatives focused on insulation for the façade, the stakeholders wanted to install fully prefabricated façade elements over the existing one. To study different alternatives, they used scenario thinking, they composed

different kinds of solutions, made a full scenario and look which were going to be the consequences. In total, five scenarios were evaluated varying the insulation, PV panels installation, windows size to increase the area of the closed façade, windows frames materials and closure. Since the roofs were renovated three years ago, they were not considered. The final renovation solution comprises the insulation of the full façade, installing a prefabricated façade over the existing one. This new façade includes the windows and doors. Moreover, the ground floor and the foundation were also insulated, and a new ventilation box was installed to improve the indoor air quality.

Stakeholders and Criteria

The main stakeholders in the Spanish case were the owners, the project's supervisor, and an external designer. The owners selected the final solution *in terms of technical solution, they also had to consider the cost which is really important, and they had to consider also the final appearance of the building.* It was not possible to implement the best solution in terms of technical aspects due to the cost, the designers *considered also to install a heat recovery system for the ventilation... the best technical solution is that one to avoid condensation problems... but at the end it was not affordable for the community.* Moreover, social aspects such as comfort were implicitly considered in the alternatives, *the comfort inside is considered in the whole frame of the project, with the minimum conditions, insulating and connecting to the district heating, comfort conditions improve higher than the current regulation in Spain.* Criteria such as maintenance costs were not relevant for the owners due to their perception of future uncertainties, the interviewee quoted one of the owners: *I do this investment now and who knows what will happen in 15 years.* However, the supervisor considered *how a material will perform in the future, trying to reduce the maintenance of it.*

In the Dutch case, the main stakeholders were the social housing company (owner), contractor, and producer of the prefabricated façade. Moreover, architects and energy consultants worked together with the contractor to evaluate the different scenarios. The final decision was made by the owners in conjunction with the experts, *they really looked at the energy and comfort also, and of course the investment.* Other criteria *comprise durability, if materials age good and maintenance cost, mostly in the form of endurance of materials.* Aesthetics was also included since it was going to be *a whole new architecture of the district, the whole district has a new face.* A group of tenants was involved, they were inquired to know their preferences. The main stakeholders *looked very closely at how to maintain and how to make it easy for tenants.*

In both cases, social aspects were highlighted. In the Spanish case, the supervisor stated: *we realized that going from the beginning with the energy efficiency idea is ok, but we have to mix it with other social aspects.* This is aligned with statistics in Spain showing that energy efficiency is relevant for renovations, but owners focus on other aspects such as accessibility, noise and safety (Ministerio de Fomento, 2017). In the Dutch case, the aesthetic was highlighted through statements such as *the architecture will be totally different, it is a whole new house, so it is like you have a new district, it is not the most important aspect, but it is an impressive asset.*

Tools and Methods

In the Spanish case, different tools were used to estimate the criteria, the supervisor mentioned multiple commercial software available for cost estimation. Moreover, for energy performance assessment, the usage of an official software tool is mandatory in Spain. The assessment of criteria such as aesthetics and maintenance needs relied on

experts and *the technical knowledge of the company... after building more than 8000 apartments we have a very good experience.* Neither decision-making framework nor weighting or integration methods were applied during the process. Additional tools were used to support visualization, *the alternatives had at least a picture based on the BIM model, working with photoshop we created different images, so they can decide.*

The experts from the Dutch case used excel sheets to assess the different scenarios. The analysis of the different alternatives relied mainly on comparisons of the quantitative criteria, energy consumption and investment. They had specific models for energy performance and financial tools for the investment. Neither decision-making framework nor weighting or integration methods were implemented during the process, the interviewee stated that *they did not weight or have a formula to say: this is four-time more important than that.* Moreover, the experts used renderings to present how the alternatives would look like, they built a sample of the façade and presented also material samples to show the external texture of it.

Sequence of the Decision-Making Process

One of the questions from the interview was explicitly intended to identify the steps followed during the decision-making process, based on the interview from the Spanish case, the sequence chart in Figure 1 was developed.

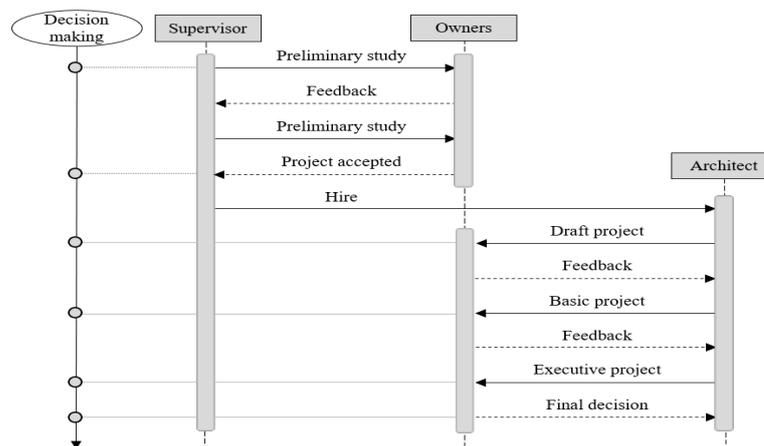


Figure 1: Sequence chart for the decision-making process case study Spain

The first step is a preliminary study, including a technical inspection. A proposal is presented to the owners, *we explain to them the different possibilities and what is the approximate cost and then they can decide if they want this project.* Then, the designer follows three steps: 1) To discuss a draft including energy efficiency actions and other possible tasks. 2) To introduce the basic project to discuss diverse aspects and provide advice to the owners. 3) To prepare the executive project, at this point *everything must be decided.* The owners analyse each renovation element, they vote and decide. In this case, the decision-making process took one year. In the Dutch case, it took around 4-5 months, however, the available data was not enough to develop a sequence chart.

Restrictions

The funding institutions in the Spanish case imposed some restrictions, they defined the connection to the district heating and insulation of the envelope as mandatory activities, influencing directly the final solution. Fire regulation influenced also the design, *when we offer the polystyrene, we have to divide the façade into different sectors just in case of fire to be under control.* Moreover, conflicts between apartment

owners and the owner of one of the commercial units ended in the partial insulation of the first-ground floor slab. In the Dutch case, restrictions came from the building borders, the new façade was installed over the existing one and enlargement thresholds had to be held. Additional, since the solution was a new prefabricated product, special attention was given to the quality assessment of the products.

Gaps and Opportunities

This section contrasts the findings with some of the concepts presented in the related literature to identify gaps and elements that should be addressed by decision-making tools for renovation projects. For instance, only a few studies such as (Dirutigliano *et al.*, 2018) consider renovation at the building and district scale in conjunction. However, in the Spanish case, the building renovation is executed simultaneously with a renovation at the neighbourhood level, funds and requirements for the alternatives were assigned in this context. This scenario calls for decision-making tools able to consider different scales and represent the effects of decisions made at different levels.

Most of the tools in the literature address only energy-related tasks, though renovation focuses on diverse activities. In the Spanish case, the project in the neighbourhood is *a comprehensive project to improve the quality, to improve the public space, to improve energy performance. At the building level, apart from this project of energy consumption reduction, we have also to add these particular things to solve what the technical inspection said.* Stakeholders may seek comprehensive alternatives, *some of the people understood this refurbishment as the possibility to do more things at the same time... they considered that once they have to invest money on the building, they prefer to invest once and solve everything.* Therefore, decision-making tools for renovation should be able to analyse not only the energy-related aspects but also other renovation tasks with different goals, that are performed simultaneously.

On the other hand, economic and environmental criteria are included in most of the related studies, while social aspects are barely considered. However, criteria such as low intrusiveness might have been relevant. In the Spanish case, the designers offer to the owners installing the pipelines from outside, *once we have the scaffolding, then we can do it from outside... what is very good because then we do not go inside the apartments.* In the Dutch case, the interviewee highlighted that the prefabricated solution was mounted in one day, and the renovation was performed in a habited condition. Moreover, other insights suggest that criteria may evolve along the process. At the beginning of the Spanish project, technical criteria such as energy efficiency were not relevant for the owners, *now maybe it is improving, but at the beginning of the project nobody was worried about the energy consumption, it was something like: I do not care, I have a heating system and it works, I do not care about that.*

Users and other stakeholders play a key role in the decision-making process, even though they are not considered in the development of most of the tools for renovation. In Spain, at least 60% of the owners must agree on the final alternative to obtain permission for construction. Multiple owners may have different preferences and even investment capacities. The supervisor stated that *this particular limit has been a barrier for us to get more communities involved in this type of refurbishments.* In The Netherlands, the owner must offer compensation and 70% of the tenants must agree on it. Asking the tenants their preferences might have contributed to reaching the 70% level. The monitor stated that *having the tenants happy with the renovation was an important part of the process.* In both cases, communication channels were

relevant, in the Spanish case, there was a campaign to engage the owners with aspects such as building insulation and district heating. The supervisor stated: *it was very important to have direct communication with me, everyone has my e-mail... if it is something important then we can organize a meeting with all the community.* In the Dutch case, *all tenants got personalized information, consultation hours were scheduled.*

Finally, not only the landlord/tenant dilemma brings opposite perspectives into the process, diverse interactions are encountered in renovation projects, these should be studied further. For instance, the owners of the commercial units in the Spanish case had the right to decide whether the first-ground floor slab is insulated or not. There was a conflict *between the community of apartments and the owner of one local, he did not want to do anything in this project.* This impacted the renovation solution *since on the first floor there are three apartments, two of them will be insulated from the ground floor and the other one no. Even if the whole community will improve the energy performance, in this particular first floor the improvement will be less.* The supervisor highlighted also the role of Community managers, *they do not take an official part, but in the process, they are very important... if they agree or they think somehow that the project is interesting, they push the community in that direction.*

DISCUSSION

One of the limitations of the study is related to the particularity of the two cases, both cases were conducted under research funding projects, this might have influenced the way the decision-making process was performed, and the definition of alternatives and criteria. Moreover, findings show that stakeholders' interactions may impact the renovation solution. However, the two cases represent very specific scenarios, in the first case, most of the units are occupied by the owners; while in the second case all the inhabitants are tenants. Scenarios with comparable quantities of owners and tenants may provide additional insights into the decision-making process and how the objectives, criteria and alternatives are modified by stakeholders' interactions.

CONCLUSION

The process fragmentation, the large number of proposed criteria and the lack of studies regarding stakeholders' interactions may reflect the complexity of the decision-making process in renovation. This paper studied how the decision-making process was performed in two real residential cases. The results suggest that not only energy-related activities are considered in the decision-making process, but also other renovation tasks that are performed simultaneously. Social criteria seem to play an important role in engaging stakeholders. Moreover, renovation projects may deal with stakeholders' interactions, not related to the landlord/tenant dilemma, which impact the process and final solution. Studies covering these aspects may support the development of future decision-making tools in this field.

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A MULTILEVEL SOCIO-TECHNICAL PERSPECTIVE ON WORK HEALTH AND SAFETY RELATED DESIGN DECISION MAKING

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Research in construction has identified considerable benefits in the integration of construction expertise and knowledge into early project decision making. Improved constructability and health and safety (H&S) have been frequently highlighted among other benefits. Research evidence has suggested that early-stage collaboration and effective interaction within and between design and construction participants are vital to make construction process knowledge accessible to design decision makers. Nevertheless, effective interaction still seems to be a problem in practice and in many cases, the efforts to promote collaborative interactions have failed to cope with the complex nature of the design process. Six case studies were undertaken to explore the way in which the interactions between design and construction decision makers impact on the quality of design decisions and H&S outcomes. The results of one case study are reported in this paper. Social network analysis (SNA) was applied to explore the patterns of interaction between project participants. Unlike the previous applications of SNA in construction, which have largely been cross-sectional and single-level in their focus, a multi-level framework was implemented to recognise the socio-technical complexities and interdependencies in design decision-making. Thus, the design process and its underlying interactions were explored jointly. The study evidence suggested that positive outcomes could be achieved through an alignment between the information interdependencies of the design decisions and the communication patterns that underpin them. The findings of this study can be used to understand, proactively design and maintain interaction networks that support effective decision-making in the context of ‘safety in design’.

Keywords: decision-making, health and safety, social network analysis, multi-level

INTRODUCTION

During the past two decades, there has been a growing understanding that the root causes of H&S incidents on construction sites can be linked back to problems inherent in features of work systems conceived in the early life-cycle of construction projects (e.g. planning and design stages). This understanding has led to the recognition of ‘safety in design’ (SiD) as a proactive H&S risk management approach. SiD aims to anticipate and ‘design out’ H&S risks at early project stages.

Despite the growing momentum surrounding SiD, research has indicated that, in many cases, designing for H&S has achieved suboptimal results in the construction industry

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(Atkinson and Westall 2010; Gambatese *et al.*, 2005). A number of factors have been proposed contributing to successful implementation of SiD, such as designers' knowledge and attitude towards the concept (Gambatese *et al.*, 2005) and clients' motivation and commitment and involvement of contractors (Goh and Chua 2016). However, a key issue, which remains unresolved, is that the efforts to improve H&S at the design stage have failed to achieve the required level of collaboration and integrated decision-making between design and construction participants.

Previous studies (e.g. Lingard *et al.*, 2014a; Gambatese 2000) have suggested that positive constructability and H&S outcomes are more likely if construction process knowledge is made accessible during design decision-making. Collaborative and effective interaction between participants involved in making design and construction decisions can facilitate knowledge and information sharing between project participants. Thus, participants' knowledge gaps can be addressed and there would be less reliance on inaccurate assumptions. This is particularly important in relation to SiD, which involves knowledge from two main areas, the design of the final product and the design of construction process. However, the organisational and contractual separation of the design and construction functions in projects often impedes free and effective communication between constructors and designers (Lingard *et al.*, 2014a).

Efforts to address this issue have not been completely effective. For example, it has been pointed out that integrated project delivery methods, aimed at addressing the separation between design and construction functions, do not guarantee improved safety outcomes (Atkinson and Westall 2010), and will not generate, as a matter of course, a positive cultural orientation to H&S (Ankrah *et al.*, 2009). In addition, knowledge support tools and processes, which aim to assist designers with H&S related decision-making, mostly take a linear and reactive approach. They normally draw on a limited set of pre-identified design solutions or encourage an add-on review process to enhance H&S after the design has already progressed through its stages and key design decisions are already made. The underlying problem with these efforts is that they mostly fail to acknowledge and cope with the complex and reflexive nature of the design process (Lingard *et al.*, 2014b).

A case study is presented in this paper to explore the way in which project interactions can address the knowledge requirements of design process and facilitate integrated design and construction decision-making. The study explored H&S related design decision-making and its underpinning interactions in a construction project. The aim was to understand the way in which interaction networks support collaborative design decision-making and impact upon construction H&S in the complex context of a construction project. To obtain a realistic view of the design process, a multi-level network analysis approach was combined with in-depth qualitative interviews with project participants. This approach particularly enabled the simultaneous investigation of technical decision interdependencies and the social interactions from which the decisions emerge. Consequently, it was possible to understand which alignments between social and technical aspects of design decision-making can lead to better H&S decision outcomes.

Socio-Technical Complexities Of Design Process

Design is socially and technically complex. Design activity involves a high level of interdependency between technologies, tasks or inputs from participants (Lingard *et al.*, 2012). Design teams are referred to as 'temporary, multidisciplinary and network-based organisations' (den Otter and Emmitt 2008). Design outcomes emerge from a

network of inter-related decisions made through repeated interactions between multiple participants. These interactions, in turn, form a complex structure of information exchanges underlying the design decision-making process.

Design is a multi-disciplinary and social process. Design solutions are shaped through the unfolding actions of participants and their interdisciplinary interactions (Çıdık and Boyd 2019). Because of the increased technical sophistication of modern construction methods and products, often, the required design knowledge is possessed by more than one participant (Pektaş *et al.*, 2006). Design knowledge and expertise becomes available during design activities when relevant participants engage in design decision-making and interact with other participants. Tryggestad *et al.* (2010) view construction design work as a collective activity characterized by social negotiations among coalitions of parties who engage in ‘trade-offs’ to find practicable solutions to emergent problems. Thus, underpinning each technical design decision, there is a network of social interactions between participants who contribute their knowledge and expertise to decision-making. As knowledge requirements of each decision-making scenario are different, the participants and the interaction network between them change at each decision point (Pirzadeh and Lingard 2017). At the same time, design decisions are technically interrelated with some decisions building on, and requiring information from, other decisions. The required information is often transferred between decisions through participants’ interactions.

The complex structure of interdependencies between design decisions and the social interactions underpinning them can be conceptualised as a multi-level network. At the macro-level, design decisions and the interdependencies between them form a technical network. At the micro-level, design participants and the information exchanges between them create a social network. The pattern of networks at these two levels are interdependent. On the one hand, design decisions at the macro-level are the outcome of interactions between participants. Each participant, depending on their expertise and decision-making power, exerts a degree of influence on shaping each decision outcome. On the other hand, the motivation for the interactions at micro-level is to address the information requirements of decisions at macro-level. Due to these between-level dependencies, the decision network and the interaction network constantly influence each other and evolve together during the design process. Recognising these multi-level socio-technical interdependencies can facilitate a realistic understanding of the nature of communication and collaboration in relation to SiD decision-making.

A network perspective has been previously applied to study participants interactions during the design process (e.g. Tryggestad *et al.*, 2010; Lingard *et al.*, 2014a). However, this application has predominantly been single level, mainly focusing on patterns of social interactions. For example, a high number of direct communication links between participants in the overall project network, indicated by a high network density, has been interpreted as a sign of better knowledge sharing and higher performance in project teams (see for example Chinowsky *et al.*, 2008). Although useful, this approach does not provide a comprehensive view of design process, as simplification is made by ignoring the decisions for which the interactions take place. Consequently, the important interdependencies between the social aspect of design decision-making (at the micro-level) and the technical aspect (at macro-level) are ignored in the single level approaches. In contrast, the multi-level network approach is powerful for recognizing the socio-technical interdependencies that exist between the macro and micro levels of relationships. In complex socio-technical networks (such as

design) analysing relationships at each level in conjunction with relationships at the other level allows more precision and detail, while analysing each level separately, would lead to losing insight about features of the bigger picture (Snijders 2016).

RESEARCH METHODOLOGY

A case study approach was adapted to enable an in-depth investigation (Yin 2009) of socio-technical complexities of design decision-making in a dynamic project context. The design and construction phases of a project were studied to understand the role of interaction patterns in supporting the integration of construction knowledge into design decision making. When selecting the project, it was ensured that (1) the project presented particular H&S challenges, and (2) all key participants involved in making design or construction related decisions were available and willing to be interviewed. Establishing the second criterion improved data reliability and ensured that project participants would be able to directly focus on and recall the decision-making process, the interactions related to it, and the decision outcomes (Lingard *et al.*, 2014a). Data collection was undertaken when the detailed design had mostly completed, and the construction activities were underway. At the commencement of data collection, in-depth interviews were conducted with six key project participants. These participants included the client's representative, client's logistics manager, client's consultant engineer, project manager, structural engineer, and construction manager. The interviews explored key decisions made in relation to design of the structure and their rationale, the process by which the structure was being constructed, the implications of the design decisions on construction process, and the way that construction H&S hazards/risks were controlled. Content analysis of the data revealed the key design decisions with H&S implications, their sequence and the decision circumstances. 19 key design decisions were identified. The data was also triangulated. This was done by comparing the statements of different interviewees and seeking further verification from them where inconsistencies between interviewees' recalls were identified. Thus, the impact of self-reporting bias and recall was minimised.

Subsequently, additional interviews were conducted to collect social network data for each of the key decisions. Using name generators, each of the key participants were asked to identify other participants whom they interacted with during each of the decisions. This approach helped to identify and include other participants in the interaction networks. The participants were then asked to rate the frequency of their interactions with each of the other participants at each decision point. All types of interactions were included. The frequency was captured using a 5-point Likert response format ranging from 1 (occasionally) to 5 (daily). The existence of each communication link was confirmed with both of the interaction participants. Where they rated the frequency differently, the lower value was used. Collecting interaction data at each decision point helped the participants to better focus on the relevant information exchanges associated with design and improved the validity of data. In addition, for each decision, participants were asked to rank other team members in terms of their influence on decision-making. A participant's 'decision-making power' was then calculated by adding up the rates received and was scaled to range from 0-5.

Analysing the multi-level interdependencies

A social network analysis (SNA) technique was applied to visualise and analyse the network patterns at each decision point. In addition, a multi-level network was created to simultaneously capture and analyse the technical interdependencies between design decisions and the social interactions between participants. The macro-level network

consisted of the design decisions and the technical interdependencies between them. The micro-level network represented the social interactions that took place between the participants during the design process. The meso-level network indicated the involvement of participants in decisions based on their decision-making power. That is, a tie between a participant and a decision was established where the participant was involved in making the decision and had power to influence the decision outcome. To analyse this network, exponential random graph models (ERGMs) were used.

ERGMs are a class of statistical models for social networks. They facilitate the empirical examination of complex network structures. They are useful for examining multi-level and multi-theoretical hypotheses about network formation (Robins *et al.*, 2007). Using ERGMs, a set of basic network configurations are selected. These configurations are assumed to emerge from local social processes, which may be in action and shape global network patterns (Lusher *et al.*, 2013). Thus, by searching for these local configurations and assessing their prevalence in an observed network, it is possible to test hypotheses about the formation of the network. This is done by comparing observed networks with networks of a similar order which are generated by statistical simulation. If the probability of observing the same network pattern by chance is low, then there is confidence in the hypothesised social processes (Scott 2012). The set of network configurations used in this study and their explanations are provided in Table 1. These configurations represent the possible patterns of socio-technical interdependencies within the network. When illustrating the patterns (in the second column), circles indicate participants and squares signify decisions.

Case study project

The case involved the design and installation of the roof structure for the storage facility of a plant in New Zealand. The project was procured using a design and construct (D&C) approach. At the early stage, the client engaged a consultant to review the design of client's facilities in other locations to capture their best design features. Based on this review, a generic design was developed with a strong focus on operations and end-use features, as well as health regulatory requirements. The generic design specifications were handed over to the constructor. The contractor suggested revisions to the roof design. It was decided to install trussed rafters connecting to the main spine trusses instead of using steel I beams. The trusses weighed less and were quicker and easier to install. All steel was manufactured off-site. Truss sections were transported to the site and bolted together at ground level, then lifted into position. All supporting columns were fitted with a bearing plate allowing trusses to be temporarily supported while connections at each end were bolted. The structure was designed so that erection could be done in self-supporting sections. These decisions greatly reduced the amount of on-site work. The large trusses were manufactured in sections and transported to the site.

RESULTS

Constructor's influence on design decisions

As the interviews revealed, in spite of the client's emphasis on end-use requirements, the constructor was still given authority to make decisions about details of the building design and the construction process, and apply their construction expertise and experience during the structural design process. Decisions about the design and arrangement of roof structural members involved the constructor, constructor's engineer and client's engineer. The constructor was central during the interactions acting as a 'broker', i.e., providing the only point of contact between the other

participants. This position, enabled the constructor to involve their experience in design activities and influence decision outcomes to improve constructability and H&S. For example, based on the constructor's experience, a decision was made to use trussed rafters, rather than I beams, resulting in a lighter roof structure which was quicker to erect. Similarly, it was decided to divide each truss span into three smaller sections. This made transportation safer, and reduced workers' exposure to hazards associated with lifting and moving heavy and large objects on-site.

Involvement of subcontractors as a source of construction expertise

The subcontractor (steel erectors) was involved in the interactions in relation to construction process, for example, when it was decided to manufacture the roof trusses off-site. This decision significantly reduced workers' exposure to on-site hazards such as fall from height, electrocution (on-site welding), ergonomic hazards, manual handling, and being struck by objects and equipment during the manufacturing process. In addition, the subcontractor suggested to bolt sections of the main trusses together on the ground and then lift them to their positions. This significantly reduced the amount of time trusses needed to be suspended from the crane, and the time and effort workers needed to spend fitting and connecting sections of trusses at height.

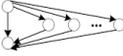
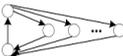
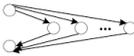
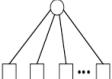
Multilevel analysis of socio-technical interdependencies

Apart from the analysis of interactions at each decision point, a multi-level network analysis was performed. The model comprised both interaction-level (micro-level) effects and cross-level effects. The goodness-of-fit check showed the model was capable of reproducing the properties of the observed network well. The absolute values for the goodness-of-fit ratios were well below suggested thresholds: that is, ratios were less than 0.1 for fitted effects and less than 1.5 for unfitted effects. The results of the network analysis are provided in Table 1. The significant estimates are marked with a * and indicate the associated configurations were observed more than anticipated (if the parameter value had been 0), given the other effects included in the model. The standard errors are provided in brackets under parameter estimates.

The positive and significant parameter estimate for a *multiple connectivity* effect in the model indicates that open two-path configurations were likely. This suggests a tendency for the participants to exchange information through others. Furthermore, non-significant *closure* estimates suggest no tendency for the participants to directly interact. Thus, there was a preference to exchange information through a few central participants in the interaction network. This result agrees with the results from the analysis of interactions at key decision points indicating that the constructor was a central actor and mostly the only point of contact between others.

The positive and significant parameter estimate for *affiliation-based closure* indicates participants' tendency to be directly involved in making sets of interdependent decisions. In addition, the negative and significant estimate for *cross-level alignment entrainment* indicates a low tendency for individuals involved in different, but interdependent, decisions to directly interact. Put together, it can be concluded that the interdependent decisions in this case were more likely to be made through direct involvement of common participants. Thus, the associated information was transferred between dependent decisions through direct involvement of relevant individuals (with power to influence decision outcomes), rather than only through interaction between them. Overall, these significant effects suggest that, where decisions were technically depended on each other, the participants were the primary means of transferring the relevant knowledge and expertise between the decision-making situations.

Table 1: Basic network configurations, their explanations and their estimates in this study

Effects	Pattern	Interpretation in this study	Estimates
Arc		This parameter refers to the baseline tendency for formation of social interaction ties.	-8.3653 (5.389)
Two-path		This refers to the extent to which social actors who send out information also receive information.	-1.0081 (0.699)
Transitive closure		This parameter indicates a tendency for social closure in network.	1.904 (3.209)
Cyclic closure		This parameter refers to the tendency for social interaction to occur in non-hierarchical cycles.	-0.1089 (3.002)
Multiple connectivity		This parameter reflects the extent to which actors interact indirectly through others.	2.6252 (1.189) *
Cross-level edge		This parameter indicates the baseline tendency for actors' involvement in decisions.	-4.628 (2.368)
Cross-level 3-star connectivity		This parameter reflects central decisions in which a high number of actors are involved.	-0.0971 (0.097)
Cross-level 3-star connectivity		A positive value for this parameter indicates there are influential actors involved in multiple decisions.	0.0076 (0.003) *
Cross-level connectivity spread		This parameter indicates influential actors in network who are involved in several decisions.	1.1004 (1.2)
Affiliation-based closure arc		This parameter indicates actors' tendency to be directly involved in interdependent decisions.	1.1498 (0.302) *
Alternative affiliation-based closure arc		This parameter indicates the extent to which dependent decisions involve a number of the same actors who are involved in both decisions.	0.1194 (0.767)
Affiliation-based closure arc		This indicates the tendency of actors involved in the same decision to interact.	-0.8361 (2.124)
Affiliation-based closure reciprocity		This indicates the tendency of actors making the same decision to engage in two-way interaction.	2.7917 (4.306)
Alternative affiliation-based closure reciprocity		This indicates the extent to which interdependent (mutually dependent) decisions involve a number of the same actors.	2.0105 (1.494)
Affiliation and within-level activity		This effect reflects the interaction tendency for actors involved in making unrelated decisions.	-0.006 (0.011)
Cross-level alignment entrainment		Indicates a tendency for actors who are involved in different (but dependent) decisions to interact.	-0.104 (0.047) *
Cross-level alignment reciprocity		Indicates tendency of actors who are involved in different, but mutually interdependent, decisions to engage in two-way interaction.	-0.3489 (0.34)

DISCUSSION

Integrated design and construction decision-making

While the network analysis revealed that the interactions were characterised by the existence of central participants, the interview data indicated that the constructor and design engineer were the highly central participants. The engineer was the main source of design knowledge who developed the detailed design. The constructor, on the other hand, was the main source of construction expertise. Their central role in interactions enabled these participants to input and combine their expertise during the design process. The result of this collaboration was improved constructability and H&S through consideration of construction process during the structure design.

Constructor's central role during communication

The multi-level network analysis helped to further understand the implications of the constructor's central role. The significant and positive effects for *cross-level connectivity* indicated the influential role played by two participants (constructor and constructor's engineer) in shaping design decisions. In addition, the significant and positive multiple connectivity effect reflected the tendency of project participants to exchange information indirectly through influential others. The overall interaction pattern indicated the constructor was the central participant through whom the majority of the information flowed. Hence, the constructor acted as a 'broker' during interactions and both facilitated and controlled the information flow. As the decision-maker about the construction process, this position enabled the constructor to draw on different sources and combine elements of knowledge to create effective solutions. The constructor's central position in the interaction network was coupled with high influence and high decision-making power. As the network analysis and the interviews revealed, the constructor had the highest involvement and influence among all participants. This enabled the constructor to understand the expectations of other parties and access their expertise as required. In addition, the constructor managed to involve their own construction knowledge and experience during the decision-making; that is, act as a source of constructability knowledge and experience where needed.

Involvement of subcontractor in decision-making

The data also revealed a high involvement of the subcontractor (steel erectors) when making key design decisions. The subcontractor was responsible for implementing the construction activities and also possessed the practical expertise about the installation process. The subcontractor's input to the design ensured that the construction process requirements and potential issues were identified and considered during the design of structural components. This finding is in agreement with previous studies which have recognised suppliers and specialist subcontractors for demonstrating innovative and independent decision-making in the design and manufacture of specialized building components (Lingard *et al.*, 2012).

Direct involvement of common participants in making interdependent decisions

The detailed multi-level network analysis indicated a significant and positive *affiliation-based closure* effect, reflecting the match between participants' expertise and decision dependencies and, more importantly, empowering the participants to directly influence decision outcomes where their skills were relevant. For example, the constructor and subcontractor were involved in both the design of trusses and structural connections which also had impact on constructability and H&S. An important finding was that the involvement of the participants was not only through interaction but also by having the power to influence the outcomes of related

decisions. This facilitated an efficient and direct transfer of knowledge and expertise between technically dependent decisions.

CONCLUSION

Effective implementation of safety in design benefits from collaboration and effective interaction between project participants. Particularly, the project interaction networks need to support the integration of construction knowledge to the design process. Understanding interdependencies between design decisions and interaction patterns can highlight opportunities for managing communication to produce better decision outcomes. The case study in this paper indicated that aligning the social and technical dependencies of design process can lead to positive constructability and H&S outcomes. Through this alignment, interaction networks would be more likely to address the knowledge requirements of design decision-making. Moreover, the multi-level network analysis indicated that this alignment was improved through two network configurations: 1) the cross-level alignment between interaction ties and decision interdependencies reflecting that the information was transferred between interdependent decisions through participants' communication; and 2) the cross-level (affiliation-based) closure which reflected the participant's high tendency to directly influence the interdependent decisions. While the importance of communication in the context of SiD has been highlighted in previous research, this study provides further evidence indicating that the direct involvement of participants with construction knowledge and their power to actually influence design decisions is a significant factor in achieving positive H&S outcomes. This direct involvement enhances the match between participants' expertise and design decision interdependencies and facilitates the effective mobility and transfer of participants' tacit knowledge between related decisions. In practice, this finding highlights that positive H&S outcomes are more likely when involving construction knowledge in design is coupled with construction participants' power to influence the decisions. For example, in the project presented in this paper, the constructor's ability to influence design decisions, in addition to their frequent communication with other participants, was a key factor for the structural aspects of the building to be designed with consideration of construction requirements. Therefore, to improve the H&S outcomes, project teams need to ensure both the involvement of construction participants in design and their ability to make decisions and influence the decision outcomes.

This study was limited in a number of respects. First, the results from a case study cannot be generalized to other projects. In future, the same approach may be used to conduct further case studies in different project settings. This will enable the comparison of the network features and patterns between cases (in a multiple case study setting) and may lead to stronger conclusions about the features of effective interaction in the context of SiD. Another limitation was the retrospective nature of data collection which involved a reliance on participants' ability to recall design events and communication activities. The impact of this issue was minimised by triangulating the data and conducting multiple interviews with participants from different organisations and roles and confirming the decision-making process and the interactions between them. In future studies, data may be collected in live projects.

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INFORMING EARLY STAGE DESIGN THROUGH LCC DATA

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Life cycle costing (LCC) has been proved to be a valuable decision-making tool for strategic facility management considering life cycle perspective of buildings. However, its application by the Architecture, Engineering and Construction industry is limited due to lack of available and reliable information. In order to overcome this challenge, researchers have proposed transferring information from operation of existing buildings to the design of new buildings. By using structured analysis methods and specifically, data flow diagram techniques, this study aims to explore how can data from existing social housing building projects with regard to cost drivers of LCC inform the design of new projects. To support the analysis, a social housing project in a Danish architecture firm is used as the case study, and data are gathered through physical artefacts and five semi-structured interviews in both the architect and building client organisation. The results indicate the availability of operational data in several of the processes in the data flow diagram of the case project. The discussion focusses on different ways that O&M data from existing buildings that are provided to the design team through a requirements' report when a new project is published, can be effectively used to identify cost drivers of LCC and inform the design of new projects. The consideration of cost drivers of LCC in early design stages will contribute to designing more economically sustainable constructions that are easy and affordable to operate and maintain.

Keywords: cost drivers, Life cycle Cost (LCC), social housing, structured analysis

INTRODUCTION

The past few years, the Architecture, Engineering and Construction (AEC) industry has shown increased interest in sustainability, focusing on the environmental performance, social quality and economic assessment of buildings in a long-term perspective. Life cycle costing (LCC) is a methodology that promotes life cycle perspective of buildings, considering not only construction costs, but also cost to operate and maintain them through their entire lifetime. Thus, LCC is used by architects and engineers as a decision-making tool to evaluate different design solutions that have different cost effect over time, based on several key factors like cost, quality and comfort (Haugbølle and Raffnsøe 2019).

Currently, there is an increased use of LCC in the design practices of the Danish AEC industry due to several new initiatives including the adoption of LCC by governmental regulations (Bygningsstyrelsen 2017) (Mortensen *et al.*, 2018), European procurement

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policies (European Commission 2014) and various certification schemes (DK-GBC 2012) (a detailed description can be found in the research by Saridaki *et al.*, (2019)).

Despite the increased application of LCC, there are still several challenges that obstruct the full integration of the concept. In a recent study by Saridaki and Haugbølle (2019), the authors conducted an extensive literature review and a case study analysis in a Danish architecture firm and identified several contradictions of integrating LCC in the Danish design practices. The results indicated that main contradictions are related to poor availability of data and the form of collaboration in the current design practices. Other researchers have also identified the lack of reliable data as a critical hindrance of applying LCC (Fu *et al.*, 2007, Gluch and Baumann 2004, Ruparathna and Hewage 2015).

In order to overcome the challenge of poor data availability, researchers and practitioners have proposed to transfer information and data from operation of existing buildings to the design of new projects. In their literature review, Rasmussen *et al.*, (2017) investigated different ways for transferring knowledge from operation to design, while Jensen (2009 and 2012) proposed different transfer mechanisms, like: codification of knowledge from building operation to increase awareness among designers, continuous briefing of facility managers and users during design process, project reviews to ensure that designers take considerations for building operation seriously as well as regulations to ensure that codified knowledge from building operation is used by the design team. However, several actors need to be involved in the process to successfully achieve knowledge transferring, including building clients to ensure knowledge transfer (Jensen 2009 and 2012), facility managers to provide great insights to new building projects (Jensen 2009 and 2012, Meng 2013) and buildings' users (Chandra and Loosemore 2012).

Throughout the practical experience of one of the authors in a Danish architecture firm, the authors recognize opportunities for transferring operational knowledge to design practices through social housing projects. Social housing (in Danish: Almen bolig), also known as affordable housing or non-profit housing, refers to residential houses owned by social housing organisations, which are characterised by a non-profit business. In Denmark, the social housing sector constitutes one fifth of the housing stock (Alves and Andersen 2015), as there are more than 600,000 social housing units that are distributed among 25 social housing organisations. Social housing organisations are, at the same time, building clients and facility managers as well as they also have close relationship with the buildings' users (tenants). Thereby, they are reasonably considered as critical actors for transferring operational knowledge to new building design.

The aim of this research is to explore the processes of social housing projects and identify cost-related data from operating existing social housing buildings floating between design processes that can be used as cost drivers with regard to LCC to inform the design of new building projects in relation to LCC. By using Structured Analysis (SA) methods, and in particular Data Flow Diagrams (DFDs) in a social housing project of a Danish architecture firm, the study aims to answer the following research question: "How can data from existing social housing projects with regard to cost drivers of LCC inform the design of new projects?"

This is the initial part of a research study that focuses on analysing the processes of social housing projects and identifying data with regards to cost drivers of LCC that can be used to inform the design. In future research, the authors aim to propose

interventions to the system that support the use of cost drivers of LCC to inform the design of new projects.

METHODOLOGY

In order to analyse the processes and identify data floating between the processes of social housing projects that can be used as cost drivers of LCC, the authors use structured analysis (SA) as an information analysis methodology.

SA was developed in late 1960s by Ross and his colleagues who use it as a methodology to describe complex IT systems such as the US Air Force Computer-Aided Manufacturing Project (Ross 1977). The methodology was commercially introduced in 1973, and since then, it has been applied in various project in diverse industries (Congram and Epelman 1995).

SA is successfully used for analysing complex systems and business requirements by describing a system of activities from a perspective of data flowing through it. Congram and Epelman (1995) stated that SA is helpful to understand what happens in delivering of a service, and it is a well suited methodology to structurally providing significant attributes of service description, such as: (i) who and what performs the activity (mechanism), and (ii) what guides or limits the activity (controls).

Various modelling tools are used to analyse systems in SA methods including, among else, data flow diagrams (DFDs). A set of interrelated DFDs, which are decomposed with the top-down approach, is used to represent a system (Wang and Tzui 1991). The top diagram summarises the diagrams below, which are arranged hierarchically and become increasingly more detailed at each level. DFDs are usually underpinned by a data dictionary and a process description document.

DFDs show the relationship between processes and data by using the following component (see Figure 1) (DeMarco 1979).



Figure 1: Data flow diagrams' components (Source: Adapted after DeMarco 1979)

- External entities, which are represented by a rectangle, are related to elements of the outside world that communicates with the system. An external entity could be an organisation, a group of peoples, a department or even another system that the model system communicates with.
- Processes/Activities, which are represented by a cycle, an oval, or a rectangle with rounded corners, are part of the system that transforms inputs to outputs.
- Data flow, which is represented by an arrow, shows the transfer of information from one part of the system to another.
- Registers/Datastores, which are presented with two horizontal lines, represent the place where data are stored to the system.

The research approach that is used in this study for analysis the processes of social housing projects is a single case study analysis. The case company is a Danish architecture firm, located in Copenhagen, Denmark, and it is a frontrunner on sustainable design and constructions including LCC. The case company is strategically selected as a paradigmatic case study in the Danish AEC, since it is a typical Danish architecture firm in terms of type and size, and it has been involved in

several social housing projects for different social housing organisations around Denmark.

To support the analysis, a typical social housing project is selected as the internal sub-case project. The case project is also a paradigmatic social housing project, managed by one of the bigger social housing organisations in Denmark. The project is designed by the case company, and it is now under operation since January 2019. In order to create DFDs of the case project, qualitative data were gathered through semi-structured interviews and collection of physical artefacts (as proposed by Yin 2009). Specifically, in total five interviews were conducted during autumn 2019; three of them were conducted internally in the case company, while the other two were conducted with employees of the social housing organisation that owns the project under examination. To support the interviews, physical artefacts of the case project were carefully collected, including several reports from both architects and the social housing organisation.

The collected data were used to create a set of DFDs for analysing the case project. Due to the limited space, this paper shows an initial part of the research study presenting the top two DFDs of the SA system, Level 0 and Level 1, underpinned by their process descriptions. More detailed levels will be reported in future studies. It is important to mention that the developed DFDs are structured from architect’s point of view since architects should identify potential data that can be used to inform the design of new projects.

Findings

In this section, the results of the case project analysis by using SA are presented. More specifically, the DFDs of the top-two levels (level 0 to level 1) of the analysis are illustrated, followed by a process description in each level.

DFD - Level 0

The top-level diagram of the case project analysis indicates that there are three main recurrent processes throughout the social-housing projects' lifetime (see Figure 2).

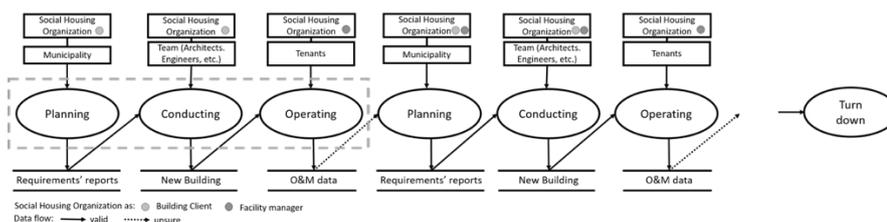


Figure 2: DFD of the case project - Level 0

As it is indicated in Figure 2, a social housing project begins with the planning process, which is initiated by the building client which is the social housing organisation and the municipality in which the project is located. The planning process results in a set of requirements' reports for the new building project which are used as input data for the next process, namely conducting the building project. The project is conducted mainly by a project team that consists of architects and engineers. Other actors are also involved in this process, including, among else, the social housing organisation, the municipality, tenants of social housing buildings, etc. When the project is executed, the new building is operated by the tenants. In the operating process, the social housing organisation is also involved having the role of the facility manager of the building that gathers several operational and maintenance (O&M)

data. Those three processes, namely planning, conducting and operating, constitute the main processes of social housing projects and are illustrated in Figure 2 with a dashed grey square. After several years of building operation, a renovation project is taken place and a new round of processes begins. Considering the performance and the O&M data of the existing building, a renovation project is, again, planned by the social housing organisation and the municipality, is conducted by a project team under the supervision of the social housing organisation, and the renovated building is operated by the tenants and managed by the social housing organisation. Those processes are repeated several times throughout the lifetime of the project until the building is turned down.

The DFD of level 0 indicates that the social housing organisation is involved in all processes of a social housing project throughout its lifetime, having different roles. Thereby, it can be reasonably assumed that social housing organisations have an overview of the building project's performance under all processes throughout its lifetime and thus, are considered as sources of plentiful data, including LCC related data. However, although the evident assumption of data sources, it is not yet fully recognizable how and in what volume those data are gathered, analysed and used in the recurrent processes of the same housing project or in similar processes of different projects in order to inform the design and improve performance of buildings. Nevertheless, is observed that the dataflow between processes of existing and new building projects is quite unstructured and this is indicated by a black dashed arrow in Figure 2.

DFD - Level 1

The DFD of level 1 is one step down in the hierarchy compared to the DFD of level 0, presenting a higher level of details. The case project that is used to map the DFD in level 1, is a completed new social housing building project, and thus, it is currently under the initial operating process, while the initial planning and conducting processes are already completed.

In this research, the authors are interested in how data for existing social housing project with regards to cost drivers of LCC can inform the design of new projects. Therefore, the analysis is focused on the sub-processes that occur at the end of planning and beginning of conducting process of level 0, in which the initial process of designing of the new project are taken place. The level 1- DFD is presented in Figure 3.

As illustrated in Figure 3, level 1 consists of four processes under examination: (a) public announcement of a new project, (b) competition process of the project, (c) evaluation of submitted projects, and (d) early design of building project.

In process (a), the social housing organisation in the role of building client announces the publication of the new project. The publication of the new project comes along with two reports that include some minimum requirements for the project submission. The one report, called Competition program, focuses on the competition procedures and describes, among else, the organisational and planning conditions, process prerequisites, requirements for tendering documents, competition theme, approval requirements, etc. The other report, called Standard Building program, focuses on the building and includes descriptions about the overall layout and architecture design, rooms' specifications, buildings' elements and materials, technical installations, electrical systems, outdoor areas as well as maintenance planning.

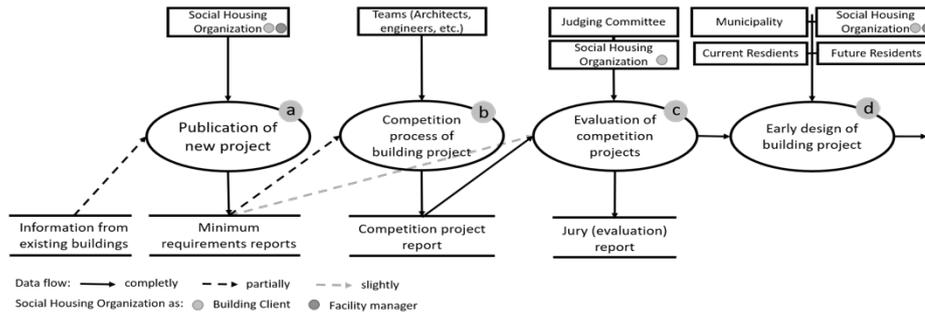


Figure 3: DFD of the case project -Level 1

Both reports include, among else, requirements for housing size, architecture quality, energy class calculations, indoor climate, daylight and sound conditions, etc. There are also several qualitative requirements in relation to LCC, like expected long lifetime of building components, low maintainability of materials and low operational costs. In addition, the Standard Building program report contains a detailed quantitative schedule of expected expenditures for maintenance activities for the upcoming 30 years of building operation (Figure 4). Specifically, the principle schedule for maintenance payments, as it is called, includes yearly expected payments for eighteen (18) maintenance activities for the first 30 years of operation (11 activities for external maintenance and 7 activities for internal maintenance). This maintenance schedule is arguably created based on cost data from other similar social housing projects; however, this is not yet clarified (illustrated by a dashed arrow between information from existing buildings datastore and process (a) in Figure 3). Thereby, it is also assumed that the social housing organisation is involved in this process of publication of the new project, having the role of facility manager of other social housing building.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
*All amounts in DKK 1000																														
Exterior maintenance																														
Joint around windows	0	0	0	0	0	0	0	0	0	0	25	25	25	50	50	400	0	0	0	0	0	0	0	0	0	25	25	25	50	400
Replacing double-glazing units	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225
Gutter repair	0	0	0	3	0	3	0	3	3	3	0	3	3	3	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Roof surface maintenance	0	10	10	10	10	15	10	10	15	10	10	15	10	10	15	10	10	15	10	10	15	10	10	15	10	10	15	10	10	15
Covering roof	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Exterior lighting	0	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Outdoor areas, paving/ asphalt	0	0	0	0	0	0	0	0	0	0	800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 4: Part of the Principle schedule of maintenance payments (translation from Social Housing's Standard Building Program report)

In process (b), pre-qualified teams consisting of architects and engineers compete for winning the project. In this process, architects use the data from the minimum requirements reports of process (a) to develop an architectural proposal that satisfies those requirements and submit their competition project report (outcome of process (b)). The competition document of the case project includes a case analysis, several drawings along with building elements' specifications and various calculation results. However, it is observed that the competition document under examination does not include any information about the lifetime of the selected materials or their maintainability, or any other LCC information to support the architectural choices. This means that the data stored in the minimum requirements' reports as an outcome of process (a), are only partially used in process (b), and this is represented in Figure 3 by a dashed arrow.

The competition project report as an outcome of process (b) is used as an input in process (c), where several reports from different design teams are evaluated by the social housing organisation together with a judging committee. The judging

committee consists of people from the local municipality as well as from other social housing organisations. In this case project, the main award criterion is the most economically advantageous tender; however, a number of sub-criteria are used for the evaluation. Those sub-criteria refer to: (1) The building system: Architecture idea, building technology and quality, variety of options and flexibility; (2) Price: compliance with given price per m², unit price, price of advices; (3) Cooperation: the contract team and their organisation.

It is observed that, although the emphasis that is given on LCC related requirements in the initial reports of process (a), there is not any criterion that evaluates the consideration of long-term cost-effective design proposals in process (c). The grey dashed arrow between the datastore in process (a) and process (c) indicates that the minimum requirements' reports are slightly used as an input in process (c).

In this case project, the case company was part of the winning team, and thus it continued in process (d) working on early design of the project. During the early design process, the winning team had continuous communication with several external actors, who support the design by providing useful information in order to ensure high quality of the project. Those actors are the local municipality, the social housing organisation as well as current tenants of other existing social housing buildings and future tenants of this building project (represented as external entities of process (d) in Figure 3). The communication between the winning team and the external actors is performed through regular meeting, where information about the cost performance of existing buildings or unexpected operational and maintenance issues is transferred to the winning team through dialogue-based briefing processes. The dataflow between architects and social housing organisation apparently seems to be quite unstructured. In level 1, however is not yet visible if and how this LCC related knowledge is used by the architects.

DISCUSSION

Through the analysis, it is observed that in the DFD-level 1 of the case-project, there are few activities where LCC related data and knowledge from existing buildings are transferred to the design team. The discussion here, however, is focusing on the LCC related data that are stored after process (a) and specifically, the schedule of maintained payments that is part of the minimum requirements' report.

As a result of process (a), cost-related data are transferred explicitly to the design team through the 30-year maintenance payment schedule, which is part of the minimum requirements' report. As it mentioned-above the maintenance payment schedule includes LCC cost data for 18 maintenance activities that are expected to take place throughout the first 30 years of building's operation. According to Jensen (2012), this can be considered as codified knowledge from building operation that contributes to increase awareness among building designers. Since the social housing organisation provide this written specification report to the design team, it can be concluded that those cost data should be used by architects to drive the design of the new building, and therefore, they are fairly recognized as cost drivers.

However, the potentials of considering those cost drivers to inform the design of new project are not fully utilized in this case-study (data from the minimum requirement report are partially used in the competition process - dashed arrow in Figure 3). A reason for this might be the lack of criteria to evaluate the compliance of the competition project with the LCC related requirements in process (c). That indicates

the lack of attention by social housing organisations to ensure that the design team will take consideration of the given data seriously. Another reason is that the design team fails to understand the value and the opportunities that are offered through this process.

However, answering the research question of this study, those cost drivers can be effectively used to inform the design of new projects. Firstly, the design team should propose alternative design solutions along with LCC calculation for a lifetime of 30 years including elements that their maintenance costs at the very least comply with the given maintenance schedule. In addition, by analysing the schedule of maintenance payments, the design team can also pinpoint the most critical cost drivers (the maintenance activities with the highest total cost throughout the 30 years) and propose alternative design solutions with lower LCC than expected. For example, in the case project's maintenance schedule report, the higher LCC in a lifetime of 30 years are related to the maintenance of the ventilation system, the paved/asphalt outdoor areas and the double-glazing units, indicating three critical cost drivers through buildings' operation. Those cost drivers of LCC can be used by the design team to inform the design of the new project, for instance, by proposing alternative design and maintenance strategies to improve long-term performance of ventilation systems, reducing the pavement in outdoor areas or designing solutions that can increase the lifetime of double-glazing units.

This is one activity that underlies valuable cost drivers of LCC that the architects may use to inform the design of the new project and propose solutions that are easy and affordable to operate and maintain. In addition, the case analysis reveals potentials also through other activities, for example through the inputs from external entities of process (d), where information from external actors about cost related performance or unexpected maintenance issues of existing social housing projects is communicated to the design team.

CONCLUSION

Life cycle costing has been proved to be a valuable decision-making tool for strategic facility management, considering life cycle perspective of buildings. Although several new initiatives have stimulated the increased use of LCC in the Danish AEC, its application in the design practices is still limited due to several challenges. One of the main challenges is the lack of available and reliable data, especially in early design stages. In order to overcome this challenge, research has proposed transferring information from the operation of existing buildings to the design of new buildings. Building client, facility managers and users are considered critical actors that can contribute on knowledge transferring.

This study focuses on social housing organisations in Denmark since they are at the same time the building clients and the facility managers of several residential buildings, as well as they have close relationship with the buildings' users (tenants). By using SA methods and specifically, data flow diagrams techniques, this study aims to identify how can data from existing social housing building projects with regards to cost drivers of LCC inform the design of new projects. To support the analysis, a social housing project from a Danish architecture firm is selected as the case project, and data are gathered through physical artefacts and five semi-structured interviews in both architects and building client organisations. The research data were used to create the DFDs of Level 0 and Level 1 of the SA system underpinned by their process descriptions. Through the analysis, it is observed that in the DFD-level 1 of

the case-project, there are few activities where LCC related data and knowledge from existing buildings are transferred to the design team. However, the potentials of using this knowledge to inform design of new projects are not utilized by the design team.

The activity that is discussed in this study, refers to the outcome of the process of publication of a new project, where the social housing organisation publishes a payments' schedule of maintenance activities as part of the minimum requirements' report. The maintenance payments schedule includes yearly expected payments for 18 maintenance activities for the first 30 years of operation. Those activities are considered cost drivers for the operation of the building for the next 30 years, since the social housing organisation calls for a design that conforms to this payments schedule. In addition to that, by analysing the schedule of maintenance payments, the design team can pinpoint the most critical cost drivers (the maintenance activities with the highest cost) and propose more affordable design solutions with lower LCC than expected. For example, in the case project maintenance schedule, one of the most costly activities in a lifetime of 30 years is related to the maintenance of the ventilation system, so the design team can use this information as a cost driver and propose alternative design and maintenance strategies to improve long-term performance of ventilation systems and reduce the LCC that are related to the ventilation system.

The consideration of cost drivers of LCC when designing new projects will contribute on more sustainable constructions that are easy and affordable to operate and maintain. In future research, other activities that are disclosing potentials for identification of cost drivers with regards to LCC will be further analysed. Moreover, the authors will propose interventions in each of the processes of the SA system in order to ensure the integration of LCC in the processes of social housing projects contributing on better design of new projects with regards to LCC.

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BARRIERS OF INCORPORATING CIRCULAR ECONOMY IN BUILDING DESIGN IN A DANISH CONTEXT

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The building sector has the responsibility to influence on recognizing the UN's 17 Sustainable Development Goals (SDGs). By considering SDG goal 12 for responsible consumption and production, buildings in Denmark account for 35% of the total waste and 40% of the energy consumption and CO₂ emissions. Circular Economy (CE) is one of the crucial concepts to reduce environmental impacts, including climate problems by reducing waste and resources. This can be achieved through the choice of alternative materials or solutions, by promoting the life cycle and circular mindset. Previous research has shown that circular design principles are not applied broadly, thus, the study aims to investigate the potential of using CE in building design to provide designers, consultants, and contractors, an insight into the various challenges, when adopting circular strategies to reduce the waste of resources and environmental impact. Semi-structured interviews were conducted, along with questionnaires and evaluation charts, with four respondents involved in building design, from architectural, consulting and developing organizations with different levels of experiences in sustainable buildings, specifically in using circular concepts. The interviews were analysed to investigate how CE is incorporated into building design unfolding barriers and pointing out some key factors to promote CE principles, e.g., organizations behaviour, collaboration, politics, and economy. The results indicate the complexity of the CE transition, as numerous aspects need to be considered. It reveals that actors can improve their interdisciplinary interactions to use circular principles, raising their awareness as true intermediaries in progressing wider sustainability goals. Other barriers are related to a lack of circular materials passports.

Keywords: circular economy, design, sustainability, sustainable development goals

INTRODUCTION

With the global population growth set to continue its rapid development, the need for housing in cities worldwide will similarly expand (State of Green 2020). Buildings are responsible for a very big part of the planet's resources (MacArthur Foundation 2015), they consume 40 % of the resources, and create one-third of the world's waste (Danish Environmental Protection Agency 2014), therefore there is a need for the

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sustainable conversion of the Danish building sector. Circular economy (CE) With no doubt will play a key role in the coming years (Hildebrandt and Brandi 2017) being proposed to tackle urgent problems of environmental degradation and resource scarcity (Almas Heshmati 2015). Thus, we need a real shift in how we typically design and construct buildings, finding solutions that reinforce the shift from linear to CE and promoting waste as a resource for new solutions (State of Green 2016). At the international level, initiatives have already been initiated to promote the transition to a CE. The UN has in 2015 adopted 17 global goals for sustainable development (SDGs) To direct the world in a sustainable direction. Here, CE is a very central and transversal means because it can enable continued economic growth and high prosperity in a way that the globe can keep up with. Entry transformation into a CE will, therefore, help to implement the government's new action plan for the UN's 17 global goals, especially, goal 12 for responsible consumption and production (UNDP 2015). It will also contribute to supporting companies' commitment to the SDGs with a view to both new business opportunities and increased expectations of local and global sustainability. Thus, there is a need for green businesses and actors in the building industry to work closely together to create value for the entire community (State of Green 2020). The concept of CE is not widely understood by the profession. Mobilizing this opportunity will remain a challenge until many more business leaders adopt a “circular mindset” (WBCSD 2018). To some business leaders implementing CE can seem too complex. To others, these complications stand as great challenges as well as grand opportunities (Lendager and Vind 2018: p.193).

Potential of CE in Building Design

Rethinking buildings' design process represents an enormous potential for reducing waste and increasing recycling and reuse. Discarded materials from construction and demolition account for approximately 35 % of waste generated in Denmark (Danish Transport and Construction Agency 2016). The construction sector reuses around 84 % of it from construction sites, but it happens in such a way that most of the value in the materials are taken out by decomposition. Thus, there is a great potential for increased conversion to a CE in the construction industry (Hildebrandt and Brandi 2017). The transition to a CE will catalyse the most transformational economic, social, and environmental changes. This requires enabling conditions that remove existing barriers in circular building design and materials utilization. Solutions that contribute to more circular construction, include a design for disassembly, waste prevention, and design from upgraded waste to be used within the building sector (Danish Cleantech Hub 2018). There is also a great economic potential in CE. Calculations from MacArthur Foundation (2015) show that conversion to CE in Denmark will be able to increase the total production by 0.8-1.4 %, increase exports by 3-6 % and will result in the creation of between 7,000 and 13,000 new jobs by 2035 (Hildebrandt and Brandi 2017). A thoroughly calculated Danish business case by Jensen and Sommer, documents that a demolition, which today would cost DKK 16 million, can be turned into a DKK 35 million business upside in the circular future building industry (2018). Despite positive claims about the potential of CE implementation to simultaneously reduce environmental burden whilst enhancing business benefits, not all circular solutions (or circumstances) Bring the desired positive effects, especially in the broader context of sustainability. For this reason, any decision to adopt a CE strategy ought to be carefully assessed with regards to its potential sustainability performance, before its implementation (Kravchenko, Pigosso and McAloone 2019). Several challenges and barriers that may prevent or slow down

the implementation of CE have been recognized in the literature. In Denmark, no concrete studies exist that investigate current state-of-the-art drivers, barriers, and practices in CE (Govindan and Hasanagic 2018). Adopting CE faces many challenges (Olsen 2019). The main barriers are lack of early-stage chain corporation and partnerships in the building sector, lack of economy of scale, lack of quality assurance marking schemes of reused building materials, and content of hazardous substances in existing building products currently embedded in buildings. From the perspective of policymakers in Denmark, it is expected that new regulations cannot stand alone for overcoming the above-mentioned barriers nor as to the only policy instruments for accelerating a transition toward a CE in the Nordic construction sector. It is expected that companies may need stronger economic incentives to change their existing and often linear business approach (Høibye and Sand 2018). This study aims to assist in strengthening CE to boost sustainable building solutions by investigating barriers that may prevent or slow down its' implementation, which has been recognized in the literature and from experiences presented by involved actors through semi-structured interviews. Thereby, this article seeks to answer the research question: What are the barriers of incorporating a circular economy in building design - in a Danish context?

LITERATURE REVIEW

Economic Barriers

Financial risk is involved where capitalization of the value of recycled elements will happen in 50 years or more from the time of investment, so who can finance the cost for this added feature? The value from improved possibilities will not be gained until the demolition of the building. All stakeholders in the industry will perceive this as a huge risk, as no one knows what the value of the improved elements will be, compared to the traditional elements and a price in the market will be speculative until the elements are available. Only clients with the specific demand to erect buildings designed for disassembly or legal requirements, e.g., in the building code are realistic drivers in the current market. Additionally, the lack of material prices that reflect the real environmental costs and hence economic optimization of building design often leads to results that do not reflect and take the real costs into account. There are also a few legal barriers in CE, related to the consequences of the legal framework e.g., standards and tests are based on virgin materials and not on recycled or upcycled materials and components (Jensen and Sommer 2018). Another barrier is related to the structure of the industry itself, which leads to split incentives along the value chain. There are limited vertical integration and each player, including the investor, architect, developer, engineer, sub-contractor, owner, and tenant - naturally maximizes their profits at the expense of the others. Since designing for circularity requires some alignment of incentives to close the loop in the value chain, not having such incentives makes the economic case for reuse difficult to make (MacArthur Foundation 2015). Results from a survey of 77 companies in the UK show that firms favour practices related to resource and energy utilization efficiency, while practices related to investment recovery, green purchasing, and customer cooperation are less prevalent. The significant investment cost, lack of awareness, or sense of urgency were identified as implementation barriers (Masi *et al.*, 2018).

Collaboration Barriers

A study by Guldmann and Huulgaard (2020) confirms that barriers exist at all socio-technical levels. Most barriers are encountered by companies at the organizational level, followed by the value chain, the employee, and then institutional. A case study on a conventional office building conducted by (Eberhardt, Birgisdottir and Birkved

2019) reveals that the main barriers are identified as complex supply chains, focus on short term goals that create short-term profit that misfit the long-term goals of sustainability. This creates competition among the stakeholders resulting in insufficient collaboration between them, and the absence of a commonly agreed definition of CE within the industry (Jrade and Jalaei 2013). A transition to a CE is a paradigm shift that requires a change of mindset among, the financial sector, policymakers, and companies. Collaboration between various stakeholders will be key to a successful transformation (State of Green 2016). The transition to a functioning CE regime requires systemic multi-level change, including technological innovation, new business models, and stakeholder collaboration (Witjes and Lozano 2016).

Materials Passports (MP) and Digitalization

Identifying the MP after use and disassembly is a challenge. MP contains a huge amount of complex information that needs to be updated regularly and be accessible by many different parties, this creates a complicated security issue. It must be easily accessible and updated when changes happen to the building during its entire lifetime. The main challenge is how to handle and structure the huge amounts of data that are accumulated when mapping out the elements and materials in a building. Building Information Modelling (BIM) Can handle that, but not optimally, due to the extensive amount of data that causes models to become extremely heavy. Existing technologies must be improved, and new ones must be developed to enhance the use of digital MP (Jensen and Sommer 2018: 153). Digital information on the materials used in component production that would be very helpful at the point of refurbishment or demolition is lacking or unevenly distributed: while BIM approaches are developing, they are not yet in widespread use (MacArthur Foundation 2015).

Policies Barriers

The government can act as a market player to stimulate the development of a CE. Current policies and legislation are generally written in and for a linear economy. They may (unintentionally) Hinder the transition to a CE (Bod *et al.*, 2017). Among various stakeholders, the governmental perspective has the maximum positive impact on the implementation of the CE in supply chains. CE can be promoted through laws, policies, risk reduction (through tax levies), and strict governance (Govindan and Hasanagic 2018).

Social Barriers

Social and behavioral aspects of modern consumerism is a challenge, as the psychological bias to value exclusivity and authenticity undermines the principles of recycling and reuse. There are inertia factors, pointed by experts in the construction industry in the form of customs and habits and a lack of the requisite capabilities and skills that make reuse difficult to implement (MacArthur Foundation 2015). Designers use traditional construction approaches which makes it difficult to implement CE (Svendsen and Tang 2018).

Technical Barriers

Buildings traditionally contain a complex mixture of compounds that are often difficult to separate, making material reuse and recycling difficult. There are several challenges when reusing/recycling materials from existing buildings; hazardous chemicals (including those no longer permitted in building materials today); and the technical performance of components/materials not designed for reuse/recycling (MacArthur Foundation 2015). A Nordic study indicates that demolition and proper

material handling can be challenging in terms of problematic and/or unknown content of substances as Nordic building stock tends to be relatively old (Nordic Council of Ministers 2015). Recycling is generally benefited by using single pure materials. Another challenge is how to model continuous loops of materials and thus account for the benefits of recycling, including substitution rate and loss of quality (Olsen 2019). A Danish office building “The Four Boards” was designed to be flexible and future proof by using durable and energy-efficient materials. Barriers to CE were many guidelines for designing steel structures in buildings and the extra rules for occupant safety, fire safety, technical installation requirements, and minimum strength requirements which all heavily influence the building process of an office building in general. These regulations could impair circular solutions, which could make it a deterrent. Also, a building is designed with a certain lifespan in mind, which can be achieved through durable materials and/ or maintenance. The balance between costs, durability, and efficiency can be proven to be difficult. It either requires large amounts of technology and resources or compromises to achieve the set life span at maximum efficiency as CE (Optimize) Would entail (Bod *et al.*, 2017). The Circle house is a Danish case that addresses CE challenges by analyzing the project in all its value chains, business models, case studies, and framework conditions. The biggest barrier to building up a market for reuses of bricks is the certification to guarantee the quality of the bricks, as old materials are not subject to the rules on CE marking (3XN Architects 2019). A study in the UK by (Akinade *et al.*, 2019) explores the barriers when Designing for Deconstruction (DfD) Using CE; lack of stringent legislation and policies, lack of adequate information at the design stage, lack of large enough market for recovered components, difficulty in developing a business case, and lack of effective tools.

RESEARCH METHODOLOGY

A mixed-method approach was applied in this study. First, a literature review (presented in the previous literature review chapter) Was conducted, followed by semi-structured interviews (Kvale 1996). The project design aimed to produce information from four respondents, selected through purposive sampling, with profound knowledge in sustainable buildings in the organizations, to capture the controversies and diverging assessments of the single movements undertaken in the organizations. Interviews were conducted with one architect (R1), two consultant engineers (R2) And (R3), and a project manager in an organization for sustainable business development. All respondents support the CE mindset but have various levels of experience and were chosen based on their practical experience of working with CE in construction. An interview guide was prepared, following the strategy for ‘semi-structured interviews’ (Kvale 1996). The interview guide was structured according to three domains of technology presented by Orlikowski and Gash (1994), the three domains cover what the technology is, why it was introduced and how they were used are: Nature of Technology refers to people’s images of the (generic) Technology and their understanding of its capabilities and functionality, benefits and demands. Technology Strategy refers to people’s understanding of the motivation behind the adoption and its likely adding value to the organization, concerning actual plans assisting its implementation. Technology in Use refers to people’s understanding of how the technology will be used on a day to day basis and the likely or actual condition and consequences associated with such use.

A qualitative questionnaire and a quantitative evaluation chart were sent to the respondents by mail before interviews. The chart depicts some challenges in CE

based on the results of the literature review, to stimulate the respondents to evaluate them according to the Likert Scale (1932), with five responses. The respondents had also an option to identify new challenges. The chart served as a structuring common object during the interview and as an agent for producing insight into the investigation. The interviews were recorded, then transcribed, and analysed using the analytical framework by Orlikowski and Gash (1994). The framework was applied to structure the data. The three domains characterizing the enactments of the subjects acting to make practical use of CE in their position in the building project organization. The domains overlap and interact but are useful for directing questions and interpreting answers.

FINDINGS

The analysis focuses on the sensemaking domains (Orlikowski and Gash 1994).

Nature of Circular Economy

R1 admits the potential of using CE, where big benefits can be achieved, but still many challenges need to be solved when reusing materials. They have recently grown focus on CE, attempting to find new knowledge in it and willing to distribute it further to the entire organization. Actors today are more conscious of using CE, they are trying to find new solutions to recycle and reuse some building materials, such as reusing old bricks. This requires strict requirements and documentation, e.g., which standard is used to fulfil the technical requirements, who is transporting the material, who is constructing it, and what are the expected economic benefits. CE solutions can cost more but can then enhance sustainable developments.

Most often, builders are constrained by a fixed economic frame that we must deal with. So, it is a matter of whether there is space to adopt CE design solutions and CE estimations or not, thus the economy can be a stopper! R1

R2 is highly experienced in DGNB and CE, his organization supports CE to a large extent, partly about using the right resources in the right place and in terms of proposing or using mechanical assemblies to ease of recycling and reducing the number of components that are difficult to disassemble. R2 mentions that it requires efforts to get everyone to do something different than they usually do and to consider the possibility of CE in a project. CE does not distinct from the DGNB system, apart from being less bulky. However, the development of digital aids to support assessments from an early design phase onwards will be decisive for achieving a value of CE. Especially Life Cycle Assessment (LCA) And Life Cycle Cost analysis (LCC) Tools. The biggest barrier is the lack of understanding of the economic consequences and the harmful effects and environmental consequences of some design choices.

Benefits of CE can be recognized if CE solutions that others have used and approved are shared, here knowledge and experiences should be gathered and shared. R3

Respondents ensure that the economy is a crucial influencer, contractors focus on financial savings but not on environmental impact. Actors should gain value when working with CE, and this is important to drive CE forward. Actors lack knowledge and experience, in terms of what CE provides in the long run.

Circular Economy Strategy

From R1 experience, many actors are eager to collaborate but have unclear responsibilities, e.g., who is responsible for what and who takes responsibility for these materials and solutions in 10, 20, or 30 years. According to R2, the collaboration challenges are lack of understanding of the environmentally harmful

aspects of recycling or rephrased, everything that cannot be recycled has sometimes met some resistance and using the right material in the right place should be highly prioritized.

CE can in some cases incorporate the sins of the past or even expose them again. The pursuit of a good CE narrative can overshadow building physical knowledge. R2

All respondents agree that promoting CE is a common responsibility for all actors in the buildings sector. R4 reveals that there are many successive CE cases, that can inspire and motivate actors but are not exploited. Politics and regulations are essential to boost CE. Also, builders have a key role in promoting CE. Attention must be taken to materials when demolishing buildings as they can include hazardous substances.

Circular Economy in Use

R2 declares that traceability and materials passports will be obvious, and preferably in a public database so it is easy in the future to see what materials have been used and their MP. Similarly, R4 confirms that the availability of MP will improve the adoption of circular materials. The profession lacks knowledge and data regarding which building parts can be recycled without problems and calls for a bigger focus on the overall economic impact. Other challenges are the absence of MP and an unknown lifetime of materials. Almost all respondents mention that tools to document economy and environmental impact are available, but not all actors use them. Thus, simplified tools will make it easier to use. According to the availability of guides and standards, R2 and R3 reveal the lack of guides, while R3 and R4 do not consider it as a barrier.

DISCUSSION

It is evident from the interview analysis that actors in the building industry lack of understanding the economic consequences and hardly recognize the economic benefits of CE. Organizations need clear and strong economic incentives. Designing for circularity requires some incentives to close the loop in the value chain (MacArthur Foundation 2015). Jensen and Sommer (2018) reveal that financial risk is involved when using CE, the value from improved possibilities will not be gained and known until the demolition of a building. All stakeholders in the industry will perceive this as a huge risk (2018). Interviewers inform that there are many positive CE business cases to learn from, which provide economic and environmental benefits, but actors do not utilize these opportunities to learn from. Similarly, knowledge is available but not exploited well. Calculations by the MacArthur Foundation (2015) show that conversion to CE in Denmark can increase the total production and export. A Danish business case, by Jensen and Sommer (2018) documents that economic benefits from demolition can be turned into a profitable business. However, Kravchenko *et al.*, (2019) admit that not all CE solutions bring the desired positive effects. Interviews and literature confirm that changing the behaviour of actors to transfer from linear to CE is a big barrier. Actors are inclined to traditional construction approaches which makes CE difficult to implement (Svendsen and Tang 2018). Customs and habits make reuse and recycling difficult to implement (MacArthur Foundation 2015). Furthermore, all interviewers perceive CE with high complexity, which reflects the complex nature of CE. To some business leaders implementing CE can seem too complex (Lendager and Vind 2018: p.193). All interviewers confirmed that politics and regulations are a big influencer. The Danish government is currently developing the building regulations to include a new voluntary sustainable building class (Nielsen *et al.*, 2018). All respondents strongly believe that politics new action will directly

increase the adoption of CE and in a natural way. The government enables and stimulates actors to use CE, this will both boost and enforce changes. (Bod *et al.*, 2017). However, Høiby and Sand (2018) expect that the new regulations cannot stand alone to overcome CE barriers, companies may need stronger economic incentives to change their existing linear business approach. Interviewers reveal that most actors are willing to collaborate, they confirm the necessity of collaboration between all actors and at all levels and that CE cannot be achieved by one actor but requires collaboration between all actors in the value chain. However, according to Eberhardt, Birgisdottir and Birkved (2019) complex supply chains, focus on short term goals that create short-term profit leading to misfit the long-term goals of sustainability. This creates competition among the stakeholders resulting in insufficient collaboration between them. According to Høiby and Sand (2018), the main barriers are lack of early-stage chain corporations and partnerships in the construction sector. Cooperation between different stakeholders will be key to successful transformation (State of Green 2016), (Witjes and Lozano 2016).

Interviews reveal that lack of MP is a barrier when reusing or recycling materials, due to the unknown contents and hazardous chemicals as well as unclear lifetime of materials. While the literature mentions that identifying the MP after use and disassembly is a challenge due to the digital challenges when processing building materials huge data and BIM (Jensen and Sommer 2018: 153). The reused or recycled materials must fulfill the technical requirements, e.g., strength and fire as these materials/ components were not designed for reuse/ recycling (MacArthur Foundation 2015). Bod *et al.* (2017) mention that technical requirements could hinder CE solutions. Jensen and Sommer mention that once relevant information of an MP is available, it becomes easier to decide if the component is suitable for the intended reuse and can then be included in a circular building (2018). Lack of quality assurance marking schemes of reused building materials and content of hazardous substances in existing building products currently embedded in buildings (Høiby and Sand 2018). Finally, the respondents requested that MP will be obvious, and preferably in a public database so it is easy in the future to see what materials have been used. They also requested more user-friendly analysis tools and guides to simplify the adaption of CE, e.g., LCA and LCC calculations.

CONCLUSION

CE is one of the most promising concepts for more sustainable development, where business benefits go hand in hand with resource efficiency, however, it is considered as a complex approach. The research investigated several CE barriers that include economic, politics, collaboration, social, and technical barriers including lack of materials passports. Other minor barriers refer to a lack of technologies, knowledge, and information. To convert to a more circular economy, we need to strengthen collaboration between everyone involved in the value chain. The CE must become a natural and integrated part of the building sector. Clear and predictable legislation is essential to respond appropriately. It is evident from results that among various stakeholders, the governmental perspective has the maximum positive impact on the implementation of the CE in value chains. This study contributes to existing knowledge by investigating barriers for CE in building design, and the results can be useful/applicable for both researchers and practitioners within the field. The limitation of the study lies in the limited number of interviewees - a larger number of interviewees would increase the generalizability of the study and improve the validity of making general conclusions.

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BEST PRACTICES FOR DIVERTING DEMOLITION WASTE FROM LANDFILL: A SYSTEMATIC LITERATURE REVIEW

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Demolition Waste (DW) tremendously contributes to the global solid waste production with a major portion destined to landfills. The DW should divert from landfill to improve the use of natural resources while reducing the adverse environmental impacts of using many land resources for waste landfilling. The development of effective processes to reuse and recycle is important to reduce landfilled waste. Thus, changing the traditional linear supply chain into a circular arrangement is a value-adding mechanism and herein, the notion of 'Reverse Logistics Supply Chain (RLSC)' has captured the attention of the construction industry. With align to this, the purpose of this paper is twofold. First, a systematic literature review (SLR) was conducted to identify the best practices for diverting DW from landfill to promote RLSC in the construction industry. Second, it outlines the next line of research which will assist future researchers to further improve the domain under study. The SLR was conducted using 81 articles available in six search systems from 2000 to 2019. The study found the best practices during pre-dismantling, dismantling and on-site operations and material recovery phases. These best practices should initiate from the design and planning phases of the project delivery process. The value of the study is to provide the industry practitioners with the best practices to reduce the amount of waste reaching the landfill. Furthermore, the study acknowledges the practitioners the corrective measures for impediments which challenge the execution of best practices in the practical context.

Keywords: demolition waste, landfill, Reverse Logistics Supply Chain

INTRODUCTION

Despite the construction industry's enormous efforts to reduce the negative environmental impacts, the construction operations are still perceived as a major source of environmental pollution. The construction industry utilises 40% of natural materials and produces 10-35% of total waste (Abarca-Guerrero *et al.*, 2017). The previous studies found that more than 44% of Construction and Demolition Waste (CDW) in the United Kingdom (UK) and 29% in the United States of America (Yu *et al.*, 2013) destined at landfills. Furthermore, 44% of CDW in Australia has been disposed of via landfill (Shen and Tam 2002), and this is 27% in Canada (Yeheyis *et*

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al., 2013). This figure is correspondingly alarming in plenty of other countries while attaining 35% of an overall global average (Solís-Guzmán *et al.*, 2009).

The CDW is generated due to activities related to construction, renovation, civil and infrastructure works and demolition. It has found that around 70% of CDW is contributed by DW (Ding *et al.*, 2016). For the past decades, landfilling was the cheapest option available for DW disposal (Oyedele *et al.*, 2013). At present, the rapid increase in construction-related activities generates an uncontrollable amount of waste at alarming rates (Ding 2018). This high rate of waste generation has congested many landfill carrying capacities while producing a plethora of adverse effects on society, both economically and environmentally (Ding 2018). Burying a large amount of DW in landfills produce volumes of CO₂ and methane due to anaerobic degradation, and this will lead to extensive air, water and soil pollution (Yuan *et al.*, 2013). Landfilled DW also engenders enormous pressure on the inadequate space available in highly congested cities (Oyedele *et al.*, 2013). Thus, there is an acute need for diverting DW from landfills (Yuan *et al.*, 2013).

The notion of 'Reverse Logistics Supply Chain (RLSC)' has captured the attention of the construction industry as a viable approach to divert waste from landfills (Hosseini *et al.*, 2015). The Reverse Logistics is defined as "the process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal" (Rogers and Tibben-Lembke 1999: 2). The RLSC of DW contains a series of operational phases, namely, dismantling and on-site operations, acquisition, collection and transportation, off-site resource recovery and marketing of reprocessed products (Hosseini *et al.*, 2015). Therefore, the RLSC facilitates the maximum recovery of salvaged waste while minimising the waste destined at landfills.

Despite significant efforts made to promote RLSC, the construction industry still pays less attention to the best practices which divert waste from landfills (Chileshe *et al.*, 2019). Thus, there is a need for an in-depth investigation of the diversion of DW from landfills. The current study aims to undertake a systematic literature review (SLR) to answer the review question of: 'what are the best practices which encourage the diversion of DW from landfill to promote RLSC in the construction industry?' Brondyk and Searby (2013) described the 'best practices' as robust and reputable practices which are applied and tested in the practical context while strongly rooted in the present, rigorous research. In other words, they facilitate the works to be more effective by using the latest knowledge, technology and procedures (Zemelman *et al.*, 1998). Therefore, the practices that are effective and empirically proven to divert DW from landfills are known as 'best practices' in the current study. The original contribution of this study is that of amalgamating existing knowledge of the best practices of diverting DW from landfills and determine the next line of research which assist future researchers in improving the domain under study.

METHODOLOGY

This study draws upon a SLR based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), which is a widely recognised standard procedure of conducting SLRs (Moher *et al.*, 2009). Two search strings with several keywords linked with Boolean connectors such as "OR" and "AND" were used to search articles as in Table 1. The keywords were searched in six electronic search systems, namely Google Scholar, Emerald Insight, Web of Science, Scopus,

ScienceDirect and Taylor and Francis. Several search systems enable to extract rich repository of articles without permitting any bias in selection (Ali *et al.*, 2017). These search systems are readily available in academic institutions and hold a wide range of multi-disciplinary publications (Ali *et al.*, 2017). As per the review by Hosseini *et al.*, (2015), the first study on RLSC in construction was done in 2000. Since the research on RLSC in construction started to emerge in 2000, the time frame for the study was established from the year 2000 to 2019.

Table 1: Keywords and search strings

Title/ Abstract/ Keywords		
Search 01	("Reverse Logistics" OR "Reverse Supply Chain")	AND "Construction Industry"
Search 02	("Deconstruction" OR "Demolition" OR "Dismantling" OR "Sort*" OR "Recycling" OR "Reusing" OR "Landfill" OR "Disposal")	AND "Construction Industry"

The initial search retrieved 351 articles for the subsequent refinement. The titles and abstracts of the 351 articles were examined to find the applicability of them for the current study. The peer-reviewed journal articles, conference papers and book chapters which published in English were included for the further refinement. The articles which were on unrelated subject areas were excluded from the repository. Subsequently, 170 articles were endured for the succeeding refinement. Next, the introduction and conclusions of each paper were examined, and 85 articles were excluded due to their inapplicability and duplications. There were six inaccessible articles, and the authors of these articles were not contacted to provide those articles since the abstracts of them affirm that they are not significantly contributing to the current review. Thus, a total of 87 articles were selected, including eight articles which were added from cross-referencing. During the full document review, the quality of papers was examined based on their rationale regarding the association of topic, methodology, findings and significance (Miles and Huberman 1994). Hence, six articles were rejected, leaving 81 articles for the current review.

The selected articles were subjected to two types of analysis. First, the bibliographic details of the selected articles were tabulated. The second involved a content analysis, which helps to make various decisions on the comprehension of the paper (Seuring and Muller 2008). Due to the space limitation, the inclusion of findings of all the reviewed articles was not permitted. Therefore, only the most relevant results of the content analysis were disclosed.

Results of the Content Analysis

This section presents the significant findings of each structural dimensions which formed from analysing, synthesising and classifying the knowledge in sorted articles.

The Best Practices to Divert DW from Landfills

The best practices related to CDW management are essentially operationalised circular economy principles within the construction and demolition sector and beyond. The following sections discuss the best practices to divert DW from the landfills.

During pre-dismantling phase

The best practices to divert the DW should initiate from the inception phase of a construction project. The designers should consider end of life (EoL) operations when they are designing a structure, and the practices like Design for Reverse Logistics (DfRL) and Design for Deconstruction (DfD) assist in diverting the DW from landfills (Chileshe *et al.*, 2018). Flexible scheduling between dismantling and salvaging stages

is also significant to encourage deconstruction and on-site sorting, which are essential practices to minimise waste sent to landfills (Chileshe *et al.*, 2016b). The authors further specified that provision of adequate space for on-site sorting is essential to divert DW, which ended up at landfills.

The Site Waste Management Plan (SWMP) of a building provide a guide to separate salvaged waste into different waste groups (Williams *et al.*, 2014). Furthermore, it broadly describes the ways of reprocessing and disposal of each waste stream collected on dismantling site (Tischer *et al.*, 2013). This helps to minimise the contamination of waste after dismantling, which is a significant cause that leads to landfilling. Therefore, some developed countries like the UK have mandated to develop SWMPs for buildings that are more than £300,000 value (Aminu and Angela 2018). The authors further suggested that all the governments should dictate to develop a SWMP for each building to minimise waste destined at landfills.

Before dismantling a building, a comprehensive on-site investigation should be conducted (Kleemann *et al.*, 2017). Herein, conducting a pre-demolition/ deconstruction audit of a building is essential to identify the potential recoverable and hazardous materials (Aminu and Angela 2018). This audit classified all the salvaged waste into reusable, recyclable, hazardous and waste for landfills (Williams *et al.*, 2014). It also reduces the uncertainty on materials which generate after dismantling (Jiménez-Rivero and García-Navarro 2016).

During dismantling and on-site operations

In many cases, the most prevalent method to dismantle is the mechanical demolition of buildings, which, as traditionally perceived, highly destructive and sophisticated technique which produces large amounts of contaminated waste to landfill (Akinade *et al.*, 2019). On the other hand, deconstruction is an alternative technique for demolition which involves methodical disassembly. A hybrid of both deconstruction and demolition has considered as a pertinent dismantling technique to maximise diversion rate from landfill (Vegas *et al.*, 2015). Thus, the decision to deconstruct/ selective deconstruct instead of demolition is a best practice to minimise waste to landfill (Chileshe *et al.*, 2018).

Effective on-site operations are important to improve the recovery rate of DW and diversion rate of waste to landfills (Yuan *et al.*, 2013). The on-site sorting helps to separate hazardous and foreign materials before they contaminate with other waste (Williams *et al.*, 2014). The construction waste management regulations of some countries like Hong Kong mandated the on-site waste sorting after dismantling. To facilitate on-site sorting, Tischer *et al.*, (2013) suggested keeping moveable containers at different locations in the demolition site from the beginning of dismantling. The waste collected and sorted at the upper floors of the building could be transported to the ground floor through vertical ducts without permitting the manual handling, which encourages the contamination (Tischer *et al.*, 2013).

According to Jiménez-Rivero and García-Navarro (2016), storing properly sorted waste on-site is a crucial practice to avoid contamination. Poon *et al.*, (2004) expressed the importance of storing the extracted salvaged waste at designated locations and labelling each category to avoid contamination. It is essential to store waste in an appropriate arrangement to prevent exposure to the moisture and unfavourable weather conditions. The guidelines which specify the precise way of handling and storing salvage waste on-site is important to ensure a maximum recovery rate from the on-site operations (Poon *et al.*, 2004).

During material recovery

The workers at the material recovery facility (MRF) should monitor the condition of salvaged waste provided by different suppliers (Huang *et al.*, 2018). This is because malpractices like random collection and subsequent sorting by unprofessional waste pickers expedite the waste to landfill. Mercante *et al.*, (2012) stressed that a detailed preliminary inspection is needed to ensure that the waste is not contaminated. The MRFs are having their waste acceptance criteria (WAC) guideline, which acknowledges the requirements to determine the acceptance or rejection of the waste load (Jiménez-Rivero and García-Navarro 2016).

Before reprocessing, the salvaged waste is introducing to the mechanical sorting plant. During the sorting phase, chemical tests are conducting to ensure that the salvaged waste is not mixed with hazardous materials like asbestos (Chileshe *et al.*, 2016a). As specified by Huang *et al.*, (2002), the impurities such as small wood chips and the old mortar mixes should be removed from the samples before introducing them to testing. The authors further explained that the material streams which sorted from mechanical sorting process are introduced to a series of material tests such as sieve analysis, Los Angeles (LA) abrasion test, friability test and the fineness test. Complying with specifications and standards during the reprocessing stage is important to divert DW from landfills (Martín-Morales *et al.*, 2011).

The Impediments to Best Practices and the Corresponding Corrective Measures

The construction practitioners, such as designers and contractors, do not consider the post-EoL building operations during the designing and planning phases (Chileshe *et al.*, 2016a). These practitioners are not aware of the best practices such as deconstruction, DfD, DfRL and preparation of SWMP. As a result, they are reluctant to consider them during the designing and planning phases of the buildings.

Therefore, it is required to educate contractors and designers on the benefits of deconstruction, DfD, DfRL and SWMP (Chileshe *et al.*, 2016a). The standards should be available regarding design tools comply with DfD and DfRL to encourage designers to follow these concepts. Densley Tingley *et al.*, (2017) suggested that local governments should amend local planning regulations in such a way to incorporate DfD and DfRL objectives in upcoming projects.

Rameezdeen *et al.*, (2015) highlighted that most of the dismantling sub-contractors are not aware of the positive outcomes of deconstruction, and even the builders only concern the budget and time of dismantling. As revealed by Jiménez-Rivero and García-Navarro (2016), the demolishers do not have adequate knowledge and skills required for efficient source separation and subsequent storage. Training and educating labourers on deconstruction and various sorting techniques improve the waste diversion from landfill (Chinda and Ammarapala 2016). Furthermore, all the demolition workers and labourers assigned for on-site sorting should have a license from the corresponding authorities (Nikmehr *et al.*, 2017). As suggested by Jiménez-Rivero and García-Navarro (2016), a separate person should be assigned at demolition sites to check and monitor the on-site sorting operations periodically.

Governments and regulatory bodies in some countries do not persuade best practices such as deconstruction and on-site sorting. For instance, Chileshe *et al.*, (2016b) revealed that the South Australian government as a client wants the buildings to be dismantled quickly due to the time and space restrictions. Therefore, the demolition sub-contractors in South Australia tempt to demolish the public buildings instead of deconstruction. Chileshe *et al.*, (2016a; 2016b) revealed that the storing extracted

salvaged waste for on-site sorting is not permitted by the Environmental Protection Authority (EPA) in South Australia. Herein, EPA considers any material without immediate use as waste and ask to remove them from the site immediately. Rameezdeen *et al.*, (2015) declared that on-site sorting is not feasible because of strict environmental, health and safety regulations. Therefore, the government and regulatory bodies have a critical role to play in promoting best practices such as deconstruction and on-site sorting to minimise waste destined at the landfill. Herein, they should establish standards, specifications, guidelines, regulations and norms for the production and application of reprocessed products (Huang *et al.*, 2018). The government and regulatory bodies should promote quality assurance in RLSC by providing incentives and industry-wide training (Jin *et al.*, 2017). Besides, Ling and Nguyen (2013) specified that universities also have a responsible role in doing research and developments.

The Conceptual Framework

The summary of literature findings related to the best practices of DW diversion from landfills is depicted in Figure 1, as the status quo of the research. The study found the best practices of pre-dismantling, dismantling and on-site operations and material recovery phases in RLSC. There are impediments which challenge the execution of these best practices in real life. The SLR revealed that people in RLSC are not familiar with the best practices due to lack of knowledge, awareness and training. The lack of standards, regulations and incentives by government and regulatory bodies also affect the DW diversion from landfill. Therefore, government, regulatory bodies, industry and universities should play a critical role in promoting best practices in RLSC to divert DW from landfill.

The study helps the practitioners in RLSC to get an understanding of the best practices that need to be employed for diverting the DW from landfill. Being aware of and following these practices could be considered as the first step in the successful management of diverting DW from landfills in the construction industry. This is further confirmation to the practitioners that testing and complying with standards, regulations and specifications during RLSC would not be the adequate option to divert DW from landfill. Instead, it highlights the prerequisite of diverting bulks of DW from landfill should be considered and initiated from the early design stage of a building.

A well-executed literature review that constitutes an extensive research agenda makes a robust contribution to the domain of the study (Snyder 2019). Congruently, as shown in Figure 1, and in line with the status of quo of contemporary research, several future research directions were proposed through the analysis of what has been done and what needs to be done related to the field of study. Accordingly, there is a need to investigate how early phases in a building life-cycle contribute to diverting waste at the EoL of the building. The current study is focused only on the presentation of best practices during pre-dismantling, dismantling and on-site operations and resource recovery phases. However, since the acquisition, collection and transportation and marketing are also considered as important phases in RLSC; more empirical research is needed to identify best practices within these phases. The study found that the best practices of DW diversion from landfills are impeded by the causes which rooted from the elements such as people, process, policy and technology in RLSC. Therefore, future research could be done to investigate the impact of these four elements in RLSC on DW diversion from landfills. The current study underlined that most of the

practitioners engaged in the forward supply chain and RLSC in construction are lacking the knowledge on best practices of DW diversion from landfills. Manowong (2012) found that even if some practitioners in the forward supply chain are knowledgeable on these best practices, they are not encouraged by the clients who have the attitude that implementing these practices are a financial burden for the project. Correspondingly, the attitudes of the practitioners are discouraging them from following these best practices. Therefore, how to change the attitudes of practitioners in forward supply chain and RLSC to increase DW diversion from landfill in an interesting future research direction.

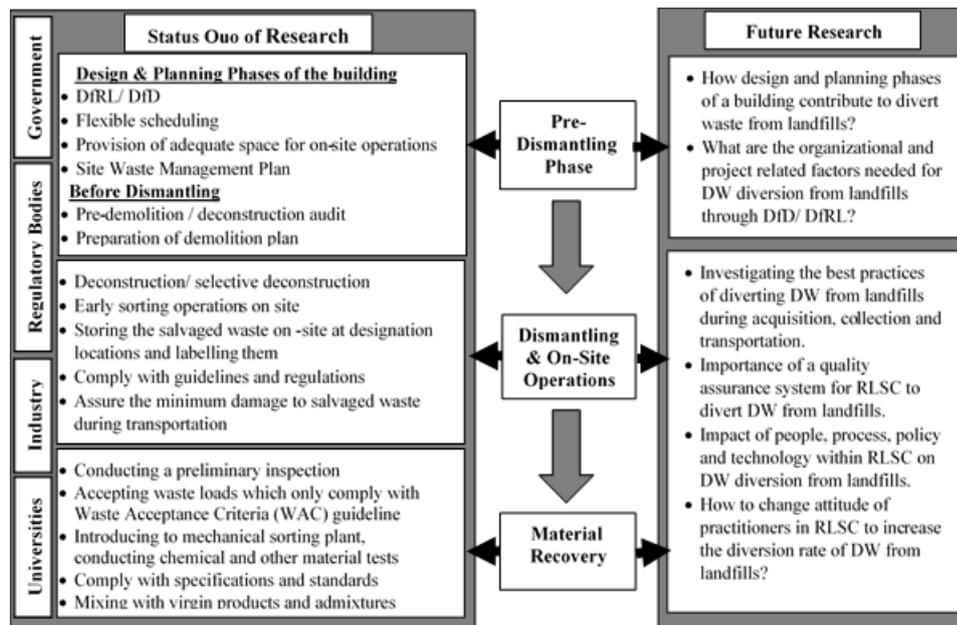


Figure 1: Future research directions of DW diversion from landfills

CONCLUSION

Diverting DW to landfills is a highly notorious activity which has led to a plethora of adverse effects on environmental and social wellbeing. This study aims to identify the best practices which divert the DW from landfills to promote RLSC in construction and determine future research in the domain of the study. The SLR was done using the PRISMA guideline, including 81 articles from 6 search systems during the period from 2000 to 2019. The study found the best practices during pre-dismantling, dismantling and on-site operations and material recovery phases. These practices should initiate from the designing and planning phases of a building. However, there are constraints for the successful execution of best practices. The study found that the lack of knowledge on these practices impedes the execution of these practices. Besides, the absence of incentives and support from government and regulatory bodies also affect the implementation of these best practices. Thus, the study established that the government, regulatory bodies, industry and universities need to play a proactive role in promoting the best practices to divert DW from landfill.

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**COMMUNITY ENGAGEMENT:
THE CASE FOR SERVICE TO
THE COMMUNITY**

POST-DISASTER AFFORDABLE AND SUSTAINABLE HOUSE DESIGN AND DELIVERY: AN INTERNATIONAL NON-GOVERNMENTAL ORGANISATION (INGO) PERSPECTIVE

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The frequency and devastation of disasters, both natural and manmade, are becoming, both more common and extreme, resulting in large numbers of displaced populations throughout the world. Combined with population growth, housing shortages in many regions continue to escalate beyond previous records and based on current trends, are set to increase further in the coming years. In the context of least developed and middle-income countries, these are often the worst effected, due to their inherent vulnerabilities. The built environment, and housing in particular, is often worst effected by disasters, resulting in large numbers of displaced populations in these countries. In this context, the permanent reconstruction phase of recovery following disasters can be viewed as an opportunity to rebuild, in a more sustainable manner, with beneficiaries and communities central to the process, to help build resilience against future disasters. Non-governmental organisations (NGOs) are often tasked with the design and delivery of post disaster housing in many of these contexts. The purpose of this study is to explore the approach of an international NGO in the design and delivery of post disaster housing. A case study approach from Sri Lanka with a leading international NGO is used to explore this complex area. Data collection utilised included semi-structured, documentation reviews from the organisation and observation studies from the field. The research findings outline the various design and project management stages and considerations the NGO undertakes, from inception to completion of the project. This research offers a unique evidence-based insight into the real-life practice and decision-making process of an INGO, working in a challenging post disaster context and contributes to both the theory and practice in this field.

Keywords: disaster management, engagement, equality, resilience, sustainability

INTRODUCTION

The right to adequate housing has being recognised globally as far back as Universal Declaration of Human Rights in 1948 to current day. The current United Nations Sustainable Development Goals 2030 make specific reference to the need for

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adequate, safe and affordable housing for all communities and further recognises the need for sustainable and resilient building that utilises local materials. However, despite the recognised need and human right for adequate housing globally the level of housing shortages in least developed countries (LDCs) is at an all-time high and it is set to continue in this trend in the future. The tangible impacts of these housing shortages to large populations worldwide include homelessness, poverty and vulnerability to other natural and manmade phenomenon e.g., natural disasters and conflict. Conversely it is often man-made and natural disasters that contribute to housing shortages in many LDCs and increase their vulnerability to future disasters. The purpose of this research is to explore an INGOs approach to the multifaceted area of both the design and delivery of sustainable and affordable housing in a LDC and post disaster contexts. A case study approach with a selected INGO focuses on the design decision-making and delivery process of the selected INGO and seeks to establish the various stages and key considerations that are critical to the organisations overall approach. The study covers aspects from the domains of architecture and project and design management; all of which are fundamental in the overall process.

Housing and Sustainability

The task of how to respond in the most effective manner to these shortages as a result of disasters has been a particular challenge for decades to many actors worldwide who operate in the area of housing provision in these contexts. Various approaches and responses to addressing the housing need have been employed in the past many of which have failed to address the complex area of housing design and provision that is appropriate to its context and best serves the community it is to serve. These approaches have included top down approaches from governments that fail to engage the communities and inappropriate design and construction techniques all of which fail to holistically address the complex and multi-dimensional area of housing design and delivery and the many different stakeholder involved. Central to the design and delivery of appropriate housing is the need to ensure that the aspects of affordability and sustainability are adequately considered and incorporated into the process. Affordability and sustainability are intrinsically linked and to be affordable; a house must embrace sustainability principles and be designed and constructed to last (Hayles 2006). In many LDC's affordability in mainstream housing markets is associated with economic sustainability often with little emphasis on environmental social sustainability (Randolph et. al. 2008).

Sustainability is a relatively new concept in LDC's construction industries and sustainability, and sustainable construction are not yet an essential part of the decision-making process (Raffat 2004). This is often attributed to perceived higher costs and lower levels of social acceptability in the affordable housing market (Sibley et. Al 2008). Othman (2013), notes that a wide range of challenges exist that affect delivery of sustainable construction projects in LDC's outlining 5 main headings under which they fall which include human development, technical, managerial, political and the triple bottom line of sustainability (environmental, social and economic). In order for long term solutions to be implemented all aspects of affordability and sustainably need to be considered in the decision-making process. Further barriers to appropriate housing delivery include a lack of expertise and knowledge by the organisation and communities in post disaster contexts which are the cause of much housing shortages (du Plessis 2002, Ngowi 2002). The disaster management cycle consists of 4 stages; 1. Preparation, 2. Mitigation, 3. Response and 4. Recovery. Post disaster reconstruction forms one part of the cycle and the

implementation of long-term post disaster housing takes place in the recovery stage of the process. The process of reconstruction requires considerable medium- and long-term strategic consideration in order to capitalise on an opportunity to improve on the built environment that preceded it and build resilience into the community against future disasters.

RESEARCH DESIGN

The research proposes to describe and interpret the organisations design and delivery process from inception to completion while operating in a specific environment and establish causal links in this process to inform a coherent overview of the organisations overall process. The research questions to be addressed are 1. What are the stages that the organisation goes through in a project from inception to completion? and 2. what are the various considerations the organisation takes in to consideration at different stages of the overall process. The study involves aspects of research relevant to social science given the human aspect of the study as well as organisational interactions. Baxter and Jacks (2008) state that a qualitative case study is a tool that enables researchers to study complex phenomena in their context and inform professional practice and evidence informed decision making. Yin (2003) further outlines that qualitative case study use is appropriate when the focus of the study is to answer “how” and “why” questions or if the researcher wishes to cover contextual conditions as they feel they are relevant to the topic under study.

Based on the research questions and aim, a case study qualitative approach was identified as appropriate for this study to better understand the complex environment in which design making is made in LDCs post disaster contexts. A case study with a large international NGO organisation was selected. The organisation has extensive experience in both Sri Lanka and internationally and operates on a global basis in the design and delivery of low cost and sustainable dwellings to communities in LDCs and post disaster contexts. A case study in Sri Lanka involving the design and delivery of 100 post disaster houses following the 2004 Indian Ocean tsunami was utilised. The study was located in a semi urban context on the outskirts of the capital city Colombo. The overall objective of the project was to achieve a complete self-recovery for tsunami affected families and communities to their everyday lives in a sustainable manner which would result in minimal displacement and a long-term cohesive community. The case study project utilised a core house incremental approach to the delivery of the houses. This was utilised as it enabled the community members to plan for the long-term future while still only having sufficient funds to build the main house core in the short term with the funds made available. A participatory design and implementation approach was adopted for the project as this was believed to be the most effective approach for a long term sustainable community development by the NGO based on previous experience in similar contexts. Sri Lanka as a country, offered a wide range of diversity in terms of its context e.g., culture, geography, climatically and it also had being subject to a relatively recent disaster and a 30 civil conflict which is was recovering from. The study was undertaken 5 years after the completion of the initial core houses. This period following completion enabled the study to assess the success of the project in terms of future expansion of the core house and how the overall community had developed. As well as the actual physical construction of the houses, the project also endeavoured to go beyond this and address the often-overlooked other adverse effects after the tsunami disaster e.g., restoration of livelihoods, re-establishing self-confidence, dignity and self-reliance, restoration of social capital, empowerment of community and restoration of normal

family life all of which contribute to the long term success and sustainability of the project. In order to gain a diverse understanding of the context and individuals involved multiple sources of information was collected and analysed. Data collection consisted of 4 sources:

1. Literature review of the subject area.
2. Documentation from the case study organisation.
3. 3 Semi structured interviews with head people involved in the organisations housing design and delivery. The national director of the organisation and the countries senior project manager and architect were interviewed.
4. Observation and recording of the physical artefact. This involved the author visiting the community and undertaking a field survey of the dwelling which included measure and draw studies of the dwellings, post occupancy evaluation studies to assist in assessing the effectiveness of the organisations overall approach and if the selected approach was successful 5 years after the implementation of the housing.

Data analysis utilised a number of approaches appropriate to the various data collections and aims of the research. These included the following;

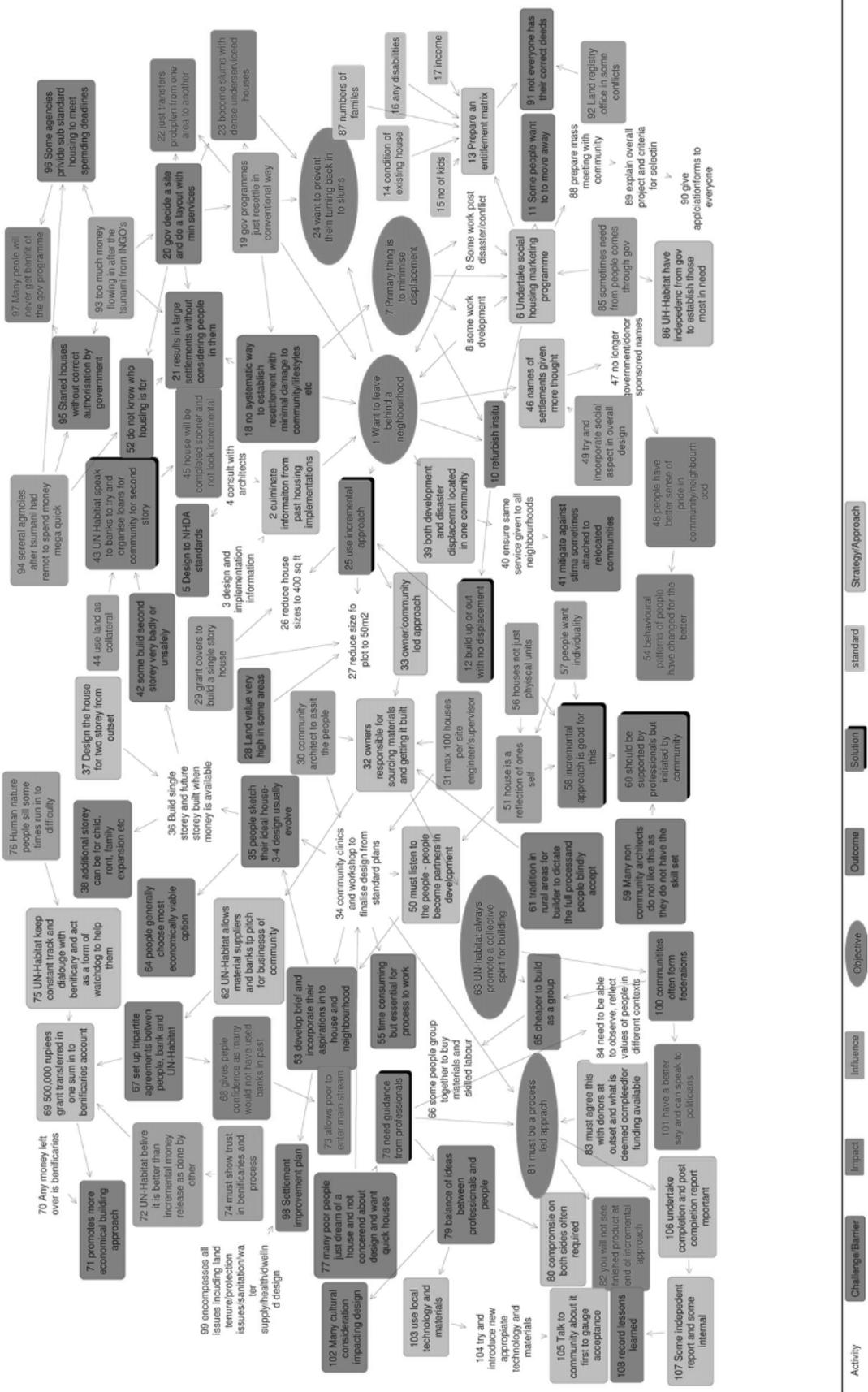
1. Cognitive Mapping - Hurby (2006) defines cognitive mapping as a form of empirical research that uses a theoretical and methodological approach that contends that cognitive maps represent manager's (designers and project managers) causal knowledge. A cognitive map is sometimes called a "causal" map and has 2 main features, namely concepts or nodes and causal links or arrows between them, where the direction of the arrows implies believed causality. Cognitive maps are much more than a graphical representation of what was said in an interview, but they are rather interpretations of what is meant by the interviewee and the quality of this representation depends on the quality of the interviewer as a listener and interpreter (Eden and Ackermann 2004). Fiol and Huff (1992) define cognitive maps as graphic or visual representation of thought or sense making that locate people in relation to their information environments and can be linked to decision making. Banxia Decision Explorer software was utilised for the cognitive mapping process and analysis. Cognitive causal maps were constructed for individual transcribed interviews. A global organisation map was constructed from the individual maps for the overall organisation (Figure 1). Maps were formed with identified colour coded concepts/nodes that arose out of the interviews

2. Logic Models - Yin (2009) states that pattern matching logic is one of the most desirable analytic techniques for case study analysis. A logic model stipulates a complex chain of events over a period of time with repeated cause and effect patterns where a dependent event at an earlier stage becomes a causal event for the next stage (Yin 2009). Kaplin and Garrett (2005) describe a logic model as:

a graphic display or 'map' of the relationship between a programme's resources, activities, and intended results, which also identifies the programme's underlying theory and assumptions

Organisation level logic models trace actual events and processes in individual organisations over time tracing the chronological order of events and highlighting causal links and patterns emerging for a process. Logic models are also referred to as process flow charts (PFC) and are useful in providing a clear and simple method of communication to the various stakeholders of how an individual or organisation approach a process. Figure 2 represents the selected the logic model that emerged of the selected organisations for the selected case study.

Figure 1: Organisation Global Map (Source: Author)



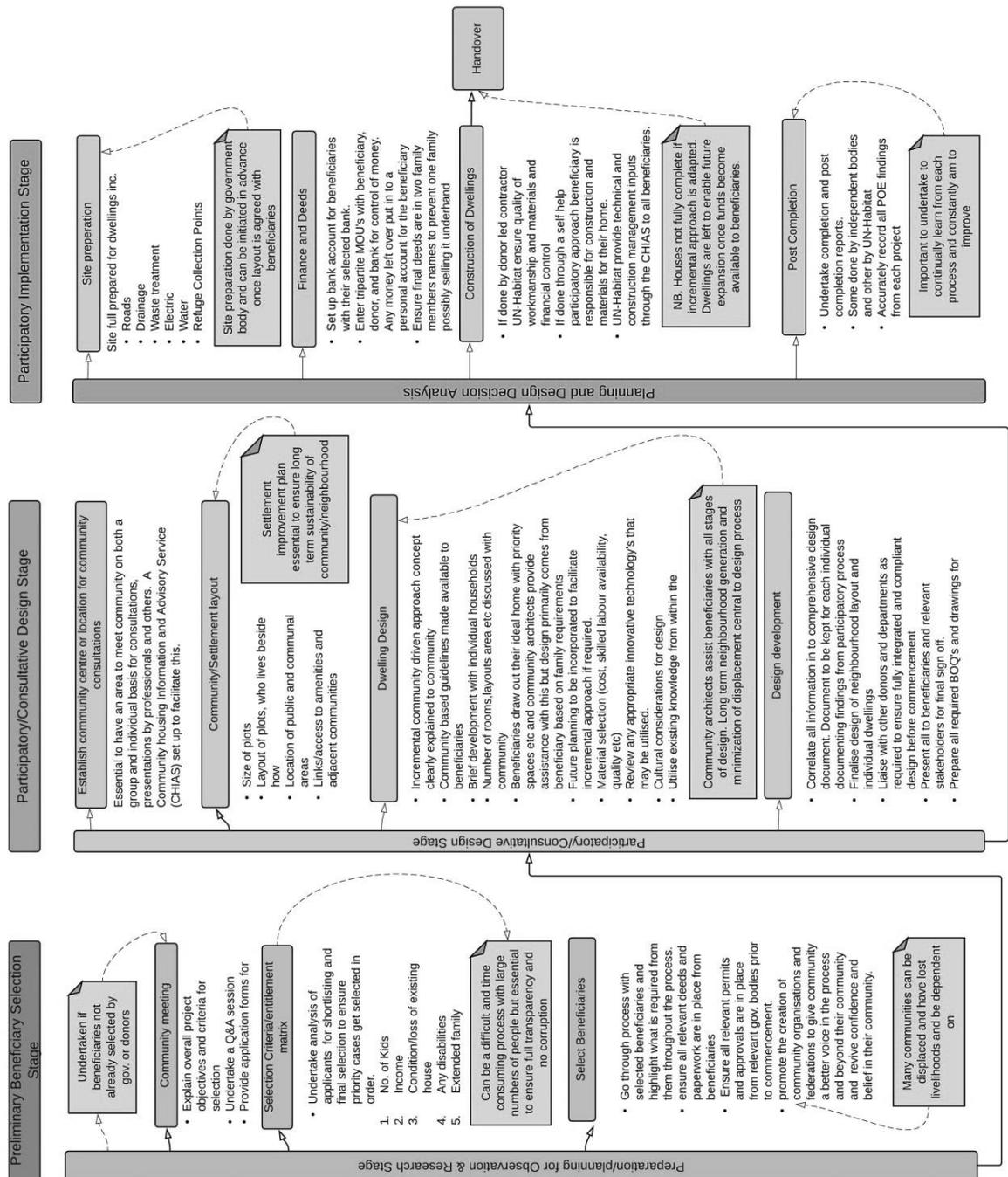


Figure 2: Logic Model of Organisations Process and Key Stages (Source: Author)

3. Observation studies - the physical artefact that this research relates to is the dwelling itself which is inhabited by the beneficiaries' this is the physical output of the design and delivery process which is being studied. The dwellings from the case study are located in their natural settings and created the opportunity for direct observations and are another additional valuable source of evidence for the study. Direct observation from the field involved dwellings been analysed and recorded in the form of measured surveys, photographs and condition surveys by the researcher.

RESULTS

A total of 108 concepts were identified in the global map formed from the 3 individual interviews with each concept falling in to one of 9 identified themes.

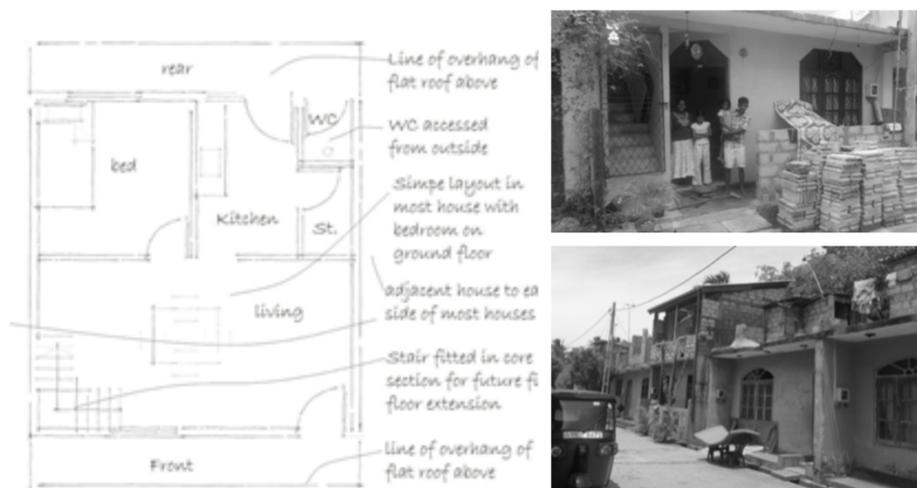


Figure 3: Example of case study data collection (Source author)

Central and Domain analysis of the global map using Decision Explorer identified 10 top featuring concepts under various identified categories.

Table 1: Top 10 Central and Domain Analysis from Interviews

	Rank	Category
Want to leave behind a neighbourhood.	1	Objective
Community clinics and workshops to finalise design from standard plans.	2	Activity
Use incremental approach.	3	Solution
No systematic way to establish resettlement with minimal damage to community/lifestyle etc.	4	Challenge/barrier
Refurbish in-situ.	5	Strategy
Must be a process led approach.	6	Objective
Gov. decides a site and do layout with minimal services.	7	Challenge/Barrier
Undertake social housing marketing programme.	8	Strategy
Gov. Programmes just resettle in conventional way.	9	Influence
Primary thing is to minimise displacement.	10	Objective

Key findings from the interview analysis outlined that the organisation was driven by specific goals e.g., minimising displacement, wanting to create a neighbourhood and identifying that there was a need for a process led approach as opposed to merely just providing housing. These goals were identified and developed through experience that demonstrated that successful neighbourhoods lead to sustainable communities and dwellings that will be used along term. Consistent with the literature the organisation did identify inadequate approaches from the government as a key challenge in a post disaster context and resettlement. In their experience governments select a site and layout with minimal overall services in some instances before INGOs are involved in the projects thus reducing the opportunity to be involved in effective decision making at the all-important stages at the outset of the project.

The organisation identified the need for a community participation approach to the design and delivery of dwellings and from the outset used resources to market their approach to social housing to get a buy in from the community from the beginning. This approach was heavily influenced by the organisations knowledge of previous resettlement and post disaster housing programs undertaken in the country and elsewhere where the default approach of the government was to resettle in a conventional way e.g., government bodies decide on community location and design and beneficiaries have little or no input throughout the process. The participation process was further implemented by enabling community involvement in the design process. The organisation undertook community clinics and workshops as a key activity to finalise dwelling designs with the beneficiaries. The participatory design stage identified that available funds would not enable beneficiaries to achieve their desired dwelling straight away so an incremental design and construction process as well as refurbishing dwellings in-situ where feasible was employed. This approach enabled the beneficiaries to construct a good quality dwelling with available funds in the first instance which was designed to be easily expanded on in the future as future needs and resources became available to do so. In this particular project space was at a premium and the dwelling was designed to be extended upwards in the future. This approach informed the technical design process at the initial delivery stage e.g., larger foundations and sufficient structure and access for future upward expansion as well as a layout that facilitated future expansion with no or minimal disruption or abortive work in the initial core dwelling.

Observation studies of the site confirmed that 5 years after the core dwellings were completed over one third had already extended upwards with an additional story or part storey and others were in the process of construction of additional living accommodation or in the process of stockpiling materials for expansion. Feedback from beneficiaries living in the dwellings was positive in the main in terms of the dwellings performance in meeting their long-term requirements and aspects of durability and maintenance. Observation studies highlighted that the dwellings were well constructed in masonry construction and well ventilated with adequate levels of natural light, security and personal outdoor space. Social and economic sustainability outcomes were positive as the community had grown since the completion of the core houses and dwellings were extended in an affordable manner over time.

Analysis of the data identified a clear process led approach to the overall design and delivery of projects within the organisation albeit the organisation had no formal process in place but recognised the need to have one. 3 Clear stages emerged under which substages were grouped (Figure 2). Stage 1 consists of preliminary work prior to any design commencing. This stage involved initial community engagement to make the community aware of the project and its aims and approach and also to enable a process of selection of eligible beneficiaries. The organisation developed a clear matrix for assessing potential beneficiaries. It was highlighted that this preliminary stage can be quite time consuming in the aftermath of a disaster given the number of displaced people but that it was essential that the process was maintained in a clear transparent manner to mitigate against any possibility of corruption which is also prevalent in post disaster contexts. Having selected the eligible beneficiaries this stage culminated in making all beneficiaries aware of the design and delivery process and all input and requirements from them as beneficiaries. A particular challenge in this respect was the existence of critical paperwork such as deeds of previous home and land ownership much of which was lost or destroyed in the aftermath of the

tsunami. It is also at this stage the organisation promoted the community working together as a whole in terms of having a voice and for other practical aspects e.g., purchasing power of construction materials in larger quantities at better rates for greater affordability. All provisional statutory approvals for the project are put in place at the preliminary stage also.

The second stage involved the overall design of the community and individual dwellings with participation from the community. This stage was a resource intensive but essential stage for the organisation as decisions made at this stage had an impact on the overall long-term success of the project from both an affordability and sustainability perspective. A community consultation process and meeting location was established from the outset to enable clear communication on both a community and individual basis throughout the full process. The design process incorporated many individual considerations including material type/use, affordability, planning for future expansion, cultural considerations and individual beneficiaries needs. This stage was undertaken in conjunction with the organisations in house architects.

The third and final stage involved the implementation of the works with participation from the beneficiaries. The beneficiary's involvement was on the individual dwelling units while larger infrastructure work e.g., drainage, roads, sewer and site preparations is undertaken usually by governmental contractors given the nature and scale of the work. In some instances where beneficiaries were not in a position to physically participate in the dwelling's construction contractors appointed under the organisation undertook the work. In instances where beneficiaries did undertake construction works the organisation provided technical guidance in the form of construction management from project managers, engineers and architects. The project management and documentation aspects of the implementations stage of the works were considered essential to ensure the longevity of the community and protection of the beneficiaries' legal interests. These included undertaking all internal and external completion reports, memorandums of understanding and that the ownership deeds were in place for the beneficiaries in two family member names. Official handover of the dwelling would only take place once all documentation was completed and recorded.

CONCLUSION

The demand for housing globally is projected to continue to rise with LDCs disproportionately affected in terms of demand. The need for adequate process led approaches to provide an appropriate housing response is now critical more than ever. Many current top down approaches from governments and other organisations are undertaken in an ad-hoc manner and have failed to adequately address the key aspects of affordability and sustainability and the synergies that exist between both when implanting projects. The need for useful input from the communities being served is an essential component in terms of the overall process. The level of involvement must be of a significant level at the right stages so as to have the required impact on the overall process as opposed to an insignificant box ticking exercise. This research is unique in nature in that it enabled an in-depth study to be undertaken of a leading international housing organisation in the area of sustainable and affordable housing design and delivery in an LDC post disaster context. The research examined the real-world decision-making process of the organisation with the use of cognitive mapping and documented the overall approach undertaken by the organisation utilising logic modelling to identify key themes and approaches undertaken by the organisation for

best practice. This study provides pivotal new information on the various aspects and stages involved in the overall complex process. The study's findings on key themes that influence design decision makers both confirm findings from the literature review and provide additional findings. The research crosses the fields of project management and architecture and contributes to both theory and practice in this field. The findings are also useful for other stakeholders e.g., governmental organisations, donors and communities when establishing various project guidelines and documentation that relates to housing provision e.g., project briefs, criteria to be adhered to, checklists and building regulations etc.

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ASSESSMENT AND IMPROVEMENT OF A REQUIRED CONSTRUCTION MANAGEMENT SERVICE-LEARNING COURSE

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There is a trend for universities to embrace high-impact educational practices in their curricula to enrich the student learning experience. During a recent curriculum revision, the faculty at the McWhorter School of Building Science at Auburn University made the decision to add a service-learning course as a requirement for graduation. The service-learning course is centered on a small construction project that serves the community and incorporates the application of various critical facets of construction management: engagement and communication with all stakeholders, planning, estimating, scheduling, and constructing the project. This study is a continuation of previous research concerning the efficacy of the service-learning focused construction management course. Previous research focused on student feedback concerning the execution of the course and project accomplishments. This research continues that work by analysis of data collected from structured interviews of the instructors teaching the course, as well as the evaluating the impact of implemented changes to the course based on data gathered from students. In addition, this study includes an extensive literature review analysis which identifies the current standard of practice for assessment of student learning in service-learning courses in construction management education.

Keywords: engagement, community, high-impact education, service learning

INTRODUCTION

The emergent trend in higher education in the United States is to include high-impact educational practices in their curricula to enrich and improve students' educational experience. It has been recognized that exposing undergraduate students to real-world experiences as part of their education better prepares them to enter the workforce (Farrow and Burt, 2018; Kuh, 2008). Like other land grant institutions in the United States, Auburn University has "impactful service" as one of its strategic goals. This includes innovation and community engagement to enhance the quality of life in the State of Alabama and beyond. (Auburn University, 2019).

In keeping with the trend to include high-impact educational practices in curricula and in order to meet the university's goal of providing "impactful service" to the community, the McWhorter School of Building Science at Auburn University incorporated a service-learning (SL) course as a required part of its curriculum.

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Service-learning is defined as “a form of experiential education in which students engage in activities that address human and community needs together with structured opportunities intentionally designed to promote student learning and development” (Jacoby, 1996). In this case, a SL course includes the planning and execution of a construction project that benefits a non-profit entity that works to improve and/or support the community. Prior to the addition of community engagement to the university’s strategic goals, the McWhorter School of Building Science has long been active in offering opportunities for community engagement to the students. For over 25 years, several faculty members spearheaded the incorporation of service projects as a component in various elective courses in the curriculum. As part of a recent curriculum review in 2016-2017, the faculty made the decision to increase the school’s commitment to community engagement and high-impact educational practices by adding a required standalone SL course as part of the new curriculum. The ‘new’ SL course is offered in the penultimate semester prior to graduation and is designed to integrate all components of the construction process including planning, collaboration with stakeholders, management, safety, quality, and execution while at the same time enhancing community engagement.

Using the experiential learning process to teach construction can be filled with difficulties and is prone to chaotic undertakings that serve as examples of how not to properly manage construction projects. The research focuses on faculty experiences creating and executing the first five semesters of the newly created required SL course in the curriculum and provide recommendations for effectively using SL in construction management curricula. This course differentiates itself from previous courses at Auburn University, and other universities for that matter, because it is a requirement for graduation rather than being an elective. The authors of this paper were not involved in the development and instruction of the course in the first five semesters the course was integrated into the curriculum, which differentiates this research from the majority of previous research on the subject. Most commonly, the authors of SL research in construction management (CM) are also the instructors of record for those courses implementing SL pedagogy. This research is a continuation of work previously conducted concerning this new SL course. The previous research focused on student perceptions and non-profit partner perceptions of the course and have been previously published. The continuation of the research focuses on the experiences of the two faculty members who created and deliver of the new SL course.

LITERATURE REVIEW

The acquisition of knowledge is not a passive process. Cognitive psychologists have studied various experiential learning and educational theories throughout the 20th and 21st century. This foundational research includes Kolb’s work in cognitive learning styles (2015); learning copers and defenders studied by Burner (1986); and Witkin and Goodenough (1977) looked at issues of the field dependence versus field independence. The work of these researchers, as well as others, recognized the cognitive learning process and how deeper learning is achieved when a learner applies concepts from the classroom to real-world experiences.

Engaging the student to experience and apply a set of ideas, processes, or problems notably advances the learning process as compared to other methods of receiving information - such as reading or hearing it through lecture only (Senior, 1998; Smith *et al.*, 2018). The approach of experiential learning is utilized by construction

management educators to reach students at a deeper metacognitive level (Korman, 2015; Park *et al.*, 2016; Slattery *et al.*, 2008; Wu and Luo, 2018). Collins and Redden (2020) evaluated the use of a hands-on, experiential learning experience that goes beyond the typical construction management coursework in a construction estimating course with 102 students over several semesters. The study found that each student's ability to grasp the subject improved, and their preconceived perceptions of construction estimating skills were positively changed. Farrow and Burt (2018) found students that participated in small SL projects, international study, competition teams, or an industry internship connected those experiences to a more profound level of learning.

Cline and Kroth (2008) found the practice of using SL projects in CM curricula challenging for instructors due to logistical concerns, course time constraints, and by the very qualities that set SL apart from other forms of experiential learning. A critical element for success when implementing SL is for the educators to provide assistance and structure for students to ensure they are prepared to learn from experiential opportunities (Cone and Harris, 1996). Under conditions in which frustration, anxiety and other emotional responses are too high, individuals have difficulty forming clear concepts (Eysenck, 1982). Therefore, preparing students and shaping student expectations in order to minimize frustration and debilitating anxiety is a critical element (Cone and Harris, 1996).

The literature illustrates enriching SL elective courses in construction management. In 2010, Auburn University (Bugg, Collins and Kramer, 2017; Farrow, C., Kramer, S., and Meek, D., 2011) initiated a short-term study abroad elective course with a humanitarian aspect incorporated for the students enrolled to assist in the construction of an after school care center in Quito, Ecuador, for underprivileged children in partnership with the non-profit organization Servants in Faith and Appropriate Technology (SIFAT). Colorado State University recently published on the development and success of a SL elective course (CON 464 Construction Leadership) which began in 2011, occurs each spring semester, and is centered on one larger-scale SL project for the total class to work on throughout the semester. The elective course has "an established structured selection of students that wish to enroll in the course and participate in a SL project." (Olbina, S., Mehany, M. and Jesse, K., 2018). While SL elective courses in CM programs are well-documented as valuable and enriching to those students that participate, students who are unable to participate because they were not selected or could not afford additional fees are not able to benefit from the learning experiences afforded by SL elective courses. One primary gap in previous research is the development and implementation of a required course in the CM curriculum that features the execution and management of a large-scale SL construction projects as the focal assessment theme for successful completion of the course. The literature also lacks evidence of a consistent, well-documented implementation of a required course where the program or school has continued refinement and achieved successful balance of the required SL course.

METHODOLOGY

The research was performed by two faculty members not involved in the formulation or execution of the SL in order to maintain 'third party' perspective of the data. The research methodology consists primarily of information obtained during semi-structured interviews executed separately with the Service-Learning Coordinator (SLC) faculty member and the faculty member that has been the instructor for the

course since its creation in Fall 2018. These interviews focused on planning and logistics for the class, institutional enablers, institutional inhibitors, challenges faced by administrators and instructors, lessons learned, improvements and how the class has evolved since its inception in the 2018 Fall Semester. The SLC and instructor were interviewed after the first semester of the course in December of 2018, and then again during the fifth semester in March 2020. This paper incorporates the data obtained from these interviews. The systematic process of organizing and identifying categorically meaning of the interview data was performed by the researchers by thematic coding (Vaughn and Turner, 2015; Rubin and Rubin).

In addition to conducting the interviews with the SLC and course instructor, students completing the course were asked to complete a questionnaire to determine the students' perception of the efficacy of the course, course strengths and course weaknesses. The same was true for the non-profit owners after each semester's project completion to collect their perceptions. The results and analysis of the students and owner perceptions of the required SL course is presented in a conference paper that was scheduled to be published in April 2020 but has been delayed until August 2020 due to the COVID-19 global pandemic. However, it should be noted that students had an overall positive perception concerning the efficacy of the course and owners were positive about their experiences as well. However, both students and owners noted the same challenges noted in the faculty interviews and described below. Complete results are contained in the companion paper.

Course Background

The first time the new SL class was offered was in the Fall Semester of 2018. The current semester (Spring 2020) is the fifth semester the class has been offered. For the Spring and Fall semesters each year, there are two cohorts of 30 students each. For the Summer Semester, there is one cohort of 20 students. In total, as of Spring 2020, 264 students have completed the course. Each cohort is divided into 10-student construction teams; therefore, the maximum number of projects in one semester is six (6). The construction teams are selected randomly by the course instructor. Each construction team selects a leader or "project superintendent". The project superintendent is the single point of contact between the team and the project owner. The project superintendent also is responsible for submitting weekly communication reports which consists of total man-hours logged, look ahead schedules, material and equipment usage, and other field supervision data points. In order to minimize liability concerns, one of the prerequisites for enrolling in the SL course is the Construction Safety Course which includes the requirements for OSHA 30 certification. In addition, students are required to sign a waiver of liability.

In order to select suitable projects, shortlisted non-profit organizations (owners) participated in a request for proposal (RFP) process. The shortlisting process is completed by the McWhorter School of Building Science School Head, the SLC, and the course instructor. Owners submit a written response summarizing the scope of their proposed project(s). After the RFP responses are vetted by the SLC and the course instructor, owners were invited to present their projects to the student construction teams. Each student team then selects the project they will work on for the upcoming semester.

At the start of the semester, each team is assigned to prepare and submit a Site Specific Accident Prevention Plan, a cost estimate with detailed material purchase lists, and construction schedule for their selected project. Each student team then

makes an oral presentation to the owner and course instructor summarizing these documents prior to the start of work. Each team then receives notice to proceed for the project after receiving the owner's written approval of budgets and schedules. The student teams each spend the balance of the semester executing the physical construction of the projects.

The course is designed for the student teams to work approximately four to six hours per week on the planning and the physical execution of their selected project. The students receive two (2) credit hours for completing the course. Table 1 contains the student assessment and evaluation information from the course syllabus:

Table 1: Student evaluation and assessment

Course Objectives	% of Course Assessment
Written Proposal, Estimate, Schedule, Safety Plan and Quality Control Plan	30%
Oral Presentation of the Proposal to the Client	10%
Communication Reports	10%
Mid-Project Inspection (safety procedures, quality, interaction with owner, and involvement of team members)	20%
Completion of Service-Learning Construction	5%
Final Presentation (written and visual documentation, reflection of process)	25%

All members of the student construction teams receive the same grade for the course with one exception. The student assessment has a peer review component where students assess each other's participation and contribution to the project. If a student performs poorly on the peer review, a letter grade is deducted from their final course grade. This assessment component encourages collaboration of all student team members, allows the students to hold each other accountable for the equality and parity of work commitment as well.

RESULTS

Institutional Enablers

As stated above, this required class was instituted, in part, because of Auburn University's stated commitment to community engagement. This, combined with the McWhorter School of Building Science's long history of SL engagements, made the inclusion of a required SL class in the curriculum a natural evolution of the undergraduate education program. Because of the past integration of SL as a course module in Concrete Structures classes or extra-circular activities sponsored by CM student organizations, the McWhorter School of Building Science has established relationships with a network of non-profit entities- locally, regionally, nationally and internationally. These prior relationships facilitated the initial search for eligible SL projects within a 30-mile (50 km) radius of campus. In addition, several of the McWhorter School of Building Science's financial donors earmarked donations to be used to support SL projects, both domestic and abroad. The support of the university administration and generous donors provided a strong foundation for the initiation the course as well as its continued development.

Institutional Inhibitors

According to the SLC and the course instructor, the biggest institutional inhibitor is the credit hour allocation for the course, which is only two semester credit hours for

completing the course. All other courses required by Building Science in the junior and senior level are three or four credit hours. In the view of the SLC and instructor, the credits awarded do not reflect the work required by the students to complete the course work. In addition, the time commitment for the course instructor is far in excess of the time requirement for a normal two credit course. This is due to the instructor having to travel to multiple jobsites all in various locations within a 30-mile (50 km) radius of the campus on a weekly basis to monitor the work, answer questions, and give guidance to the students.

Another institutional inhibitor for this course is the compensation instructors receive for teaching the class. Since this is only two credit hour course offered in the undergraduate curriculum, instructors receive two-thirds of the compensation they receive for a three-credit hour course. However, the compensation factor is minor compared to the considerable time commitment required to plan and successfully execute this SL course. These factors combined do not make this an attractive course to teach.

Efficacy of the Course

The researchers questioned the SLC and the instructor about the educational effectiveness of the course and how they each defined “success” in teaching the course. The following is the consensus of their answers concerning the effectiveness and the most valuable aspects of the course from their perspective:

- The breadth of the educational experience as shown by the course requirements (Table 1) for both planning and execution; the course ties the theoretical into practical application.
- Gaining an appreciation for thorough pre-project planning and the overall efforts it takes to succeed in the preconstruction phase of a project.
- Developing/managing a relationship and communicating with project owners.
- Problem-solving and overcoming obstacles.
- Learning the importance of teamwork/collaboration.
- Gaining actual hands-on construction experience.
- Feeling the gratification of completing an actual project.
- Developing a “heart for helping others.” This particular outcome is based on anecdotal evidence provided by the class instructor. Many students spoke of how completion of the SL project gave them a great deal of satisfaction because it helped the community, and many expressed a desire to continue to participate in community service after graduation.

Challenges

According to the SLC, one of the biggest challenges is selection of SL projects for the students to construct. In the interview, the SLC stated it takes about 95% of their time to solicit, screen, and manage the project selection process. When the class started in the Fall Semester of 2018, it was envisioned there would be many more projects than the students could execute in any semester. In other words, the students would be able to choose from multiple projects when selecting their project. This has not been the case. For the first four semesters that the course has been offered, the number of projects available has been roughly the same as the number of student teams. This was especially problematic in the first semester. Two of the projects were located approximately 65 miles (105 km) from campus. As a result, the student teams assigned to these projects spent three hours each week travelling to and from their

project sites. This resulted in the students either spending less time onsite or increasing their time commitment to the course. Another challenge in the first semester was that the readiness of the projects to be constructed. These challenges included: incomplete designs, project permits had not been obtained, funding shortfalls for materials, and changes in owners' points of contact.

According to the course instructor, the biggest challenge faced by the students is that majority of them have no experience actually building a project. While they have been taught how to plan, schedule, and estimate, the majority of students do not have any practical, hands-on experience at the time they enter this course in their senior year. As a result, many students are apprehensive and anxious about the construction phase of the course. In order to overcome this apprehension, the instructor emphasizes the importance of planning. The instructor is available to offer technical assistance when needed. However, because of the number of project sites and the distance between them the time of the instructor on any one job site is limited. This can lead to construction delays as the students await guidance and/or assistance. The limited availability of the instructor for any one project team has been a major student criticism in course evaluations each semester.

Incorporation of Lessons Learned

The following are the major lessons learned by the SLC and course instructor after offering the course every semester (Spring, Summer and Fall) for the last two years: (1) thoroughly vet and evaluate all owner proposals; (2) keep all project sites within a 30 minute drive of campus; and (3) one instructor for this course is insufficient to handle the workload. It was obvious after the first semester that a more rigorous system to vet projects was required to minimize delays and disruptions caused by design changes, permit issues and other owner caused delays. Just as planning is a major of student work in the class and is required for project success, planning is equally important for owners of SL projects.

To make sure that owners stayed on track with the planning process, the SLC developed a detailed tracking mechanism (Excel spreadsheet) for owners' project progress. Items tracked on the spreadsheet include preliminary contact made, preliminary scope defined, schematic drawings, preliminary estimate/budget, construction drawings, stamped construction drawings, 100% funding available, City of Auburn approvals, final scope/design, project site ready/available, building permit, and approval for presentation to students. The owner progress spreadsheet is used during weekly meetings between the SLC, the course instructor, and the school head to insure there are always sufficient projects to support the execution of the class. The spreadsheet tracking system and weekly meetings have been very effective in improving owner planning which has enhanced the student learning experience. Keeping viable projects in the pipeline takes an intensive effort by the SLC and course instructor to keep owners, who are not always familiar with the project planning and delivery process, on track. While changes, delays and problems can be expected on any construction project, these should be minimized on SL projects of short duration. Otherwise, students are unable to glean the full value of the class and owners can become frustrated with a lack of progress if even they are responsible for the lack of progress.

Incorporating the lesson learned to keep all project sites within a 30-mile radius of campus has become easier now that the course has become established and the school has expanded its pool of eligible project owners. The problems encountered in the

first semester with project sites being so far from campus were due to the limited number of project available for the students to select from. While choices were limited for the first three semesters, the pool of projects had been expanded to the point that students had several choices from which to select.

Now that the course has been offered for five semesters, it has become obvious that one instructor to teach two simultaneous courses with 30 students each (total of six large-scale projects in construction at the same time) in the Spring and Fall semesters is not sufficient as noted by both the instructor teaching the course and the student feedback obtained through previous research. As noted above, in the Spring and Fall there are 6 projects under construction simultaneously. Due to the students' relative lack of construction experience, in an ideal learning environment the instructor would be available to provide guidance and answer questions all times students are working onsite. This is simply not possible given the number of and dispersion of the project sites. In order to address this issue, the faculty met and made the decision to recruit more instructors to teach the class. In recognition of the extraordinary time requirement to teach the class, the decision was made to divide each 30 student course into three, 10 student sections. Instructors would earn 2 semester hours teaching credit for each section. Partly as a result of this policy change, several of the faculty who had previously expressed an interest agreed to teach the class on a trial basis. The additional instructors are scheduled to begin sharing the workload in Fall Semester 2020.

CONCLUSION

The McWhorter School of Building Science continues to recognize the benefits, for both the recipients and providers, of offering a SL course based on multiple large-scale projects each semester. The importance of immersing students into high-impact practices, specifically SL, in CM provides a strong opportunity for student growth and prepares them for their first position in the construction industry. Gaining and formalizing the perceptions, experiences and attempted improvements of the key faculty engaged in the course from its inception to the present is critical to evaluate the course's efficacy and determine how the faculty as a whole can continue to support the extraordinary endeavor to teach every student in the program through a required SL class.

The time commitment and constant, year-round engagement required to assist and guide the non-profit partners through the preconstruction phase of SL projects is a vital element that has revealed itself as a direct factor in the success or failure for the student teams to achieve substantial completion by the end of the semester. The role of the SLC is necessary for the required SL course to achieve maximum educational effectiveness for the students. Having the financial means and institutional support to resource a faculty or staff member to perform the skills of a preconstruction manager for the non-profit owners is imperative.

The instructor of the course must work with the students on day one of the semester to prepare and plan for the successful execution of their projects. This assistance and guidance must continue throughout the semester. The existence of student anxiety surrounding misconceptions and lack of experience in projects of this magnitude requires the instructor to have resources and time to provide all students with direction, and at times a lot of hands-on assistance. As Cone and Harris (1996) and Eysenck (1982) summarized in their research, preparing students and shaping student expectations in the beginning [with an assignment of this magnitude with a lot of

moving parts and responsibility] will minimize frustration and will reduce anxiety so the learner's mind is open to obtain the fullest benefit offered by the SL experience.

Future research includes continuing for the researchers to track the continuing evolution of the course. Because of the COVID -19 global pandemic, the university was required to transition to virtual instruction during the second half of the 2020 Spring semester, as well as the entire 2020 Summer semester. Future research will focus on the examination as to how this transition to virtual classes effected the content of the course, as well as faculty and student perceptions of the effectiveness of the learning experience. Another opportunity for further research is to collect data from alumni of the course to determine if the course has helped them in their professional careers, and if the required commitment to serve the community during their education instilled a desire to continue service work after graduating from the university. Lastly, while service learning (SL) is recognized as a powerful pedagogical tool the authors' see opportunity to initiate studying any ethical issues this course may present. Highlighting possible dilemmas and providing awareness to ensure all involved are prepared to address ethical issues will strengthen all stakeholders' engagement in the course.

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ENHANCING STUDENT MOTIVATION AND LEARNING WITH MONETARY PRIZES IN A CONSTRUCTION MANAGEMENT UNDERGRADUATE SUBJECT

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This study developed a competition mechanism that is integrated into an industry-sponsored project to enhance student motivation, engagement and learning achievement in a construction management under-graduate program. As part of the formative assessment exercises in a construction technology subject, students were tasked to propose an alternative precast concrete building solution for a four-storey car showroom that was originally designed to be constructed as an in-situ reinforced concrete structure. An industry partner was actively involved in establishing the scope of the project, provided all necessary documents, arranged site visits and introduced the range of precast concrete components that were available for use. A design engineer from the company was invited to present a lecture on the design and construction of precast concrete structures. Students also visited a project where these precast concrete elements were being erected. Students were assigned to work in pairs to develop an alternative precast design and propose a detailed construction plan for the client's consideration. More importantly for this assignment, the industry partner offered cash prizes for the best solutions. An experiment was conducted to examine the effects of the competition by comparing the students' performance in this competitive environment to another assignment in the same subject that did not offer any cash rewards. The results of a survey of the students indicated that many were more motivated, worked at a higher level and attained a more positive experience compared to a previous assignment that had no cash rewards. However, a small number of students reported that they were not influenced by the prize money and did not report any improvement in performance or learning. These findings indicate that individual learning preferences may influence the outcomes from competition mechanisms. This study will inform on future industry engagements with the construction management program in terms of cash rewards to enhance educational value. The pedagogical strategies linking educational outcomes with competition and rewards will have implications for academic teaching and student learning.

Keywords: competition-based learning, industry engagement, motivation

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INTRODUCTION

Studies on teaching and learning in the field of built environment have determined that contextualised experience in the form of industry engagement have been useful. In addition to the main objective of giving students an opportunity to gain practical experience by observing and applying the methods and theories learned in the classroom to real-world scenarios, these engagement activities enhance students' networking opportunities with professionals who can potentially provide employment references and future employment, improve students' communication skills and allows students to gain a broader perspective on their intended career path (Burns and Chopra 2017). Examples of industry engagement activities include internships, field trips, guest speakers and problem-based learning using real or simulated industry case studies. In engineering education, capstone design courses have been developed to better prepare graduates to meet the needs of industry. Having an industry-sponsored project-oriented capstone course has resulted in students progressing from feeling responsible and accountable to a project, to having expectations as an industrial "customer". This appears to be an important factor in their learning (Dutson *et al.*, 1997). While the industry partner's involvement may include a liaison engineer to provide the project brief and details, other criteria such as course requirements, learning outcomes, schedules and other university restrictions remain the responsibility of the course academics.

Being fully cognisant of these benefits, the construction program at the University of Melbourne has long been strong advocates of industry engagement with site visits and case studies strongly embedded in the curriculum. Mills *et al.* (2006) were a major proponent of experiential learning from site visits suggesting that the learning experience by being physically on site, observing the construction process and followed up by a debriefing session to unpack their observations far outweigh the logistical difficulties in organising these visits. Academics in the US (Eiris Pereira and Gheisari 2019) who conducted a survey on site visit experiences shared a similar view but reported a decline in the willingness of faculty members to utilise visits citing spatiotemporal challenges as the most significant barrier.

This paper describes efforts to create a pedagogical environment that seeks to influence the learning experiences of students not only with an industry partner but with the additional reward of monetary prizes for the best solutions. Specifically, this paper broadens the lines of inquiry from issues of active and problem-based learning and industry engagement to include competition and reward as motivational factors to support learning. In collaboration with an industry sponsor, an assignment in a construction technology subject in the built environment degree was conceived as a project with an industry sponsor as client. The task was for students to work in groups of two to propose a precast concrete alternative to a conventional reinforced concrete structure. The assignment culminated in an industry-sponsored competition, where student teams presented their solution to a panel of expert judges from industry. The best solutions were awarded cash prizes. The objectives of the study were: (i) to examine the impact of the monetary rewards on the levels of motivation and engagement in the assignment, and (ii) to assess their learning of the intended content for this course.

Context and Pedagogical Issues

Prior research suggests that learning is facilitated when the learner is provided with the relevant foundations of knowledge, engaged in solving a real-world problem,

guided by appropriate coaching that is gradually withdrawn, and given the freedom to create, invest and explore new ways to use their skills or knowledge. However, despite the opportunity to work independently and actively on realistic problems, higher education still suffers from a lack of student motivation (Cuevas-Martínez *et al.*, 2016) and a decline in academic performance (Figas *et al.*, 2013, Munoz-Merino *et al.*, 2014).

Competition-based learning however has been observed to result in stronger motivation in students and increases their learning performance (Burguillo 2010, Cuevas-Martínez *et al.*, 2016). Competitions in this context refers to tournaments, leader board, or other academic competitions in the likes of mathematics Olympiads, discovery challenges, and robotics contests. Academic competitions, especially those that focuses on collaboration enhances student motivation and promotes interaction with other course-mates (Munoz-Merino *et al.*, 2014). Collaboration and coordination developed in teamwork assignments are also key career requirements. Academic competitions can also expand the scope and depth of content, allowing students to explore subject areas far beyond the opportunities available in a regular classroom (Ozturk and Debelak 2008). An example of a competition is where a tournament is organised at the end of the semester where additional points can be gained from the competition. The learning result is therefore independent of the student's score in the competition. The additional points to be gained from the competition only improves the final mark of the group and do not affect the others negatively. In this case, the competition is among different groups where students must collaborate to enhance their team's performance.

It follows that an extension to competition-based learning would be to offer a reward to the winners of the competition. Sternberg and Baalsrud-Hauge (2015) investigated extrinsic motivation by introducing monetary prizes to two cohorts of students. They observed that monetary prizes have a higher impact on already motivated students who exhibited stronger group dynamics and motivation to not only work for a course grade but an extra prize money. They also argued that students in the less competitive cohort, being in a higher level of education and expected to be responsible for their own learning, were hardly affected by this offer of prizes. Literature suggests that when a person engages in an intrinsically interesting activity, under certain conditions, the imposition of extrinsic rewards may have detrimental effects that have been labelled "hidden costs of reward" by Lepper and Greene (1978).

RESEARCH METHOD

This research project has been granted approval from the University of Melbourne Biomedical Sciences Human Ethics Advisory Group, Ethics ID: 1954376.1, approval date: April 24, 2019.

The construction technology subject was structured as follows. The first part introduced the concepts of steel structures and describes the various framing systems including portal frames for industrial buildings. The second part was devoted to the construction of basements both single and multi-level with the corresponding systems for earth retention and waterproofing systems. Various systems for shallow and piled foundations were discussed. The third and final part was devoted to precast concrete and exemplified by tilt-up construction, prestressed hollow-core floors, and precast beams and columns. The course was delivered through 30 hours for lectures, 11 hours of tutorials and discussions, and around four visits to construction project sites. Assessments consisted of two reports to be completed during weeks 5 and 9 of a 12-

week semester followed by a final exam at the end of the semester. The first assignment was to report on the design and construction aspects of a steel portal frame. The second assignment, which was the competition task reported in this paper, was to propose an alternative precast concrete solution for a conventional reinforced concrete structure. Students were required to find their own partners to work in groups of two for these assignments.

Cash prizes were offered for the best solutions for this second assignment. In order to separate the activities of the competition from the regular teaching and learning activities in the course, the assignment tasks and grading were conducted in accordance with the usual arrangements. Students were given three weeks to complete the task, and reports were graded by the instructor within a week. Participation in the competition was entirely voluntary with the top ten groups with the highest grades invited to present their solution to a panel of expert judges.

A questionnaire survey was created to explore three aspects of this competition-based assignment: motivation, engagement and learning. Motivation is defined as the reason for wanting to do something whereas engagement is the actual commitment or effort put into the activities. Learning, on the other hand, is the knowledge or skills gained from the activity. Students were asked to compare their level of motivation, engagement and learning between the two assignments - the first without, and the second with an offer of prize money. Students' responses were recorded on a seven-point scale ranging from 1 point, strongly disagree, to 7 points, strongly agree. A free-text question sought qualitative feedback on the students' competition experience.

The schedule of activities relevant to the competition was as follows:

1. Assignment 1 (Week 5): A first assignment on steel portal frame construction was completed by the students. Students worked on this assignment in groups of two and was run conventionally without any competitive mechanism. The assignment was worth 15% of the total subject grade.
2. Lectures (Week 6): The instructor covered the concepts of precast concrete design and explained the construction process of using these precast elements in a multi-storey project in the lectures. These lectures were supplemented by photographs and videos of visits to previous sites where precast concrete was used.
3. Assignment 2 announcement (Week 7): The project and competition briefs were released to the students together with a set of drawings (site layout plan, building floor plans and elevations). The project brief was from a car showroom and warehouse project that the industry partner had been working on recently.
4. Site Visit (Week 8): A project site visit was organised by the industry partner to a building site where similar precast concrete components were being erected. Students spent more than an hour at the project site and were given detailed briefings by the design engineer and construction manager.
5. Submission of reports and Questionnaire Survey (Week 10): The survey was conducted in a session when students submitted their reports. The survey was administered in-person by the first author who is a teaching specialist at the same university but not involved with the teaching of this construction subject. The second author who was also the instructor in the course left the room when the surveys were carried out. Student reports were graded according to an assessment rubric. The ten best groups were invited to present their project

to a panel of expert judges. Participation was voluntary, and all ten groups agreed to present.

6. Questionnaire Survey (provided on submission of project):
7. Presentation to judges (week 12): Ten groups presented their proposal on a Friday afternoon. The judges scored each group during the presentations and results were announced at the end of the session. Cash prizes were handed out immediately to all the winners.

Given the small cohort and sample of students in the course, the data generated from the survey was processed manually in a Microsoft Excel worksheet. Students' responses were statistically analysed to determine if there was a statistical difference in their perceptions of motivation, engagement and learning between the competitive and non-competitive assignments. A significance level of 0.05 was adopted in this study.

RESULTS

From a total of 74 enrolled students, 37 survey questionnaires were returned indicating a response rate of exactly 50%. This survey response rate is very similar to the subject experience survey carried out online at the end-of-semester. Internal consistency is measured using Cronbach's alpha. The responses over the nine questions produced an alpha value of 0.9032, indicative of a strong reliability or self-consistency (Taber 2018). This high value of alpha may also suggest some redundancy in the survey questions. The t-test result of $P < 0.05$ suggested that the responses for all nine survey questions were significant.

The survey results indicate that the students were broadly in favour of the competitive assignment with the means exceeding 4.0 in all the questions across the three dimensions of motivation, engagement and learning, as shown in Table 1. The highest agreement was in challenge and stimulation to learn more while motivation was only slightly above neutral. The competition also resulted in students being more engaged with more time spent on the assignment and more collaboration between team members. Twenty-four students indicated that the prize money was an extrinsic motivator for them compared to seven who disagreed. A further six students were indifferent.

In terms of engagement, students reported spending an additional 3 hours on the competitive assignment 2 (22.1 hours) compared to assignment 1 (19.1 hours). Nearly three-quarters of the students reported spending more time on this assignment while only five students reporting spending less. Twenty-four students agreed that the competition contributed to a greater engagement between team members to achieve this common goal compared to the non-competitive first assignment.

The most significant results were from the learning perspectives where more than 80% of the participants agreed that the competition stimulated them to learn more. More than half the students surveyed agreed that the competition has resulted in a better output for the assignment task and that their overall experience was better. There were about seven students who did not agree with these outcomes and another dozen or so who felt indifferent.

Students were given the opportunity to provide additional feedback on the competition experience via a free-text question and during a focus group meeting. Some examples

of comments from students who reported positive perceptions of competition were as follows:

The whole competition with industry engagement was all win, win, win.

Money was an incentive, but we were just trying to get it done.

No negatives, except the extra step of the presentation.

Most students mentioned that the cash prizes did not make a difference to the number of hours put in or to the quality of the work as they were more concerned with their marks. Another student forgot that the assignment had a competition component.

They said:

The group experience was awesome with or without the competition, but it would have been better to get the industry person involved earlier.

I forgot it was competitive Lmao

The nature of this course doing both architecture and construction leaves me with little time to spare. Therefore, my marks come first before money

The negative perceptions were related to the difficulty of the project and lack of time to complete:

My mental wellbeing is not okay - I have hardly slept.

It wasn't the competition that made me spend more time or the money. It was that the assignment was so difficult."

Luckily, I've got an extension for my assignment of another subject - otherwise, I might have been completely exhausted by now.

I'm so sleepy now - I wish subjects in the same faculty can be due in different weeks rather than adjacent days. I have to stay overnight this week (though I shouldn't have started so late.)

Table 1: Mean and standard deviations of the student survey (Responses were recorded on a 7-point scale with 1-Strongly disagree and 7-Strongly agree)

Comparing Assignment 2 (competitive) vs Assignment 1 (non-competitive)	Perspectives	Mean	Standard Deviation	Signif.
More challenging	Learning	5.84	1.38	P<0.001
Stimulated me to learn more	Learning	5.81	1.17	P<0.001
Spent more time and effort	Engagement	5.49	1.76	P<0.001
More long-term gains	Learning	5.46	1.22	P<0.001
More collaboration	Engagement	4.84	1.66	P<0.01
Time well-spent	Learning	4.78	1.53	P<0.01
More motivation	Motivation	4.78	1.73	P<0.05
More positive experience	Learning	4.70	1.39	P<0.01
A better product	Learning	4.68	1.45	P<0.01

DISCUSSION

The results show that 65% of students were motivated to a greater extent and likely resulted in higher engagement during the assignment with the competition and offer of cash prizes. Students who reported higher motivation also reported greater engagement and consequently better learning outcomes. This is compatible with Tauer and Harackiewicz's (2004) finding that competitions made students become more involved in the activity and Chen and Chiu's (2016) observations regarding

higher engagement among team members. In fact, Tauer and Harackiewicz argued that combining cooperation (two students in a group) and competition in the form of intergroup competition leads to the most positive outcomes.

It must also be emphasised that seven students did not agree and a further six reported neutral responses that the promise of cash rewards increased motivation. This corresponded closely to Bolocofsky's (1980) assertion that the inconsistency may be due to differences in student's cognitive style. Students who are intrinsically motivated will not require an additional reward structure to achieve higher marks. It was not possible to ascertain if there were detrimental effects brought about by the offer of extrinsic rewards as the survey was anonymous. Lepper and Greene (1978) have earlier suggested that the offer of extrinsic rewards for an intrinsically interesting activity may have detrimental effects under certain conditions.

Written feedback from the students indicated that many were working under significant work and time pressures. With most subjects having two formative assessments during a 12-week semester, these assignments will invariably fall around weeks 5 and 9 leading to heavy workloads during these periods. Many students accept this as part of the challenges of higher education, but a small number may be overwhelmed by these pressures and this was reflected in their free-text responses. The additional pressure of a competitive assignment structure will add undue stress to these students.

The industry partner who shared their project with the students, sponsored the cash prizes, organised a visit to their project site, delivered a guest lecture and contributed to the panel of expert judges were extremely pleased with the outcome. They observed that the students' proposals were all very similar to their final solution and that their estimated erection schedules were also within days of the actual work program. All the participants were able to answer probing questions from the judges. The construction manager later presented their solution to the assembled students with pictures and videos of the actual erection process. These activities were closely aligned to the best practices for effective industry engagement reported in Massey *et al.* (2006) and Male and King (2014). The value of such contextualised teaching especially in construction studies was held in high regard by Tennant *et al.* (2015). Pedagogical studies suggest that experience-led, contextualised teaching offers students enhanced education value. The level of industry engagement in this study was far in excess of the carefully orchestrated construction site visits including onsite briefings, project documentation and hand-outs that Tennant *et al.*, were referring to.

It became apparent after the competition that industry engagement and competition could appear as confounding factors in this study. Massey *et al.* (2006) observed that direct industry involvement not only allows the showcasing of skills and knowledge by the students but facilitates recruiting and employment opportunities for graduates. Dutson *et al.* (1997) also alluded to the fact that students feel more responsible and accountable to an industry client which may be an important factor in their motivation and learning.

CONCLUSION

The issue of integrating a competition into a problem-based learning assignment with significant industry involvement was addressed in this study. A simple competition mechanism was added onto a regular course assessment task for third-year students enrolled in an under-graduate course in construction. The study was designed to

compare students' perception of motivation, engagement and learning between competitive and non-competitive assignments.

As the principal findings in this study indicated, competition could be a useful motivating strategy that can be introduced to collaborative problem-based learning tasks. While confirming previous research that competitions and rewards can improve motivation, engagement and learning, it has also flagged that some students who are intrinsically motivated may choose to ignore these offers or reward or in a more radical response, react with disdain over the extra pressure to perform.

The small number of negative responses indicate that no single method can be recommended for the diverse personality traits of the students in a cohort. Innovative methods of teaching and learning have to be studied and trialled in various environments and under different conditions to expose potential shortcomings.

This study also demonstrates the difficulties in the integration of a competition and cash prizes into an existing course structure and the obligation to maintain educational integrity and equity in the teaching and learning. Not only was participation in this study voluntary, students had to be assured that their grades will not be in any way affected by their performance during the competition.

While this study has resulted in findings that have both theoretical and practical implications, some limitations should be clarified. Firstly, the competition and prize money were sponsored by a leading local manufacturer and supplier of precast concrete components. With such strong industry involvement acting as client and facilitating visits to their project sites, it is possible that the motivational factors may be influenced by industry engagement and the nature of problem-based learning. Therefore, the finding that cash prizes serve as motivation and engagement may not be as applicable to other cases where the independent variable was only competition. Second, since this study was carried out on a group of final year construction students who were keen to demonstrate their work readiness and employability to a panel of judges from industry, caution should be exercised in generalising these results to a broader range of students. It would be of interest in future studies to investigate the effects of competition and monetary reward by considering the students' different interpersonal orientation towards competitions, their individual learning preferences and motivations.

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BUILDING ENGINEERS AND CONSTRUCTION MANAGERS: THE IMPACT OF INTERNATIONAL SERVICE PROJECTS ON THE DEVELOPMENT OF UNDERGRADUATE STUDENTS

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University students' involvement in curricular and co-curricular international service projects continues to become more prevalent. If such involvement provides the student outcomes which much existing literature asserts, these activities fill a much-discussed skills gap for entry-level engineers and construction managers. Exploring student outcomes from involvement in a year-long team-based design and build project with the Milwaukee School of Engineering (MSOE) chapter of Engineers. A multi-disciplinary research team with backgrounds in engineering, construction management, the humanities, and international development addressed this research gap by implementing an IRB-approved project to observe students during a 2017 trip. Qualitative field data was obtained via 10 days of ethnographic observation of four of the ten student participants during the construction of a 165-foot cable suspended bridge alongside host village members in El Temal, Guatemala. With a guiding question of "What impact does an EWB-USA international construction project have on the development of college students?" and a sub-question of "What professional, technical, and social skills do students engender in an EWB-USA international construction project?", the most salient discovery is that not only are all three skill sets developed, but also that said skill development is interconnected on such a project in a way which would be difficult, if not impossible, to replicate in a classroom setting.

Keywords: design and build, developing countries, education, leadership

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INTRODUCTION

The EWB-USA student chapter of the Milwaukee School of Engineering (MSOE) is an extra-curricular international project-based LTS¹ program which has worked alongside Guatemalan communities since 2008 in accomplishing their own development goals via specific infrastructure projects such as schools, bridges, and water distribution systems. A typical project duration is one year, during which the students work as a team in project design and construction planning, with oversight from faculty, professional mentors, and EWB-USA Guatemalan staff. The in-country construction trip is typically ten days and is the culmination of a year's work.

The host village, municipal government, and student chapter all contribute financial and/or material resources towards the project as well as providing hands-on labour. The students, faculty, and professional volunteers work side by side with an EWB-USA Guatemalan contractor and approximately 40 community volunteers each day.

The focus on community empowerment and student mentorship illustrates EWB-USA's two-fold mission to build "...a better world through engineering projects that empower communities to meet their basic human needs and equip leaders to solve the world's most pressing challenges" (<https://www.ewb-usa.org/mission-and-history/>). Any holistic impact assessment of such partnerships would investigate the project's impact on the community itself. EWB-USA has developed a Project Monitoring and Evaluation (PMEL) program which aims to evaluate impact for every project, and this has been conducted for the project discussed in this study.

Regarding student impact, MSOE's EWB-USA faculty advisors had empirically observed how projects contribute to developing well-rounded engineering and construction management students with professional, technical and social skills. Therefore, "What impact does participation in an Engineers Without Borders USA (EWB-USA) international construction project have on the development of college students?" was chosen as the broad guiding question, and the sub-question articulates specific metrics: "What professional, technical, and social skills do students engender in an EWB-USA international construction trip?"

This work is relevant to employers and accrediting agencies who stress the importance of strong professional, technical, and social skills, and it relates to previous work by incorporating direct field observation to what is predominately comprised of self-assessment and reflection.

LITERATURE REVIEW

Professional, Technical, and Social Skills

While the accreditation requirements of both the Accreditation Board for Engineering and Technology (ABET) and American Council of Construction Education (ACCE) heavily weigh technical skills, non-technical (professional and social) skill proficiencies are emphasized as essential by the National Academy of Engineers (2004) and the American Society of Civil Engineers (2019) (Ahn *et al.*, 2012).

¹ As a variety of service programs and activities exist, Bielefeldt et al. (2013) provide a beneficial framework for categorizing university student service activities: Service Learning (SL) is curricular based, whereas Learning Through Service (LTS) encompasses Service Learning (SL) as well as extracurricular service activities.

Construction and engineering industry employers consistently emphasize that entry-level professionals lack the necessary non-technical skills to be effective (Mahasneh and Thabet 2019, Brunhaver *et al.*, 2018). Engineering graduates themselves highly ranked specific non-technical skills as the most important ABET competencies in their current professions (Passow 2013). Furthermore, non-technical skills were ranked highest in importance in a survey of recruiters from over 100 construction companies in the eastern United States (Ahn *et al.*, 2012). Among 14 technical and non-technical competencies, the top six were non-technical skills: ethical issues, problem-solving skills, interpersonal skills, leadership, adaptability, and collaborative skills.

Meanwhile, an abundance of literature, the most comprehensive of which is Astin *et al.*'s (2000) work, posits that curricular and co-curricular service activities equip students with those very skills.

Assessment Methods

Among the first endeavours to assess student outcomes from service participation is Giles and Eyler's (1994) work which surveyed 72 undergraduate students at Vanderbilt University which specifically assessed civic attitude development. Students reported an increased belief that people can make a difference and should be involved in community service, especially in leadership.

A much broader survey of over 3,400 college undergraduate students from 42 universities, which assessed multiple metrics, demonstrated that community service participation positively affects a student's academic development, life skill development, and sense of community responsibility (Astin and Sax 1998). Expanding even further, Astin *et al.* (2000) performed a longitudinal mixed-method study involving over 22,000 university students from a national sample of U.S. universities who were involved in service learning, extra-curricular community service, or neither. Service activities positively impacted academic performance, values, self-efficacy, leadership, choice of service career, and plans for service participation after college. Student interest was the most important factor in having a positive experience, indicating that service should align with one's major.

As LTS among construction and engineering students became more common, literature examining student outcomes began to emerge. McCormick *et al.* (2008a) administered a simulation exercise with 44 students from Tufts University to assess any differentiation among students involved in service-learning in three skill categories: Analytical, practical, and creative skills. As individuals, service-learning students scored higher on analytical and practical skills, but equal on creative skills. As a group, however, service-learning students scored higher in all three categories.

McCormick *et al.* (2008b) also performed a case study with engineering students on an EWB-USA service trip to Ecuador which involved pre-travel, post-travel and "post-post-travel" surveys as well as daily surveys and personal reflection journaling. The authors concluded that students developed "...a greater complexity in their thinking..." and gained valuable skills outlined as ABET competencies.

The National Science Foundation sponsored a 20-participant summit in 2009 on Project-Based Service Learning (PBSL) which included warnings against relying on the self-reporting metrics so commonly utilized to assess student outcomes (Bielefeldt *et al.*, 2009). Nonetheless, much research continued to rely on self-reporting.

Mostafavi *et al.* (2013) conducted a case study of two of Purdue's Engineering Projects in Community Service (EPICS) curricular projects, one domestic and one

international. Qualitative data provided in student journals and the students' documentation of technical and non-technical skill acquisition was combined with the researchers' description of each project's details to draw the conclusion that students obtained relevant competencies outlined by ABET and ASCE (2008).

Litchfield *et al.* (2014: 7) assessed ABET-related outcomes for University of Colorado Boulder students involved in EWB-USA, other engineering LTS organizations, or neither via student surveys. Students' own perceptions revealed that those involved in EWB-USA or similar organizations believed they had "...greater broad and holistic skills..." than those who were not.

Songer and Breitzkreuz (2014) investigated Boise State service-learning student outcomes from a 10-day trip to Belize in which the students created school ground paths. Combining students' perceptions (from surveys and journals) with the professors' description of the project, the authors concluded that students developed teamwork skills and increased global understanding and self-confidence.

A University of Michigan Service-Learning project, in partnership with Bridges to Prosperity, involved design and construction of a pedestrian bridge with local community members in Bolivia. Jeffers *et al.* (2015: 56) examined all five students' reflective journals which were guided by specific daily questions. Journal content from before, during, and after the four-week trip demonstrated that such projects help students learn adaptability and refine their technical skills while increasing global awareness and an "...understanding of the social context of engineering work."

Litchfield *et al.* (2016) included both students and professionals who were involved or not involved in engineering service in interviews, focus groups, and a large-scale survey to ascertain whether those involved in service would self-report higher levels of proficiency. No difference was reported in technical skills rankings, but students and professionals involved in service reported higher professional skills.

Leung (2016) conducted a three-year longitudinal study of 76 construction engineering students involved in service-learning at a Hong Kong university. Students completed pre- and post- program surveys and kept reflective journals, which together revealed an increase in "generic" skills. Their service involved no design or construction, but this does illustrate the global interest in assessing student outcomes.

This chronological review of literature highlights the lack of research which uses direct observation to assess student outcomes related to participation in international service learning and LTS experiences. While self-assessment and reflection are both valid assessment tools, according to Schuh *et al.* (2016), observation offers an opportunity to collect rich data that is not "...influenced by participant interpretation." Therefore, the researchers sought to contribute to the research of student outcomes related to participation in international LTS experiences through the unique perspective of field observation.

METHODOLOGY

Existing literature overwhelmingly concludes positive student outcomes from international LTS projects, but such conclusions are primarily dependent on self-perceptions of the students themselves. This study fills that gap by employing third-party observation via the collection of field data through ethnographic observation, focusing on veins of direct relevance to a wide range of stakeholders: employers seeking to hire entry-level professionals who excel in professional, technical and

social skills, MSOE's EWB-USA faculty advisors, the MSOE community at large (leadership, faculty, and students), and other universities with similar objectives.

Ethnographic field data was gathered by a qualitative researcher during a spring 2017 construction trip to Joyabaj, Guatemala to assess student outcomes in areas of technical, social, and professional skill application and development. The research team included the following:

- Civil and Architectural Engineering and Construction Management (CAECM) Department faculty member, who is also a faculty advisor for MSOE's EWB-USA chapter. This faculty member led the construction trip being studied, and as such, might be less objective.
- CAECM faculty member who was also the Chair of Servant-Leadership at the time of the study and is now the Director of the CREATE Institute focused on real-world engagement in experiential-learning. This faculty member has had no involvement with MSOE's EWB-USA chapter.
- Faculty member from Humanities, Social Science, and Communication (HSC) Department who has had no involvement with the MSOE chapter of EWB-USA.
- Data collector with a Bachelor of Civil Engineering and MA in International Development (which included coursework on ethnographic research) who lived in Central America for eight years working with an engineering NGO who did not, and does not, serve in any formal capacity at MSOE and was chosen to heighten objectivity.

Upon obtaining project approval from MSOE's Institutional Review Board, a research team member introduced the project to the ten student trip participants and gathered signed consent forms. Nine travellers consented to participate. The same team member then chose four students to ensure a diverse representation: two female and two male students, two junior/senior and two freshman/sophomore students, and students with and without defined leadership roles. The four students' names were provided to the field observer who developed pseudonyms. The other two research team members did not know which four students were selected, and only the field observer knew the identity of the pseudonyms.

Ethnographic field data was gathered by the data collector over the ten-day construction trip and the notes were passed on to the research team for coding and analysis. This study was limited to observing the participants during the construction trip. Therefore, a baseline of skills prior to trip was not possible to establish. Future longitudinal studies could address this limitation.

Project Context

The MSOE chapter of EWB-USA has been partnering with the Municipality of Joyabaj in the western highlands of Guatemala on civil infrastructure projects since 2008. The chapter is heavily student-led by upperclassmen student officers in addition to project managers for each project. Two CAECM professors serve as faculty advisors. Engineers, construction managers, and architects from the Wisconsin Professional Partners chapter of EWB-USA provide additional student mentorship.

The chapter holds weekly meetings with an attendance level of approximately 25 committed members. Each project is subdivided into teams often led by upper-class

students who then mentor younger students, although occasionally first-year students have leadership roles. Student officers select the most involved and committed chapter members as project managers and travel team participants. Travel teams include 8-10 students of various academic years, gender, and major. The typical project follows a yearly schedule which begins with site assessment in the spring. Students meet with the municipality and local community leaders to learn about the community's assets and resources as well as the project specifics, and then conduct the necessary site investigations (e.g. topographic surveys, soil studies, etc). By summer, the students are working on the engineering design (e.g. structural, geotechnical, hydrology) in close communication with faculty advisors, professional mentors, community leaders, and EWB-USA staff. Students draft the final construction drawings by late fall, and winter months are dedicated to construction planning (e.g. estimating, scheduling, skills training). A team of students, faculty, and professional mentors travel in the spring and (1) work alongside the community to construct the project and (2) assess the next year's project.

This study's project was a 165-foot cable suspended bridge in the village of El Temal as shown in Figure 1. The bridge is unique in that it was built to sustain the traffic of three-wheeled motorized taxis known as "tuk-tuks." It has a wooden deck on top of steel cables which are anchored into large masonry towers on each side of the 60 ft deep gorge. The bridge provides a critical transportation link for the community to local markets, schools, and healthcare.



Figure 1: El Temal "Tuk-Tuk" Bridge under Construction

Before one can even assess student outcomes the very nature of the project itself must be scrutinized. In this case, the project fosters community empowerment, involves mutual learning, and builds upon the creative and collective capacity of the host community such that their own confidence and ability to set goals and accomplish them is reinforced.

Field Observations

The interconnected nature of the students' technical, social, and professional skill development was evident throughout the field data. Watching the accrual and application of technical skills was in fact an observation in human communication, as the social-professional skill of communication was crucial through the entire project. Without proper and effective communication in engineering and construction, unsafe conditions, delays, waste, and other problems can emerge.

The blend of technical and communication skills was observed in the reading and interpreting of construction drawings and in explaining them to team members. Students gained experience in explaining technical topics and processes to other team members, and in one instance to clarify something a professional did not explain well. The pseudonyms for the four students who were observed are as follows:

- Jonathan, student with a defined leadership position;
- Ashley, student with a defined leadership position;
- Allison, student without a defined leadership position; and
- Benjamin, student without a defined leadership position

Field observations noted both verbal and nonverbal communication, nonverbal being used when hearing was difficult or to overcome language barriers in a tri-lingual context. Students proficient in Spanish communicated directly with Spanish-speaking community members, and hand signals or a translator served to communicate with monolingual K'iche' speakers. Students who only spoke English relied on a variety of non-verbal cues and/or others to translate for them. This web of communication required a great deal of teamwork as well as cultural sensitivity.

For example, Allison and Ashley practiced verbal and non-verbal communication to explain to other students the process of mixing concrete and mortar, as well as to communicate with local volunteers. At one point, Ashley said in Spanish, “¿Necesita piedrin?” [do you need gravel]? Sometimes non-verbal cues were used even by Spanish-speaking students as not all Guatemalans spoke Spanish. Ashley, when asking a local volunteer about mixing another pile of mortar, used eye contact with the local volunteers to enact the work.

Both communication and problem-solving skills were key when students had to adjust their plans and estimates. Before the construction trip, the students had calculated materials estimates and established a step-by-step construction process. Upon arrival, however, they realized the excavation was not done correctly, resulting in the need for a longer span and different tower elevations. This required the students to rerun design calculations and material estimates based on the new dimensions to ensure the cable forces were not too large, bridge deck was not too steep, and materials on site were sufficient.

As is often the case in the developing world, there were multiple delays in deliveries. The students were constantly updating the estimates to ensure there were enough materials on hand when needed. Evening planning sessions recapped the day's events, sessions in which the professional skill of foresight was essential as they made necessary adjustments for the next day's plan. Jonathan demonstrated his communication skills—and leadership ability—one evening when the team was discussing the day's work, specifically regarding his approach which involved asking more questions than making statements:

- “The large rock and sand... split between us?”
- “How are we on rock, sand, and gravel everywhere?”
- “We got enough sand for the tower part?”

By asking questions of his fellow students instead of simply providing direction, Jonathan included the other students in the conversation (Benjamin and Allison among them) and helped develop their own skills of planning and foresight.

Students also noticed opportunities to learn from their Guatemalan counterparts who had more hands-on construction experience. As all the mortar and some of the concrete mixes were mixed on the ground without a mechanical mixer, it was a process which Guatemalan volunteers had already refined from much practice. Initially, the students mixed differently than the local volunteers. As the week progressed, the students adapted the local method which produced a quality mix but required less physical exertion. The adjustments included how the ingredients were mixed, order of steps, the tools used, and even how the bags of cement were opened. The students thus discovered the skills and talents of the host community and recognized that learning was two-directional.

Learning and problem-solving continued as the students adjusted to work-related variables. The students gained invaluable technical insights regarding how one must think of construction feasibility when drawing up plans. There were construction tasks that the students planned very well and some in which the fine details were unplanned and left for later. The students were at times quick to solve or prone to delay and observed how the process can grind to halt when decisions were not made. Occasionally they exhibited astute foresight in considering possible problems. During the cable tightening phase, for example, the students gained technical experience with a builder's level and in conducting calculations necessary to ensure the cables were pulled to the correct sag.

The ability to combine technical and professional skills to communicate and engage in problem-solving strategies had great impact on the project's overall quality control. Each student was tasked with quality control to ensure that the bridge was built according to the drawings and specifications. This included (1) inspecting excavation for dimensions and elevations; (2) monitoring the concrete and mortar mixing process for strength and workability; and (3) inspecting the work of local volunteer masons for conformance to drawings and specifications, both for quality control and to minimize waste.

Just as the students were expected not to compromise the quality of the project, they were similarly expected not to compromise safety. The team brought the proper personal protective equipment (PPE) for both EWB-USA team members and community members. Daily safety briefings were held in English, Spanish, and K'iche' to cover potential dangers and risks. When the students observed potentially unsafe situations, they were able, and empowered, to intervene and enforce safety measures in a cross-cultural, tri-lingual context. Ashley served as one of the project's Safety Officers. She was continually active in this role as illustrated in the following actions: ensuring the mixing pile was located away from where rocks were being transported, advising team-members when they needed to wear safety glasses, suggesting that Ben wear a hardhat when rocks were being transported, and then later requiring everyone on the job site to wear hardhats.

FINDINGS

After analysing and synthesizing the literature with the field data, the research team discovered the following:

- Students benefit from participating in a coordinated effort to blend their technical, professional, and social skills. For this project, it occurred all year, although observations were drawn specifically from the 10-day project trip.

- The construction project provided students with a context to utilize terminology and concepts discussed in the classroom as they learned to communicate concepts, tasks, and processes in a real-world project.
- Although the nature of the project required leadership skills from every participant, the professional skill of leadership was developed most in students with defined leadership roles.
- The greater the student investment - both technically and socially - the more likely they exercise leadership. Enacting engineering skills in a cross-cultural, developing world environment forces student investment, especially given the need to continually adapt to variables and unforeseen conditions. Therefore, the transferability of these findings would not include projects for which the students do not have a year-long team-based commitment involving design, planning, and ultimately construction done in partnership with local community volunteers in an international setting.

CONCLUSION

The study's goal was to discover what professional, technical, and social skills are engendered by students who participated in an MSOE EWB-USA international construction trip. Gathering field data as a method to observe students proved useful. As was demonstrated in the team's cohesion, the development of technical and non-technical skills did not solely take place during the 10-day trip in Guatemala but rather over the course of the academic year. This was evidenced in the quality of verbal and nonverbal discourse while working together in-country, and their focus on exercising engineering and construction skills through constant social interaction.

The researchers see value in long-term, real-world, community-based, problem solving projects such as those with EWB-USA where students are working alongside community volunteers in an international setting. Working with other student groups which share similar purpose and philosophy of community engagement may prove useful for growing students with strong professional, technical, and social skills.

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SERVICE LEARNING: ALIGNING UNIVERSITY MISSION WITH DESIGN AND CONSTRUCTION

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Service-learning balances community service for societal needs with a pragmatic, progressive educational experience. Typically, service learning provides an opportunity for direct application of classroom knowledge bridging the divide between theory and practice. Goals for service-learning projects often include increased understanding of curricular content, application of the discipline, and development of civic responsibility. Most educational experts quantify service learning as a high impact educational practice (HIEP), and as an applied discipline, construction management (CM) is uniquely poised to engage in such practice. This paper analyses the literature on service learning in the context of design and construction to identify the perceived benefits and challenges associated with service learning. Based on this literature review's findings, the paper maps service learning at seven universities within the U.S. within CM to determine how service-learning efforts connect with individual university strategic plans, construction unit strategic plans, and how service-learning practices are incorporated inside or outside the curriculum. Results indicate that six of seven universities indicate service learning in the strategic plan of the university but only two of the seven universities indicate service learning in the program-level strategic plan. A gap appears to exist between the literature review, university strategic plans, and program strategic plans. If alignment could be achieved, service learning provides a path for CM programs to meet community needs, provide meaningful HIEPs for students, and promote communication and collaboration with those outside the University setting.

Keywords: education, strategy, high-impact, service learning, engagement

INTRODUCTION

Community engagement has been a consistent, central theme across higher education (Benneworth *et al.*, 2020; Mtawa *et al.*, 2016). But, it has varied tremendously between institution, geographical area, academic discipline, and funding model (Benneworth and Sanderson, 2009; Kruss, 2012). Community engagement is defined as

...a systematic relationship between Higher Education and environment that is characterized by mutually beneficial interaction in the sense that it enriches learning, teaching and research, and simultaneously addresses societal problems, issues and challenges (Centre for Higher Education Transformation, 2003: 4)

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Specifically, this paper considers an educational tactic within the broader term of community engagement, "service learning", in the context of design and construction. Field-based "experiential learning" with community partners through service learning gives students the ability to experience issues studied in the curriculum with ongoing efforts to solve real-world problems in the community. Service-learning projects in the arena of design and construction may include such items as designing or building a small home or constructing an accessibility ramp. Students interact with the client and collaboratively work to complete the educational task. Through solving real-world problems, a knowledge exchange occurs between the students and the community (Bender, 2008). "These programs model the idea that giving something back to the community is an important college outcome, and that working with community partners is good preparation for citizenship, work, and life." (Kuh, 2008: 11).

Within design and construction, limited studies are available that examine the perceived strengths and weaknesses of a "mutually beneficial interaction" within higher education and the community. Little is known regarding the link between university strategic plans and service learning done by CM units. By exploring existing literature and available strategic initiatives of seven institutions in the U.S., this introductory paper seeks to better align service learning, community needs, HIEPs, and the exchange between the university and community. CM programs that could align these elements have the potential to increase educational value, meet community needs, and assist Universities in fulfilling strategic outreach goals.

LITERATURE REVIEW

Boyer's (1990) call to meet the social needs of the community and to expand the definition of scholarly work anchor service learning. As one of Boyer's four pillars of engagement, "application" has gained traction through community engagement (Holland, 2005).

Now, higher educational institutions must become participants in a highly complex learning society where discovery, learning, and engagement are integrated activities that involve many sources of knowledge generated in diverse settings by a variety of contributors (Holland, 2005: 12).

Community Engagement in Higher Education

There has been "widespread adoption and implementation of community engagement" across higher education institutions (Mtawa *et al.*, 2016). Many universities are making commitments to participate in community engagement as part of standard practices (Matthews, 2010).

One of the advantages of community engagement is the corresponding two-way exchange of knowledge as opposed to the traditional professor to student knowledge transfer. This two-way exchange and its balance are challenging (Mtawa *et al.*, 2016). An over-emphasis on teaching and learning might create a more inward focus while an over-emphasis on engagement may reduce learning (Cloete *et al.*, 2011). For CM service learning, student participants learn real-world lessons and acquire skills that complement the traditional classroom, introduce community responsibility, and provide opportunities for leadership. Communities have benefited from the projects completed (Clevenger and Ozbek, 2013).

In 2006, the Carnegie Foundation recognized campuses that committed to community engagement through a classification system (Carnegie Foundation for the Advancement of Teaching, 2006). Accrediting bodies have also included engagement

indicators within institutional quality assessments (Higher Education Learning Commission, 2006). All of these factors have increased community engagement within higher education in the United States. Multiple university mission statements and strategic plans indicate an emphasis on community engagement (Aldrich *et al.*, 2012). For land-grant universities, engagement is central to the mission to "provide equal access to education and service to communities" (Kellogg Commission on the Future of State and Land-Grant Universities, 1999: 1).

Adoption of community engagement by universities has been uneven. "Research universities have been relatively less involved, despite the ambitious efforts..." (Stanton, 2007: 5). The decentralized nature of the university and vague university mission statements are cited as reasons for slow adoption (Weerts and Sandmann, 2010). Often, individual units within the larger university have been drivers of community engagement. In Europe, higher education partners have placed strong emphasis on business engagement as opposed to social engagement (Zomer and Benneworth, 2011). In turn, formal, contractual relationships with public sector partners have advanced ahead of community groups. Thus, social engagement in Europe has typically remained voluntary or has become increasingly marginalized.

New forms of scholarship including "engaged scholarship" and the "scholarship of engagement" imply a broader view of scholarship including community engagement (McNall *et al.*, 2009: 318). These expansions beyond the traditional definition of scholarship have provided opportunities for faculty to engage at a deeper level in community projects. Ivey *et al.* (2016) reported the ability to integrate teaching, scholarship and service in one partnership rather than managing multiple responsibilities separately as a primary incentive for faculty. In addition, researchers report that the teaching pedagogy is enhanced by providing "engaged, responsive and efficacy enhancing experiences for students" (Curry-Stevens, 2011, p. 21).

If community engagement is critical for universities, leaders must consider the full array of activities offered (Benneworth *et al.*, 2013). For example, when a community project is required for all students, all faculty and staff must support as opposed to isolated faculty. Universities must build their capacities to deliver, accept, and embed community engagement into teaching and research as well as make and win the ethical case for engagement.

High Impact Educational Practices

The Boyer Commission offered ten recommendations for undergraduate education (Reinventing Undergraduate Education: A Blueprint for America's Research Universities, 1998). The university was considered part of a larger system that emphasized a shared mission of learning and research. The Boyer Commission noted several concerns with U.S. education including little engagement occurring in class. The report questioned whether graduates could "think logically, write clearly, or speak coherently" (Reinventing Undergraduate Education: A Blueprint for America's Research Universities, 1998: 15). From this report, HIEPs developed. The goal was to use them to provide diverse experiences, solve challenging problems, force independence and self-reliance, and foster stimulation

George Kuh ratified a group of "effective educational practices" that correlated with increased educational impact for students (2008). Termed HIEPs, each of these activities elevated the educational experience for students. Kuh focused on "deep" learning that emphasized both acquiring information and understanding the underlying meaning of the information (Kuh, 2008). Students that engage in HIEPs tended to

earn higher grades and retain, integrate, and transfer the information gained at higher rates (Nelson *et al.*, 2008).

Often a student's self-perception changes, and confidence increases as they interact beyond the classroom. Additional student outcomes include an increased comfort level for entering unfamiliar communities; increased competency in cultural interactions; and improved knowledge, skills, and attitudes (Kramer *et al.*, 2007; Peck *et al.*, 2010).

Service Learning

With growing popularity internationally, service learning is known by names including community-based learning, academic service learning, community service learning, and academic community-based learning (Hatcher *et al.*, 2013). Service learning is defined as

A course or ... educational experience in which students participate in mutually identified service activities that benefit the community, and reflect on the service activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of personal value and civic responsibility (Bringle and Clayton, 2012: 105).

Multiple studies have considered how service-learning benefits students (Celio *et al.*, 2011; Conway *et al.*, 2009; Yorio and Ye, 2012). All show positive student impacts. One found positive impacts in five domains: "attitudes toward self, attitudes toward school and learning, civic engagement, social skills, and academic achievement" (Celio *et al.*, 2011: 171). Conway *et al.* (2009) found greatest impact for students in academic and learning outcomes with relatively small impact for citizenship outcomes. This research also noted that structured reflection yielded increased outcomes. Yorio and Ye (2012) found the greatest positive impacts on students in the areas of cognitive development, understanding of social issues, and insight. For construction management, hands-on projects provide strong opportunities for collaboration, critical to today's construction practice (Clevenger and Ozbek, 2013; Tran *et al.*, 2012). Clevenger and Ozbek (2013) further illustrate that opportunities exist for service learning to be an effective pedagogy to support learning.

METHODS

This paper analysed the literature to identify the alignment between service-learning projects as HIEPs, university strategic plans, and CM programs. Definitions of key terms were established, and common themes were identified. Then, case studies of seven large, public, U.S. universities were considered. Strategic plans of those universities were studied to determine which supported service learning and related language including "civic engagement" and "community engagement". Finally, the CM programs of each of the seven institutions were considered. Strategic plans of those individual educational units were studied, and additional research was done to examine any programs that employed service learning (See Figure 1).

Several case studies were used from seven U.S. universities. These universities were selected of convenience as each participates in a peer group of CM programs that meet twice yearly to consider best practices, address challenges, and identify future concerns. All are public institutions, and six of the seven are "land grant institutions". To provide anonymity, universities have been noted as "Institution x".

RESULTS

The literature review provided context of the perspective of community engagement within higher education, introduced service learning as a HIEP, and detailed the strongest benefits with service learning.

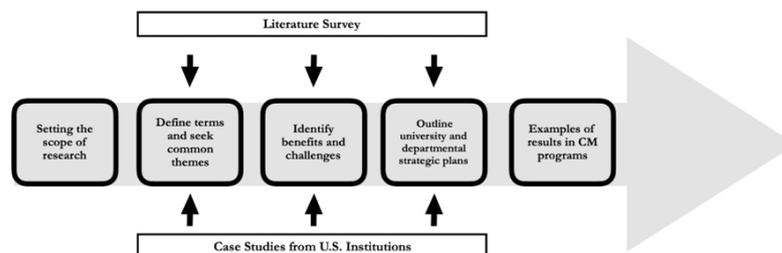


Figure 1: Graphical description of research method

Definitions of community engagement and service learning were provided in the context of higher education. Both definitions connected the highly collaborative nature of such projects and revealed the mutual knowledge creation and benefit to both students and community. In addition, the following items were identified:

- Connections exist that link institutions with societal needs through scholarly engagement
- “Widespread implementation” of community engagement by universities
- Importance of two-way exchange of knowledge and reciprocal nature of partnerships
- Slow adoption of community engagement by larger universities
- Service learning’s unique opportunity for HIEPs for students
- Strongest correlation of benefits of service learning in areas of learning
- Unique opportunities for service learning in CM

Table 1 details the prescriptive study of seven institutions within the U.S. and how their specific university strategic plan details focus on civic knowledge and engagement. Six of the seven institutions have some mention of social and civic engagement. Four of the seven plans relate directly to the engaged educational or learning environment provided by community engagement. Four universities specifically mention addressing larger societal challenges and making an impact through community engagement either locally or internationally. None specifically mention service learning, but two mention learning approaches or specific programs that include service learning. Finally, only one specifically addresses “cultural competence” development in students.

Table 2 considers how the strategic plans of the individual CM programs address civic knowledge and engagement, specifically addressing service learning. This descriptive approach considers what, if anything, individual CM programs have in regard to service learning. Only one program has a strategic plan reference to community engagement, and only two programs have a specific reference to service learning. Both programs who have service-learning objectives are done in the context of engaged student learning.

Table 1: Incorporation of civic knowledge and engagement (local and global) into Institution’s Strategic Plans

Institution	Strategic Plan Reference	Details of Strategic Plan
Institution 1	New American University - Toward 2025 and Beyond Mission 4 of 4 • “Enhance our local impact and social embeddedness”	3 Goals • Strengthen state’s network of teaching, learning and discovery resources • Co-develop solutions to the critical social, technical, cultural and environmental issues facing ... Arizona • ... personalized pathways and promoting adaptability to all accelerated social-technical changes
Institution 2	2019-2024 Strategic Plan Goal 1 • Inspire and prepare students for life through delivery of an experience characterized by distinctive, innovative curricula and engaging ... programs.	Methods in Teaching and Learning: Active Learning • Individual learning to collaborative learning Applied Experience • Classroom learning to hands-on/in-the-field learning • Theoretical skills to application-based/practical skills (i.e., skills that prepare students for careers) • Increased service orientation-direct impact on community • Greater global focus, including study abroad programs
Institution 3	2016 Strategic Plan Goal 5-Engagement • I3 will engage with communities to solve problems, share knowledge, and support progress	Objective 3 of 5 High youth and student satisfaction with opportunities for civic engagement and engaged scholarship Participation in SLiCE programs including cans around oval, alternative spring breaks, I5Unity, I5 Serves, Campus Corps, Key Service, President’s Leadership Program, etc.
Institution 4	I4 Moves Initiative 5- Transformative Education	No specific mention of civic or community engagement
Institution 5	Strategic Plan 2020-2025 2 of 6 Priorities • Enhance transformational education/student success. • Be a best place to live, work, and learn.	• Engagement in transformational learning experiences • Better integrate academic and co-curricular learning experiences so students have more opportunities to apply leadership and personal development in their field • Develop inclusive opportunities for social engagement, networking, service, and community outreach
Institution 6	The Decade Ahead: I6 Goals December 2015-Goal 5 of 7 • A strengthened engagement of the university’s programs with communities.	Increased engagement and outreach of I6 programs leading to positive impacts in such areas as health, the economy, environment and community Metrics: Percentage of faculty, staff, and students engaged in community service.
Institution 7	The I7 Difference: Advancing Beyond Boundaries-1 of 4 Strategic Priorities	GOAL 2-Increase cultural competency GOAL 3-Address critical societal issues impacting humanity and equity

Two construction programs identify learning approaches or specific programs that include service learning; Institution 2 and Institution 3. The specific program at Institution 3 is its CM Cares program. This program was established to help CM students “develop and improve their leadership and team building skills as well as ethics through community service-learning project”. Students participate in the CM Cares Program by taking an elective class CON 464 Construction Leadership. This 3-credit hour class requires students to select and construct a service-learning project during a 16-week semester. During the first eight weeks of the semester, students work with a faculty mentor to develop leadership skills and plan the project. The remaining eight weeks are used to execute the project. During the course of the class students develop and improve their leadership and team building skills as well as their knowledge of ethics (Olbina *et al.*, 2018).

Table 2: Incorporation of civic knowledge and engagement (local and global) into Construction Program’s Strategic Plans

Institution	Strategic Plan Reference	Details
Institution 1	I1 CM-QIP-Fall 2018	No direct mention of civic engagement or service learning
Institution 2	I2 School of Building Science Five Year Strategic Plan 2017-2021 BSCI Signature Identity 1 - Enriching Educational Experience	Ensure all students have multiple, diverse opportunities for deep, engaged educational experiences Appropriate Indicators • Participation in service-learning projects
Institution 3	CM-Building the Foundation for a Program of National and International Excellence Strategic Plan 2013-2018 Key Objective 2: Create distinctive undergraduate experiences	Goal 2.1: Promote excellent service learning ... that enhance students’ experiential learning. • Develop service-learning components within the curriculum. Goal 2.3: Promote student leadership activities • Encourage students’ organization of and participation in service-learning projects (CM Cares) • Encourage student clubs to participate in inter-department community service (CM Cares) Goal 7.1: Leverage departmental expertise to develop service programs to enhance student learning
Institution 4	The School of CM Technology Strategic Plan	No specific mention of civic or community engagement or service learning
Institution 5	CM Strategic Plan 2016 Goal 5: We will maintain connections with communities ... through engagement in public service, ...	No specific objectives relating civic or community engagement or service learning
Institution 6	I6 School of CM Strategic Plan	No direct mention of civic engagement or service learning
Institution 7		No direct mention of civic engagement or service learning

At Institution 2, students are required to take a senior level class that require them to work in groups to plan and execute a service-learning project. They also have the opportunity to take elective classes which have a service-learning component. Students in the Building Science undergraduate program are required to take BSCI 4360 Construction Field Lab. In this class students work in groups to conduct a service-learning project that integrates all components of the construction process. The course follows a similar format to the course at Institution 3 with the first part of the semester spent in planning the project and the remainder spent executing the project (Redden and Bugg, 2020). The program also offers two senior level elective classes. Since 2012, undergraduate and graduate students have been able to participate in 3-credit hour short term, service-learning based international study abroad to Quito (Bugg *et al.*, 2017). In 2018 a second 3-credit hour service-learning based elective class based on disaster recovery was added that required students to complete weeklong disaster recovery work in areas impacted by either hurricanes or tornadoes.

CONCLUSION

This study has considered the alignment of service learning in CM programs with program and university strategy in the context of community engagement within higher education. The literature suggests stakeholders benefit from engagement in service-learning projects, but no research could be found to verify the stakeholder’s perspective when service-learning is conducted in the context of a design-construction project and this may well be an area where additional research is required. If better alignment could be realized, service learning provides a path for CM programs to meet community needs, provide meaningful HIEPs for students, and promote communication and collaboration with those outside the university.

There is near unanimous agreement that community engagement is important at the institutional level. Clear themes in these areas include student engagement, development of “real-world” skills, and accepted engagement for faculty in both teaching and scholarship. CM, with its applied focus, has a unique opportunity to meet this institutional demand. Some disconnect is evident in how the community engagement is described from a focus on “critical societal issues” to a focus on individual student experiences.

At the construction unit level, the inclusion of community engagement is less uniform with only two programs having clear goals and objectives that include service and specific types of teaching and learning. In both cases, the focus of the unit is on the individual student learning while the focus of one of those two universities remains on community engagement. The link between civic engagement and solving community problems may be implied, but the link between it and student learning deserves additional focus. Based on this preliminary study, additional training and education for faculty and students is needed to realize collaborative benefits as a benefit of service learning. And, further research is needed to determine if the perceived benefits correlate with student experiences.

While service learning is not “new”, the concept of linking educational outcomes, community engagement, and university strategic plans remains in its infancy. For the two schools that have explored this option, they have realized strong potentials exist for more impactful and sustainable learning and community engagement. CM programs and university must move beyond the individual project or class and better examine the broader link identified in this paper between educational outcomes, community engagement, and university strategic plans. This study only considered seven public universities within the U.S., and this sample may not be representative of higher education or CM. In addition, no data was gleamed as to how universities may mandate individual units to meet overall strategic goals. Such information could influence the goals targeted by individual units. This paper has presented how strategic initiatives by institutions of higher learning can be incorporated in curriculum. And, the work has identified the body of knowledge developing around service learning within CM programs. The hands-on nature of construction work, the use of service learning as a HIEP, and the ability of service projects to meet broader university goals provide an opportunity for CM.

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THE IMPLICATION OF ADVANCES IN COMMUNITY MAPPING THROUGH SPATIAL INFORMATION TECHNOLOGIES FOR URBAN REGENERATION PROJECTS

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This research explores the application of community mapping as a tool for supporting urban regeneration projects and the potential for its growing importance due to advances in spatial information technologies (SIT's). Despite advances in SIT's it is unclear how community mapping is evolving to aid both planners and construction professionals in enhancing community engagement and representation. The research explores the perceptions of planning officers engaged in urban regeneration projects to establish current practice and explore the potential and shortcomings for using community mapping and new information technologies. Eight semi-structured interviews were conducted with senior planning officers working with urban regeneration projects and these were supplemented by a questionnaire survey eliciting responses from a further eleven officers across Scotland. The results are explored in three parts exploring perceptions of: 1) the current practice during development planning and at the project level; 2) the utilisation and limitations of existing spatial datasets and 3) seven presented elements to survey through community mapping to better aid the representation of communities and explores their potential usability and relevance. The research concludes by proposing the need for a relational database to support the application of these seven elements in a format which can be integrated with existing datasets within SIT's.

Keywords: community mapping, urban regeneration, spatial information

INTRODUCTION

People-focused urban regeneration is often referred to as 'placemaking'. Placemaking gained centrality in the UK within the National Planning Policy with the publication of *Designing Places and Designing Streets* in 2010, and in Scotland it is defined as the "creative and collaborative processes that includes design, development, renewal or regeneration of urban or rural built environments" (Scottish Government, 2014) and it has, since become a guiding principle in the design of regional as well as local development plans with a view to guiding developers to shape construction projects. Placemaking recalls bottom-up planning techniques developed as part of collaborative and communicative planning theories (Innes and Booher, 2015). Whether it is through conflict or collaboration, consultation involves understanding the needs and

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aspirations of people. As cities were historically constructed to respond to basic human needs, the gathering and understanding of what exactly such needs and aspirations are is critical, especially for the success of urban regeneration projects as they seek to deliver long lasting solutions for a sustainable community. A key criticism is that often these aspirations are not fully realised as consultation remains an act of compliance as opposed to being embedded in practice. One of the limitations to this has been the challenges of capturing the subjective lifeworld's of communities and reflecting this in a format that is valued within the decision process both at the planning and project levels. This research explores the role of community mapping and specifically the evolution of Spatial Information Technologies (SIT's) to aid representation in a visually recognisable and interactive format which can be viewed in tandem with abstract data sources.

The slum clearances of the 1950's illustrate key examples of urban regeneration projects which were strategically planned with local authorities and agencies partnering with developers to deliver mass housing. Widely acknowledged to have neglected the needs of the community they reflect two common failures: 1) for planners to adopt the 'heroic planner' approach by imposing their vision on a community and 2) for projects to be delivered by developers who see community consultation as burdensome, costly and time-consuming (Close and Loosemore, 2014). Indeed, criticism has been levelled at more recent regeneration projects associated with the Glasgow Commonwealth Games 2014 where the needs of the existing communities have been argued to have been overlooked in favour of the bigger picture and the needs of the "future community" (Gray and Porter, 2014). Placemaking has the potential to slowly change this, but it is apparent the theory and policy is moving faster than the practice. Indeed, in Scotland a planning approach focused on "social transformation" founded on consultation has become a statutory requirement for major and national developments. Despite this, planners still lack awareness of effective approaches to capture and reflect the subjective lives of the community due to the entrenched bias for positivistic indicators in decision making which hold even more importance in urban regeneration as they are linked to investment and funding allocation.

At the project level community consultation is largely tokenistic with Close and Loosemore (2014) revealing the construction professionals still view the community as a liability rather than an asset and that consultation remains the responsibility of the planners to establish prior to the project stage. A review of how community consultation is reflected in construction management research shows that it is placed within the wider stakeholder management, value management and corporate sustainability, with a dominant focus on 'managing' engagement with communities rather than actively developing projects which respond to the lives of the residents (Boutilier and Zdziarski, 2017). The emergence of social value is increasing the need to value community as an asset within the project (Troje and Gluch, 2020), but there remains a lack of effective techniques to represent the lifeworld's of the community within the dominant positivistic decision-making lens. Improving community consultation remains in its infancy at the project level but it is clear that it can't be viewed as the preserve of the planner and needs to be a project consideration (Boutilier and Zdziarski, 2017).

Community mapping is a technique which has been applied progressively over the last decade to capture the values, preferences, needs and spatial occupation of members of the community within their neighbourhood. This has remained a Cinderella activity

often ignored by decision makers both within development planning and in projects. The evolution of SIT's presents the potential to support the capture, storage and representation of communities through mapping and to integrate it within familiar digital environments such as Geographical Information Systems (GIS). The decisions which shape urban regeneration projects are traditionally supported by abstract data through a series of comparable benchmark indicators such as Census or Index of Multiple Deprivation (IMD) spatially presented through maps but aligned with a top down approach to urban decision making. SIT's such as GIS are commonly applied to inform development decisions, investment and funding applications or strategic visioning (Holdstock, 2016) and is increasingly applied by clients and developers to support individual construction projects. Lefebvre (1994) argue that this abstract representation of communities supports funding decisions by allowing for comparison of deprivation levels. Without community consultation, this fails to reflect the needs and lifeworld's of the community.

The evolution of SIT's has provided the potential to enhance community consultation allowing subjective techniques such as community mapping to be digitally captured and stored within GIS. Sandercock (1998) argues that community mapping "engages and empowers citizens in making their voices heard thus creating radical ways of doing, knowing and acting" during consultation processes, and being able to enhance this process through the digital environment has greater potential for it to be considered in tandem with spatial representations of abstract data. This can help decision makers establish a better understanding of the lifeworld's of the communities (Masser *et al.*, 1996). Despite the rapid increase of community mapping, there is a lag in bringing more subjective forms of data and information into the decision-making process both at planning and project levels. This restricted the potential offered to represent an understanding of community assets, as well as problems, and support environmental or health decisions which may affect the community (Reeve *et al.*, 1999). However, despite calls by Innes and Simpson (1993) over the potential for GIS to capture and represent new types of information it has taken two decades for this potential to fully emerge with the recent advance of SIT's.

Recent years have seen the emergence of facilitators and mediators involved in the consultation processes employing a range of community participation tools and techniques which are evolving with the introduction of new SIT's and computational capacity. From simple Q&A sessions to brainstorming, sketching and paper mapping, to more sophisticated tools like Public Participation GIS (PPGIS), 3D modelling and digital or non-digital gaming techniques, the range of tools used during consultation processes vary by type and kind, and more research is required to identify the strengths and limitations of such tools and techniques (Kheir, 1999; Brown and Kytta, 2014). However, a lack of formal procedures leaves this process as arbitral and dependent on local circumstances, and the availability of knowledge and skills. Particular focus is put on SIT such as digital maps which can aid the consultation processes as well as conceptualising the routines and activity patterns within a social group shifting away from traditional socio-demographics variables like 'income', 'ethnicity', 'age' etc. These traditionally focus in the UK around the IMD, and whilst widely used to profile and represent communities they are criticised for their inability to represent values, behaviour and activity patterns, reflecting their lifeworld's. The potential exists to utilise these innovations in SIT's in the planning process to allow communities to be better represented, but also for developers to integrate this within the individual project stages. This would allow decision makers to support a more

holistic representation of positivist ‘abstract’ data as well as the subjective ‘lived’ data associated with the life-worlds’ of communities presenting an exciting frontier for improving urban regeneration projects.

The evolution of SIT’s in recent years is providing strong potential for developing community mapping and enabling the capture and representation of preferences, values, needs and occupancy patterns spatially through consultation. Evidence suggests that the technology is moving faster than practitioners are able to adapt so a need exists to establish an understanding of the status and requirements for realising its potential. The research focused on the perceptions of senior planning officers as they have the most experience of the role played by SIT’s such as GIS in decision making through the development planning process but also can provide perspective on the nature of application by developers at the project level. Through their lens an understanding is established of current practice, awareness levels of current datasets and to establish a set of elements to survey through community consultation which can be mapped spatially aiding a more holistic representation within decision making.

METHODOLOGY

This research explores the perceptions of eight senior planning officers engaged in urban regeneration within six local authorities in West of Scotland. The interviewees were selected based on purposive sampling of planners: 1) who were within the boundaries of the Greater Glasgow Region, 2) who were available and 3) who had a senior role and experience of working across different teams dealing with varying aspects of development planning, working with construction teams, consultation and SIT’s. This paper focuses on the experience of the planning officer as they have a strong overview of practice within both development planning but also an overview of how developers are engaging with community mapping at the project level. The findings provide the platform for further research to explore with a broader group including tool developers, GIS analysts, developers, community representatives etc.

The interviews were designed through a new materialist lens with attention paid to the interaction between practitioners and the things (datasets, technology) by which they represent the communities (Beaurigard, 2016). Through the planner’s lens the extent to which subjective community data is considered during decision making, and potential of SIT’s to support this and their views on community mapping in this context. The interview is split into 1) their experience of consultation within development planning and their perspective of its role at the project level. The later parts of the interview focus on 2) establishing their awareness of the current datasets available to support community representation, and 3) to gain their views on elements which can be surveyed to enhance community mapping. This reflects the structure of the discussion of results in the paper. The interviews were analysed following thematic analysis enabling themes to emerge through NVivo Software. The interviews provided the basis for a questionnaire survey of senior planners across Scotland sent to all of the 32 local authorities and 11 responses being received which were different to those interviewed and when added to the sample of senior planners interviewed a total of 19 participated across 17 local authorities. The survey was designed to sense check the emerging findings with a view to seeking to reflect coverage across Scotland.

RESULTS

Part 1: Current Community Representation Within Planning and Projects

Part 1 investigates perceptions of senior planners of the consultation processes with a specific focus on how community representation is currently obtained for urban regeneration projects. The interviews revealed this is largely the result of a web of relations between: 1) statutes and official procedures, 2) financial resources and viability, 3) funding applications, 4) consultation work, 5) spatial information, 6) expert knowledge and beliefs, 7) some digital and non-digital techniques and approaches, 8) organisational performance, 9) collaboration with other services, 10) government policy (e.g. Business Improvement Districts), 11) ad hoc maps and 12) the private physical experiences of planners as individuals within a community. One keyway which local authorities obtain information from communities is through the Household Survey questionnaire on a yearly basis. Nevertheless, no requirement or procedure exists on carrying out community mapping as part of consultation at either planning level or for projects.

Two initial themes emerged: 1) the presence of procedures in gathering people's view and opinion as part of a statutory processes and 2) the importance of the intuitive and expert knowledge in understanding communities. The first theme reflects the importance of the Acts and policies to enforce mapping as without this it remains a luxury in both planning and definitely in projects. The second is the relationship between the lived experiences of planners as individuals within the communities and their ability to understand it. "Planners already know" was felt to have importance in how strongly mapping was viewed in planning and the perception was felt to be even more acute by clients and developers when considering their projects. A further theme (3) emerged which related to a perception that there was already "too much data" and, although data is hyped and a buzz word, often most decisions in planning and within projects are made without using subjective data. It was also reported that there is also a common lack of awareness of datasets and how to access them especially related to smart city initiatives and smart governance.

Finally, a fourth theme emerged relating to the importance of the individual involved whether it be a planner or a construction professional as their world view and previous experience and relationship with the community significantly formed their opinions on what elements are important to be gathered to represent a community and which ones can be ignored making consultation processes everything but a science. Evidence also exists to suggest that surveys and consultation were found to be often carried out by external companies and this is seen to potentially have an effect on knowledge flows with decision makers not proactively being involved in the process of knowledge generation throughout the consultation process. Some questions remain about the quality of some of these consultant reports and as a result they often get discredited by decision makers. Despite increased priority placed on the community at the project level through the growth of social value, the planners overwhelmingly still felt that developers viewed their consultation with communities as being about managing a project risk and preserving reputation. Respondents felt that construction professionals would still view the use of community mapping as a planner's tool, even although its application is equally beneficial in projects.

Part 2 Application of SIT's in Representing Communities

Respondents were asked to list different SIT's which are currently used, and these included: Database Systems, Mapping Systems, Spatial Analysis System and Spatial

Modelling System. ArcGIS appears to be the dominant information system. It emerged that during decision making 70% or more of respondents, never or rarely accessed spatial information from PPGIS and platforms like Scotland's Opendata and Spatial Hub Scotland whereas often, or always, relied on Personal Knowledge, Colleagues, Online Searches, Excel Spreadsheets and Ordnance Survey mapping. The relationship was explored between development management, mapping, spatial analysis and modelling revealing the high versatility of GIS. 90% of respondents agreed or strongly agreed with the following statement: "Using Online Google Maps and other web-based mapping, make it easier to do my job" with 80% of respondents thinking online Google maps was 'easy to use'. The only other tool receiving a similar assessment was ArcGIS or other Desktop GIS with 70% of respondents finding GIS both easy to use and useful and all respondents believed there are benefits associated to them. An important factor determining technological diffusion in decision making is the level of commitment and implementation strategy adopted by management whether in a local authority or within a project.

Issues related to availability, accessibility and usefulness of information during decision making was explored which is core to the design and development of information systems. An extensive list of 103 datasets covering different themes (social, natural and built environment) was extracted from Future City Glasgow website published under Opendata license by Glasgow City Council. Respondents were asked to consider these and discuss the extent to which they were utilized during decision making to establish a better understanding of communities. The most popular data sets identified related to land use, but many respondents recognized that they should utilize the array of datasets stemming from community planning. This demonstrated that data sets are being established due to changing policies and priorities and that planners are becoming aware of their existence but that they haven't become part of their standard data practices and that project teams are still far behind in awareness.

Representations, Scales and Business Case

One planner explained "that for large urban regeneration projects it is increasingly important to use indicators and data to support the business case as significant public and private funding will be required and it is important that this reflects a range of social, economic and environmental criteria (e.g. City deals)". Another reiterated "data provides the evidence base explaining why we should get the investment, explaining what our needs are, helping to justify wider requirements for the project such as public transport and other infrastructure connections". Urban regeneration projects require data to help justify the wider benefits to as many people as possible and the rise of social value at the project level this will become an increasing consideration. The challenge is that traditionally this has been very much tied with abstract data sources such as IMD or Census, but there is an awareness that digital tools are enabling community mapping to create subjective data which reflects the lifeworld's and preferences of the community aiding a more holistic view.

Part 3 Bridging the Data Gap Through Community Mapping

Part 3 focuses on the specific tool of community mapping and the relevance -or irrelevance- of seven different elements proposed from the research for a subjective map in the context of consultation. These were established from the literature and were identified as gaps necessary to bridge the data gap which currently exists due to the reliance on abstract data sources. These were then presented to the planners to inform a tentative design of a subjective mapping procedure relevant to practitioners

at planning and project levels. Below, a summary of seven different elements could be used to create subjective maps and on which planners' opinions were sought:

- 1) The first element corresponds to the mapping of individuals' perceived neighbourhoods called gravitation as people would gravitate around the mental model of their neighbourhood;
- 2) The second, defined as entropy, would instead understand the element of instability the investigation of residential histories (does it preserve the stability, integrity, and beauty of the biotic community?);
- 3) The third is orientation and represents the willingness to move to a particular area or place, inversely related to place attachment;
- 4) The fourth is instead made of the photographs which represent the subjects own spatial awareness of his/her neighbourhood;
- 5) The fifth called dynamics is made of the perceived changes (both positive and negative) in space as individuals perceive them;
- 6) The sixth represents hierarchies, is used to investigate the location of primary and secondary ties and related to the idea of social capital;
- 7) The last element, everyday eight, is the spatial representation or individual's 'everyday eight'. More specifically: food shops, news agents, banks, post office, primary schools, supermarkets and secondary school.

All the respondents found element 1 perceived neighbourhood as the most interesting element, although one argued that "there is a lot of literature on this (perceived neighbourhood)" and argued that community mapping would make a big contribution because postcodes geography (reflected through the likes of IMD) doesn't match where or how people live". A planner who had a high level of GIS experience discussed the link to subjective perceptions of neighbourhoods and funding bids and drew on an example where "community mapping can play a significant role to better define in town the retail and business districts" indicating that this could have implications for funding and future land use patterns. Community mapping provides the opportunity for the users and residents of these areas to express where they see the boundaries and without it, decisions are made based on arbitrary lines on a map.

The second element exposed contrasting views around the need to represent the willingness to move and its ability to capture residential stability. For a couple of respondents, they argued that residential Housing and Needs Demands Assessments already look at this aspect by reporting on the number of houses sold every year but this merely identifies the history of the market. In terms of inward or outward migration, one planner argued that planners just worry whether residents are moving in or out the local authority and they are not too worried about the destinations and origins of the people. This is having a significant bearing on the community but is not captured in the current approaches.

Representing the positive and negative changes which have happened, and which are being planned (element 3) provided again a contrast in views between the planners. One planner provided an example of a survey used to inform the open space strategy which sought to understand how people use parks and their perceptions on the health benefits of parks and open space with additional benefit emerging related to the ability to grade the quality of the park. One criticism which emerged was that this could encourage objections as a symptom of NIMBYism making it less likely developers

will seek to engage. A couple of planners felt that capturing community perceptions and knowledge through mapping provided the opportunity for expert knowledge to be used to help reflect this better in future plans rather than simply dictate to the community. However, scepticism was expressed as they argued that planners with local knowledge already had a strong feel for what was good and bad in an area. This shows that some planners are still dismissive of consulting with communities, and when explored in interviews the perception remains that if planner are sceptical then the likelihood is that those engaged at the project level would be even more so.

The established view of a strong community is that it has high social capital with residents having close ties to a number of others (element 5). For example, one of the planners argued that even in their own town 85% of people they grew up with still lived in the same town. Once again, a planner was bringing their anecdotal experience often not based on evidence and again illustrates that if we don't find ways to capture the experiences of the community through techniques like subjective mapping the potential exists for the planner to provide their own often unintentional bias.

Diversely, another planner agreed that social ties are the most important including the ability to identify the 'everyday eight' (element 7) relating to what planners simply don't know around the everyday activities of the residents because the maps give an idea of how the community operates. The everyday eight would reveal different patterns between different age profiles listing in detail the routes and activities of groups while also being quite reflexive and allowing for stereotypes to be challenged and real patterns observed. An example used by one planner was the use of community mapping by her kids to capture how they experienced green space as it made her think in a different way. The interviews concluded that there was potentially even more value at the project level for this element as clients and construction professionals may be less familiar with the local area and knowledge.

Only one of the respondents was exposed to Public Participation GIS (PPGIS) and explained that: "although it was very impressive, it was not possible to do it again because there are no resources to follow up". Similar comments of financial constraints were received. Mapping seven different elements was found to be important to many in terms of customer segmentation and customer services. However, it is generally perceived that to resource this there needs to be a business case demonstrating what can be achieved by doing these surveys. Therefore, this would need to be driven by clients or as a requirement of both planning and funding.

Need for a Relational Database to Store Spatial Information from Community Maps

The interviews also confirmed with increasing participatory processes are designed to collect subjective spatial information using a wide range of methods (questionnaire, surveys, public hearing etc) concern exists that this data was not being stored preventing its access in the future. This has an implication in the overall resilience framework, and is a practice reflected at the project level with respondents outlining concern about the staffing and resourcing being one of the causes to the loss of spatial information collected. However, no procedure exists for scanning and digitizing the community maps and that the potential exists to develop this to transfer spatial information captured during community mapping and integrate it with the existing GIS enterprise of local authorities in such a way that could be shared across multiple organisations to ensure that the spatial information gathered during consultation

processes is not lost. At the project level, it was anticipated by the planners that this problem would be even more challenging.

CONCLUSIONS

This research acknowledges that it is limited in its sample to the experience and perspective of Senior Planners working in Scotland. However, they represent a strong starting point to understanding of the potential of community mapping across both development planning and regeneration projects given their role. Their perspective will allow future research to be explored with practitioners involved in community mapping, GIS, community representatives and construction professionals involved in managing projects. As SIT's enhance the ability to spatially represent subjective data at both planning and project levels this will support the dominant abstract data found in IMD and Census therefore better reflecting the community. Traditionally undervalued at both the planning and project levels, the subjective data is criticised for not aligning with traditional benchmarking associated with funding and investment decisions. However, to overcome this community mapping requires data collection to be better resourced with improved quality control procedures. This research shows that those who have had exposure to community mapping are able to recognise its potential, but it is apparent that those who don't remain sceptical of its value. It is clear that the potential offered through mapping is moving faster than practice is able to realise it. It is anticipated that placemaking will increasingly require this more holistic approach to data in development planning and increasingly at the project level through social value (Beaurigard, 2016), with community mapping able to represent both abstract and subjective data.

In exploring the seven elements for surveying for community mapping the respondents broadly recognised the rationale for these, but concern exists about the additional resource required to support it, but also an inbuilt view amongst many that "planners know best" (and at the project level, the client or construction professionals) and that the maps tell decision makers what they already know or even confuse the process. This links to a broader discussion around the role of expert knowledge and its relationship with consultation, a debate which is equally applicable in development planning as it is within construction management (Chan, 2016). Professional judgement based on local knowledge of the community, their wider education and experience is highly valued by planners and reflects an inbuilt resistance due to concern that it can complicate or have unintended consequences for the decision-making process. Despite this, the direction of travel requires community consultation to be enhanced through both placemaking for planning and social procurement and value for construction projects (Troje and Gluch, 2020). This paper argues that community mapping is intended to view the community as an asset (Close and Loosemore, 2018) and contribute to the decision making process acting as a source for questioning the interpretation of abstract data sources and ultimately move towards co-creation with the community (Barraket and Loosemore, 2018). The research proposes that a relational database should be used to store the data and information gathered during consultation and, providing the basis to develop a 'proof of concept' or 'prototype' which is to be built and demonstrated which will allow for community based information to be stored in local GIS Enterprise of local authorities and accessible to planners and projects.

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SUSTAINABLE ENTREPRENEURSHIP IN CONSTRUCTION

MENTAL HEALTH AND WELL-BEING IN MICRO-ENTERPRISES IN THE CONSTRUCTION INDUSTRY: AN IRISH PERSPECTIVE

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Construction companies operate in a highly competitive market, with low profit margins and tight time frames, all of which is in a sector that is temporary in nature, with people working on projects with a finite time and location. Based on the conditions experienced, the mental health and well-being of those within micro-enterprises may therefore be compromised. This risk is amplified in the context of micro-enterprises providing sub-contracted services. Recent studies on mental health and well-being focus on SME's and large organisations but fails to consider micro-enterprises; that is, those employing less than 10 people; despite the number of such enterprises in the industry. This paper presents a pilot study on a group of such micro-enterprises in Ireland and how they operate in terms of their awareness, education and interventions regarding mental health. A qualitative approach is adopted, using a case study approach, interviewing those working in such environments. Results indicate that the increase in working hours, lack of security and increased pressure on both profits and timelines, has a significant detrimental consequence to those working in micro-enterprises. This study, although only a preliminary investigation, acknowledges the significant emphasis on improving physical elements of health and safety but the mental health aspect is emerging as a separate and distinct facet with a concomitant shift in focus required. Thus, there needs to be further investigation towards the introduction of mental health initiatives, particularly for those working in micro-enterprises within the sector.

Keywords: mental health awareness, health initiatives, micro-enterprises, well-being

INTRODUCTION

"Mental health is our state of emotional, psychological and social wellbeing; it affects how we think, feel and act" (ACAS, 2019). Mental ill health can affect anyone during their lifetime, however mental health problems in the construction industry are significantly higher than in many other industries. The Office of National Statistics (ONS) found "that men in the UK construction industry are almost four times more likely to take their own lives than men on average" (CIOB, 2019). Construction is a difficult industry in which to work because of location, tight schedules, low profit margins and job insecurity. These factors place employees and company owners under constant stress which can affect their mental health.

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Small construction companies often operate on tight budgets and schedules. Projects are generally short term and involve long travelling times. Payments are received on a work completed basis, placing the contractor under pressure to work long hours to ensure cashflow. Business survival is the top priority for these companies, while safety and health issues often have lower priorities because of limited resources (Hon *et al.*, 2012; cited in Wong, 2015). Small construction companies whose workforce is predominately male operate in a competitive, stressful environment where mental health does not take precedence. This issue is magnified as many men see mental health as a stigma not to be discussed openly.

Poor mental health has numerous negative effects. These effects include not being able to concentrate on the task at hand, withdrawal from colleagues, agitation which can lead to disputes and depression. When not adequately addressed, work-related mental health risk factors can result in substantial costs to the individual, their workplace, and to the economy (Harvey *et al.*, 2017; cited in Gayeda, 2019.).

Initiatives are being used to deal with mental health in construction such as the Mates' suicide prevention programme in Australia and the Mates in Mind charity in the UK. This research investigates the barriers to mental health awareness and well-being specifically for micro-enterprises in the construction sector in Ireland, an area that has been relatively neglected as evidenced in the literature review. Based on the findings from the literature review and interviews plus taking current best practice into account proposals for tackling the issue of mental health in micro-enterprises are presented.

LITERATURE REVIEW

Construction companies typically operate in an extremely competitive market with relatively low profit margins and have to complete projects within tight schedules and constrained budgets (Wong, 2010). In construction the workforce is transient, often working away from home and on relatively short-term contracts (Carmichael, 2016). The workplace in the construction industry often consists of large numbers of sub-contractors that each have their own policies, procedures, and company cultures. A Seanad report established that in Ireland the construction industry employs 84,956 people and 94% or 79,859 were employed in SMEs and micro organisations (Seanad, 2019). On any given building site, the principal contractor often only employs up to ten of their direct employees and others might be either self-employed or contracted by agencies (Carmichael, 2016). The construction sector is temporary by nature both in terms of the life-cycle of projects and the length of time workers are employed on the projects, 'therefore the psychological needs within the construction industry are diverse and a one-size-fits-all model for mitigating mental health issues and stress within the industry would only be superficially effective' (Janusonyte, 2019).

Another contextual factor that must be considered is that construction workers operate in a male dominated industry where the attitude is to get on with things. The construction industry is notoriously conservative, male-dominated and emphasizes performance under pressure (Carson, 2019). Men generally feel uncomfortable talking about their feelings, keep their emotions under wraps and tend to put their head down and carry on with their work. There is a shame and stigma attached to mental health issues which results in a reduction in the likelihood of men seeking help (O'Brien cited in (Hanna, 2019). This is highlighted and amplified through the burdens of stigma, discrimination and human rights violations of people experiencing mental illness discouraging help seeking behaviour (Mates in Construction, 2018-20). Workers in the construction industry feel discriminated against if they consult with

their employer due to having a mental health issue plus the problem is compounded since they also have a fear of being stigmatised by their fellow employees or losing their job due to their inability to complete work. These factors lead to the issue of mental health among construction workers being avoided, ignored and pushed into the background.

A common cause of poor mental health, especially in the work environment, is stress. It is suggested that in the construction industry work-related stress has become an inherent feature of the workplace environment and can negatively transcend into family and personal lifestyle issues if not properly managed (Love et al., 2010:650 cited in Hanna, 2019) as well as affecting a person at work (Stevenson and Farmer 2017). The occurrence of mental health issues within the workplace can have serious consequences not only for the individual involved, but for the workplace as a whole and ultimately the economy (Janusonyte, 2019). For instance, a report in the UK found it was the leading cause of sickness absence, accounting for 70 million sick days in a year (Davies, 2013 cited in Oswald, 2019). This is further supported by findings that the effects of psychological health conditions such as stress gives rise to direct costs associated with employees' psychological ill-being in the construction industry include absenteeism, high staff turnover, medical treatment, and compensation costs (Bowen, et. al., 2014 cited in Fordjour, 2019). There are also the indirect costs of construction employees' psychological ill-being such as poor worker morale and job dissatisfaction negatively impacting on productivity (Campbell, et. al., 2004) cited in Fordjour, 2019). Therefore, mental health, if not properly managed, can affect the person, the organisation they work in, their family and society as a whole, in both emotional and fiscal terms.

Health literacy is defined as 'people's knowledge, motivation and competences to access, understand, appraise and apply health information in order to make judgements and take decisions in everyday life to maintain or improve quality of life' (Jorm, 2019). Poor mental health literacy is known to impede early symptom recognition in the self, as well as in others, and this in turn, may delay or stymie help-seeking behaviour (King, 2018) which appears to be the case in the construction industry due to the stigma associated with mental health issues. There is now good evidence that greater awareness and education about mental health problems can facilitate help seeking behaviour (Law, 2017). Awareness can also create a sense of community around supporting and helping people who are experiencing mental stress, and this in turn can influence workplace culture and environment (Mates in Construction, 2018-20). This can be seen in the slogans such as 'It's OK to not be OK', in terms of raising the opportunity to have full discussion and facilitate improving mental health literacy of construction workers that could enable early detection of mental ill health, decrease the stigma attached to mental health issues and bring with it many personal, organisational and financial benefits..

The construction industry has made major improvements in Health and Safety [H&S] in recent times; however, research has typically focused on the physical aspects of H&S such as working at height or using PPE. The literature and experience show that individuals who work within the construction industry are at an increased risk of suffering from mental health conditions (Oswald *et al.*, 2019) yet mental health has long been the 'poor cousin' to physical H&S (Carson, 2019). Mental ill health is becoming more predominant due to conditions experienced by workers in the industry exemplified by long working hours (on site plus die to the commute), longer supply chains, increased compliance requirements, tight deadlines, a hire and fire culture and

low profit margins. Where large construction companies have the necessary resources to deal with mental ill health through being able to offer health and wellbeing initiatives (Markham, 2019), small construction companies are acutely affected due to a lack of time and monetary resources available to deal with mental ill health leaving a vast component of the sector workforce severely disadvantaged in this regard.

There are mental health initiatives in place to help tackle mental ill health such as Mates in Construction in Australia who help with suicide in construction, and Mates in Mind in the UK. Mental Health First Aid [MHFA] is an organisation that provides training in literacy for mental health. The purpose of MHFA is to equip members of the general public in recognizing mental ill health in others, providing support and information to those in crisis, and signposting them to professional help (Janusonyte, 2019). The Construction Industry Federation (CIF) is now recognising the issue of mental health in construction in Ireland and has launched the Mind our Workers campaign in conjunction with Pieta House. In 2019, the first day of Construction Safety Week focused on Mental Health and Well-being in Construction. The aim of these campaigns from the (CIF) is to provide a culture of openness about suicide and mental health within the construction sector in Ireland.

However, the existing literature has shown that despite the existence of common themes for the causes of mental ill health such as poor work environment, stigma, lack of education in the area of mental health and the fact that construction is a male dominated sector, the majority of construction companies are not introducing or maintaining initiatives to address the issue.

The literature review has also shown that whilst studies have been conducted in large companies with regard to mental health, there is a gap in that no studies have been carried out in relation to mental health issues in micro-enterprises in the construction sector, therefore further research is required.

Research Design

To investigate the attitudes towards mental health and wellbeing in micro organisations in the construction sector data was gathered through a qualitative approach using semi-structured interviews coupled with the use of Likert scales to capture quantitative information. Semi-structured interviews enabled the researcher to gather relevant concise data on the themes under investigation.

A questionnaire with 21 interview questions was designed to capture data in a manner that could be analysed without bias from the researcher. The questions were designed to cover particular themes with regard to mental health and wellbeing in the construction sector as uncovered in the literature review; Stress, Nature of Construction, Mental Health Literacy, Stigma, Initiatives and Resources. All questions were asked in the same order to provide a consistent approach to data collection with responses captured through the use of Likert Scales, option lists and rank lists. The open-ended nature of some questions provided opportunities for both interviewer and interviewee to discuss some topics in more detail (Mathers *et al.*, 1998) thereby providing a rich data source for the researcher.

A fact sheet defining terms relating to mental health covering themes that were revealed during the literature review was designed by the researcher and given to the participants to read prior to interview. Providing this fact sheet to the participants ensured understanding of the terms used and so helped prevent misunderstandings that could have occurred in the data collection during the interviews.

For this pilot study, 10 interviews, each taking between 30 - 40 minutes, were conducted with business owners of micro-enterprises across within the construction industry in Ireland. The micro-enterprises that participated were drawn from the trades sector (one was from groundworks, three were from carpentry, two were from fitted kitchen manufacturers, one was a block-layer and one was a plumber) and professional services (one was a building contractor and one had a civil engineering consultancy practice). The participants were all owner-managers with experience of running their own business ranging from 1 year to 20 years. Interviews were arranged and then conducted face to face with the participants in neutral venues to ensure the participants were relaxed, engaged and the structure also allowed the researcher to provide prompts or clarify points for the interviewees when required.

RESULTS

Interviews with the participants regarding their attitudes towards mental health and wellbeing centred around the issues identified in the literature review and focussed on stress, stigma, the nature of construction, mental health literacy, resources and initiatives. This enabled the researcher to discover if the findings from the data gathered from construction micro-enterprises correlated with the previous research on mental health within the construction industry.

Stress

The results generated from the participants' contributions showed that they described their understanding of mental ill health as feeling down, alone and stressed. They noted that feeling stressed can lead to worry, negative thoughts and unhappiness. The majority agreed that mental health and wellbeing is a major issue in construction due to the nature of the industry. Eight of those interviewed believed that the construction industry is more stressful than other industries with two participants neutral. Payments, cashflow and long working hours were ranked as the top three major stressors according to the data gathered - the same three stressors were identified as affecting both the construction industry generally and the participant's own organisations. Travel time to work was ranked lowest. To combat stress, exercise was the most common method used, whereas alcohol was ranked lowest.

Stevenson and Farmer report that "A common cause of poor mental health, especially in the work environment, is stress." (Stevenson and Farmer, 2017). The findings conform to the work of Stevenson and Farmer and also Wong (Wong, 2010) with the majority in agreement that the construction industry is more stressful than other industries due to the nature of the business. Considering work environment in relation to mental health, the participants ranked weather as the number one stressor, affecting schedules and resulting in more expensive tender prices.

Construction projects are temporary and the participants interviewed stated that they relied on word of mouth and reputation for sourcing future work. Interestingly, none of the participants interviewed had a strategy for the procurement of work - thereby not taking any proactive steps to remove stress due to a lack of certainty with respect to the availability of work once the current project has finished. Future research is required in this area to gain conclusive evidence on the effects of not having a procurement plan in place, with regard to the mental health of the owner-managers and employees in these micro-enterprises.

Stigma

With regard to the issue of Stigma as highlighted by the literature, of those interviewed two said they were unlikely to discuss their mental health with a colleague, one was neutral, six might discuss their mental health and one definitely would discuss their mental health with a colleague. Four respondents said their colleagues had discussed their mental health with them, however, six said colleagues had not discussed their mental health with them.

All those interviewed agreed that there was stigma surrounding the area of mental health in construction. The majority had colleagues who did not discuss their mental health with them. This data concurs with (Mates in Construction, 2018-20), who established that "The hidden burdens of stigma, discrimination and human rights violations of people experiencing mental illness can discourage help seeking behaviour.". However, this is in contrast to the 60% of participants who would discuss their mental health with colleagues. A larger number of interviews would have to be conducted to gain conclusive data in relation to this subject. One of the participants added that the government should provide information to small contractors to make them more aware of the organisations that are in Ireland to help deal with mental health issues. This is in keeping with Law (2017), who states that "There is now good evidence that greater awareness and education about mental health problems can facilitate help-seeking behaviour." There are initiatives available but obviously they are not reaching down to the level of the micro-enterprises who employ over 90% of those involved in the construction industry.

Nature of Construction

The participants ranked weather as the work environment factor to have the greatest impact on health and wellbeing in construction. Clients and employees were thought to be ranked by participants as what they saw as the two most important stakeholders in the construction industry generally, whereas in participants' organisations clients and subcontractors were ranked as the two most important stakeholders so the employees were not as highly ranked - this may be due to the fact that the participants were not regarding themselves as employees since they are the owners.

Musculoskeletal disorders were experienced by all of the participants, with 36% experiencing back pain and 23% experiencing muscle injuries. Eight participants said these injuries had no effect on their mental health while two said it did affect their mental health by way of worrying about not being able to work. Participants were asked if they had any other thoughts with regard to the nature of construction and its impact on their mental health. Two said that waiting on payments from clients and principal contractors was an issue as it affected their cashflow.

Mental Health Literacy

Mental health literacy was discussed with the participants, 40% agreed that they understand what is meant by mental ill health, however 40% did not understand the meaning of mental ill health with 20% neutral on the subject. They were given a list of organisations that support mental health and wellbeing in construction and asked if they were aware of them. Pieta House, an Irish based anti-suicide organisation, ranked top with 50% of participants stating that they were aware of it. None of the participants were aware of the two UK organisations, Mates in Mind and Calm.

According to King (2018), "Poor mental health literacy is known to impede early symptom recognition in the self, as well as in others, and this in turn, may delay or

stymie help-seeking behaviour." Initiatives are in place to help deal with mental health in construction, but the findings show that micro-enterprises are not widely aware of them. The participants stated that a safe open environment and mental health training would reduce the impact of mental ill health in construction. These findings agree with Janusonyte (2019) who stated that "Poor mental health is a core issue within the industry and involving external organizations for support to successfully implement MHFA within the workplace and to set guidelines and guidance similar to physical first aid training would be beneficial to the industry." The question for further study is now to make the interventions either more attractive or more accessible to micro-enterprises.

Resources

The majority of participants would make resources available to their employees for mental health as they felt they had a responsibility toward their employees' health. One suggested that evening courses should be made available to self-employed contractors to educate them on mental health issues in construction. It must be remembered that the provision of resources does not necessarily mean that they will be used by micro-enterprises. The resources would need to include supports or mechanisms to ensure that the benefits are realised within micro-enterprises as discussed below.

Initiatives

The participants ranked mental health training and a safe open environment to talk as the top two initiatives through which mental ill health could be reduced in construction. There was a recognition that current initiatives and studies were concentrated on larger organisations as they had the Human Resources Management structures in place to support them, but the participants indicated that there was nothing or very little in terms of initiatives to suit the needs of the micro-enterprises. One of them expressed the view that well known sports people who have experienced mental ill health could visit sites to give talks on how to overcome mental health issues. Another suggested that government should support the development and delivery of specific mental health awareness and coping strategy training for micro-enterprises on a local / regional level to encourage attendance and facilitate learning.

CONCLUSION

This pilot study provides a view into the attitudes towards mental health and wellbeing, from the perspective of micro-enterprise owners within the Irish construction industry. The construction industry is highly complex, operating in many sectors with different sized contractors. In Ireland, construction had 50,673 active enterprises involved in the sector, with >95% of these classified as micro-enterprises. (IPPO, Government of Ireland, 2019). The findings of this study show that issues with managing mental ill health are prevalent in this sector. According to Hon *et al.*, (2012) cited in Wong (2015), "Business survival is the top priority for these companies, while safety and health issues often have lower priorities because of limited resources". Mental health problems within these organisations affect not only the construction industry but the economy as a whole, yet there is little evidence showing that owners of micro-enterprises pay attention to this key activity.

This is further aggravated by the lack of knowledge of initiatives that are in place to deal with mental health. Education is required to improve both mental health literacy and access to the initiatives that are in place to help these micro-enterprises. The

initiatives should be supported by government and made accessible to all registered micro-enterprises, so the owner-managers fully understand what is meant by workplace mental health and wellbeing in construction. Such initiatives must be cognizant of the fact that for the most part, micro-enterprises do not have the internal structures to deliver their own initiatives. The roll out of initiatives could be co-ordinated and delivered on a localised or clustered basis where several micro-enterprises could come together for training sessions to gain knowledge and have access to a safe environment for discussion of mental health issues faced by the owner-managers and employees.

The construction sector is in its infancy regarding its understanding of mental health and its causative factors. Research has shown that large contractors are leading the way in providing help, however, micro-enterprises, which make up a very significant proportion of the construction sector, require more support and training in the future to recognise and overcome mental health issues as the findings indicate that micro-enterprises in the construction sector are particularly deficient with regard to their knowledge on, access to and implementation of supports around mental health.

The findings also show that project and procurement planning is largely absent in the micro-enterprises interviewed in this pilot study. Micro-enterprises have limited resources in terms of time, personnel and money, so better planning would enable the owner-managers to make the best use of resources available to them. Further research is needed to fully understand how planning could reduce stress within micro-enterprises. Training and enterprise support focussed on business planning should be developed and made available and accessible for the owners of micro-enterprises so that they are equipped to develop their project and procurement planning capability and in so doing so see a reduction in this significant source of stress as identified in this work.

Further research from both academic and industrial perspectives should be focus on micro-enterprises to increase the understanding of the challenges they face and facilitate the development of initiatives to specifically address such challenges in micro-enterprises.

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FACTORS INFLUENCING BID/NO BID DECISION OF FOREIGN CONTRACTORS IN TANZANIA

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Construction sector is an investment-led sector hence revolves around how to best allocate capital to maximize the returns. Bidding decision is critical to both foreign and local contractors and cannot be undertaken through perception or feeling, rather the bidder has to go through several decision-making process involving the consideration of both internal and external factors. Submitting a lot of non-winning bids in responding to request for tender is costly and also can damage contractor's reputation. Therefore, the purpose of this study is to investigate the factors influencing the bid no bid decision of foreign contractors in Tanzania. A quantitative approach using survey-based questionnaire was used to collect data. The study revealed that "Financial capability of the client", "Terms of payment", "Client payment history" "Project type" and "Project size", were the most top 5 significant factors identified by the foreign contractors. The results of this study will foster a better understanding of the factors influencing bid no bid decision of foreign contractors in Tanzania and also increase the awareness of existing decision-making practices and play a critical role in the future decisions of the construction companies, where foreign bidders need to evaluate the next opportunities encountered. Moreover, awareness of these identified "bid/no bid" factors would enable foreign contractors to select projects with greater likelihood of success in the future, which result in financial benefits and higher performance. Lastly, the consciousness of these factors might contribute to improving the contractor's behaviors when bidding in a competitive market.

Keywords: bidding decision, decision factors, foreign contractors, Tanzania

INTRODUCTION

Globally, the competitive environment in the construction industry is rapidly increasing. This has necessitated the need for investigating the bidding strategies and the factors influencing the bidding decisions become a popular topic of research since the mid-1950s (Harris *et al.*, 2006). Bidding decision is made out only on the likelihood of winning the tender, but also considering the possibility and capacity that the firm can finish the project successfully as per the contract agreement. Therefore, on receiving an invitation to bid, it puts the interested bidders in the dilemma of whether to bid or not to bid for a project (Li *et al.*, 2019). Failing to bid on a suitable

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project can result in loss of opportunity to realize profit, similarly, submitting a lot of non-winning bids in response to request for tender is costly and also can damage contractor's reputation (Lin and Chen, 2004). For that reason, bidding decision is critical to both foreign and local contractors and cannot be undertaken through perception or feeling, rather the bidder has to go through several decision making process involving the consideration of both internal and external factors simply because deciding to bid on a project may cause both tangible and intangible losses (Li *et al.*, 2019). Additionally, Oo *et al.* (2012) contends that, winning a certain job will convey implications for capacity level of a firm, in terms of its resources available to carry out future projects. Similar studies have also reported that the decision to bid or not to bid on a particular project is normally complex and very challenging because it involves consideration of numerous factors (Oke *et. al.*, 2020; El-Mashaleh, 2013). Specifically, Li *et al.* (2019) remarked that, factors affecting the bid/no-bid decisions of international projects are more complex than those of domestic projects because overseas projects are riskier due to differences in culture, economy, technology, laws and regulations, hence requiring more attention before deciding to bid. This implies that, foreign contractors need to pay special attention when it comes to deciding which projects to bid for or not to bid for. Numerous similar studies have been undertaken in other developed and developing countries including Nigeria, New Zealand, Australia, Vietnam, United Kingdom, Singapore, Auckland, Cyprus, Saudi Arabia, Jordan, Palestine, Pakistan and Egypt (Oke *et. al.*, 2020; Maqsoom *et.al.*,2018: Shokri-Ghasabeh and Chileshe, 2015; El-Mashaleh, 2013). However, with the exception of Chileshe *et al.* (2020a, b) and Kawimbe (2017) studies which only focused on local contractors, there are very limited empirical studies undertaken within the East African context. This study aims to bridge the knowledge gap by conducting a survey among the foreign contractors operating in Tanzania. Therefore, the purpose of this study is to examine the factors influencing the bid no-bid decision of foreign contractors in Tanzania.

LITERATURE REVIEW

For decades, bid/no-bid decision continued to be one of the key problems for contractors across the globe (Maqsoom *et al.*, 2018). Similar studies have been conducted by different researchers in different countries. But the problem remains the same to individual contractors. Tanzania's construction sector comprises of indigenous and indigenised firms, as well as several foreign firms. Foreign Contractors/companies referred in this study are those whose majority shares are not owned by Tanzanians and are operating in local context. Based on Tanzanian National Bureau of Statistics, the market value of the construction sector at current prices increased from approximately US\$6.6bn in 2016 to more than US\$7bn in 2017. This growth is underpinned by the increase of major public infrastructure development projects in which the majority of such projects are carried out by foreign contractors due to lack of local experts. For instance, currently a number of huge infrastructure development projects including the Tanzania Standard Gauge Railway, Ubungo interchange project and Stiegler's Gorge Power Station to mention a few are all designed and constructed by foreign contractors. Thus, foreign contractors in Tanzania dominate the large-complex project market and play a huge role towards successful execution of these projects by providing unique skill sets lacked by the local contractors, stimulate technical efficiency and technology transfer. Furthermore, the presence of foreign companies in developing countries like Tanzania help to improve the skills of local contractors and contracting capabilities through

knowledge/technology transfer. Thus, to secure projects, it is necessary for firms to go through tendering procedure to perfectly bid for a certain project or work. The preparation of bidding documents is time consuming and costly (Oke *et al.*, 2020; Maqsoom *et al.*, 2018). Most of the contractors pay attention to the benefits of bidding against the resources and the bidding costs such as document prices and required bond. The bidding process involves bid or no bid decisions, besides; it is normally associated with uncertainty and complexity because of subjective considerations such as the nature, capacity, and competition to mention a few. But since the contractors bidding behavior are influenced by several factors internal and external as well as interactive factors. A number of existing studies, have focused on either investigating factors affecting the bid/no-bid decision specifically for local firms or proposed/developed an empirical framework for making the bid/no-bid decision as indicated in Table 1 while, those for foreign firms remain scarce (Fegade, 2016).

Table 1: Summary of existing studies on bid no-bid decision factors

Country ¹	Authors	Purpose of study
Nigeria	Oyeyipo (2016) *	Evaluated the factors that affect contractors' decisions to bid for a project
Nigeria	Olatunji <i>et al.</i> , (2017) *	Investigated the factors that affect the decision of indigenous construction contractors to bid or not to bid in Nigeria.
Nigeria	Oke, <i>et al.</i> , (2020) *	Assessed the factors related to time and cost performance with a view to examining their effect on bidding decisions.
Pakistan	Maqsoom <i>et al.</i> , (2018) *	Analyzed the strategic factors influencing bid/No-bid decision of Pakistani contractors
Palestine	Enshassi, <i>et al.</i> , (2010) *	Identified and ranked the factors that affect the bid/no bid decision
Canada	Fayek, (2019) *	Investigated the bidding practices of Canadian civil engineering construction contractors
Tanzania	Kawimbe (2017) *	Explored the factors influencing building contractors bidding decision in building projects in Dar Es Salaam
Jordan	El-Mashaleh <i>et al.</i> , (2014) *	Proposed an empirical framework for making the bid/no-bid decision
Saudi Arabia	Bageis and Fortune (2009) *	Investigate how bid/no bid decisions are influenced by different characteristics of contractors.
Qatar	Jarkas, (2014) *	Identified, explored, and ranked the relative importance of the critical factors determining contractors' decisions to bid or not bid for local construction projects.
India	Holla <i>et al.</i> , (2018) *	Identified strategic factors influencing bid decision in Indian construction industry
Australia	Shokri-Ghasabeh and Chileshe, (2016) *	Identified the common bid/no bid decision factors in the Australian construction industry
New Zealand	Ma, (2011) *	Investigated the factors affecting the bid/ no bid decision making for small and medium sized contractors
Hong Kong	Oo <i>et al.</i> , (2007) *	Compared the contractors' decision to bid behavior between Hong Kong and Singapore
Taiwan	Lin and Chen, (2004) *	Devised a method for bid/no-bid decision-making using fuzzy linguistic.
China	Li <i>et al.</i> , (2019) **	Identified and ranked decision factors considered by variously sized Chinese international contractors (CICs) and categorize those groups of factors important to experienced practitioners.
Malawi	Chisala (2017) **	Developed a bid or no-bid decision support model
USA	Duygu (2016) **	Developed a practical decision-making tool to assist decision makers in making construction project bidding decisions
Northern Cyprus and Turkish	Egemen, and Mohamed, (2007) **	Developed a framework for contractors to reach strategically correct bid/no bid and mark-up size decisions
Jordan	El Mashaleh, (2013) **	Proposed an empirical framework for making the bid/no-bid decision.
Asia	Utama <i>et al.</i> , (2018)★	Introduced a decision support aid for deciding an overseas construction project

Notes: *Studies which identified/assessed/ranked factors affecting bid no bid decision; **Studies which developed a bid decision framework/model and ★Studies on bidding decision for overseas construction projects; ¹Countries in bold are from sub-Saharan Africa

Additionally, based on Table 1 the majority of studies were undertaken in Asia and Middle East. Unlike Africa in which only three countries undertook similar studies and were all based on local contractors. Hence, this study intends to bridge the gap by exploring the factors influencing the bid no bid decision of foreign contractors based in Tanzania. The awareness of these factors can contribute to innovative bidding and improving contractors’ behaviors when bidding in a competitive market.

Factors influencing bid no bid decision for foreign contractors

Several studies have attempted to identify the factors influencing the bid or no bid decision as shown in Table 1 above with the majority being focused on domestic contractors. Table 2 below present a list of bid/no bid decision factors for foreign/overseas construction Projects as identified from literature.

Table 2: Summary of international factors of foreign construction projects decision making

S/N	Factors	S/N	Factors
1	Financial capability of client	19	Rigidity of specifications
2	Terms of payment	20	Contribution to increase firm identity and brand
3	Client payment history	21	Number of competitors with qualifications
4	Project size	22	Competitors bid and win
5	Project type	23	Penalty conditions
6	Completeness bid documents	24	Bid preparation duration
7	Contribution to firm’s future	25	Firms staff expertise
8	Current workload of project	26	Financial situation of company
9	Clients stability and characteristics needs	27	Political stability and sensitiveness
10	Profit made on similar projects	28	Subcontractors and materials suppliers
11	Project duration	29	Similar project size management
12	Ability to fulfill tender requirements	30	Required qualified materials
13	Building relationships with key parties	31	Required qualified labor
14	Availability of basic infrastructure	32	Economic health and stability
15	Work client carries frequent	33	Required plants and equipment
16	Experience/familiarity with similar project	34	Consultant construction works
17	Construction site conditions	35	Technological difficulty
18	Maintain long term relations with market		

Source: El-Mashaleh, (2013); Shokri-Ghasabeh and Chileshe, (2016); Maqsoom *et.al.*, (2018); Utama *et al.*, (2019); (Oke *et. al.*, 2020).

Examination of Table 2 demonstrates that there are some unique factors to consider when deciding to bid for international projects unlike bidding for domestic projects. For instance, “Political stability and sensitiveness”, “economic health and stability” are among those factors, just to mention a few. Due to this uniqueness features this study intended to investigate the bid no bid decision factors influencing the foreign contractors based in Tanzania when bidding for Tanzanian projects.

RESEARCH METHODS

This study adopted a questionnaire survey method (quantitative research) to collect data. The targeted population was all the foreign contractors working in the Tanzanian Construction industry (TCI). The study identified from the Contractors Registration Board (CRB) that there is a total of 46 foreign contractors from all across Tanzania. However, it was noted that some of the registered contractors had finished their projects and have returned home or shifted their companies to different countries for the sake of market search and some went bankrupt. Therefore, a purposive sampling was the approach used amongst the targeted population, namely, the foreign contractors involved in construction projects in Tanzania in order to obtain valid and relevant information needed. The rationale for selecting this non-probability sampling

technique is that it can facilitate a closer inspection and understanding of the cases by hand picking them (Rowley, 2013). More so, this type of sampling has been used in similar bid no-bid studies in developing economies such as Nigeria (Oke *et al.*, 2018); and developed economies such as Australia (Shokri-Ghasabeh and Chileshe, 2016). The key criterion used in selecting the respondents included been registered as a foreign company and have ongoing projects or have completed a project in Tanzania. In this regard, a total of 25 questionnaires were hand delivered to the identified foreign contractors, out of which 19 were completed.

Research instrument: Based on the review of the literature (see Table 1) 35 potential factors influencing the foreign contractors bid no bid decision were identified. These items formed the basis of the questionnaire survey administered to the foreign contractors. The respondents were then asked to rate the identified bid no-bid decision using a five-point Likert scale where 1= strongly disagree, 2 = disagree, 3 = neutral, 4= agree and 5= strongly agree.

Data analysis: This was analyzed using the Statistical Package for Social Sciences (SPSS) 25.0 and included descriptive statistics such as frequencies, measures of central tendencies, and the independent one sample t-test with test value of 3.5 (Chileshe *et al.*, 2020a, b). The overall computed Cronbach alpha (α) value for the 35 items was 0.942 (F-statistic = 3.488, sig. = 0.000). This was deemed as appropriate and acceptable as the threshold value for Cronbach alpha coefficient (α) = 0.7. Table 3 presents the demographical profile of the respondents.

Table 3: Respondents demographic information

Respondent	Professional	Years of experience	Types of projects	Bidding decision
A	Quantity surveyor	6 to 10	Civil	No
B	Engineer	1 to 5	Building	Yes
C	Quantity surveyor	6 to 10	Building	No
D	Engineer	6 to 10	Civil	Yes
E	Quantity surveyor	6 to 10	Building	Yes
F	Quantity surveyor	11 to 20	Building	Yes
G	Const. manager	6 to 10	Civil & Building	Yes
H	Quantity surveyor	6 to 10	Building	Yes
I	Quantity surveyor	6 to 10	Building	Yes
J	Quantity surveyor	6 to 10	Building	Yes
K	Quantity surveyor	1 to 5	Building	Yes
L	Architect	1 to 5	Building	No
M	Quantity surveyor	6 to 10	Civil & Building	Yes
N	Quantity surveyor	1 to 5	Building	Yes
O	Engineer	1 to 5	Civil	Yes
P	Const. manager	6 to 10	Building	No
Q	Engineer	6 to 10	Building	Yes
R	Quantity surveyor	6 to 10	Building	Yes
S	Engineer	11 to 20	Building	Yes

Examination of Table 3 shows that, the majority (63%) of the respondents have experience of between 6-10 years with the construction industry whereas few (26%) had 1-5 years of experience. Only (10%, n=2) had an experience of over 10 years. This profile of the respondents suggests that, most of the respondents have worked long enough with the foreign contractor hence possess sufficient knowledge in making bid no bid decisions. Therefore, this justifies the reliability and validity of the findings.

FINDINGS

Table 4 shows the ranking results whereby the findings show that their mean score ranged from 4.53 (Financial capability of client) to 2.89 (Technological difficulty). In contrast, the standard deviation of all 35 factors ranged from 0.5133 to 1.499, the highest ranked bid no bid factor has the lowest standard deviation which further reinforces the consensus amongst the respondents with regards to the importance of this bid/no-bid decision factor.

Table 4: Ranking of factors influencing bid no-bid decision

Bid no-bid factors	t-test ($\mu = 3.5$)	df	Sig (2-tailed)	Mean Score (Ms)	Std. dev	Rank
1. Financial capability of client	8.721	18	0.000*	4.53	.5133	1
2. Terms of payment	3.712	18	0.005*	4.21	.976	2
3. Client payment history	2.817	18	0.010*	4.11	.937	3
4. Project size	1.837	18	0.083	4.05	1.129	4
5. Project type	2.133	18	0.047*	4.05	1.311	5
6. Completeness bid documents	1.901	18	0.073	3.95	1.026	6
7. Contribution to firm's future	1.497	18	0.152	3.89	1.150	7
8. Current workload of project	1.027	18	0.318	3.79	1.228	8
9. Clients stability and characteristics needs	1.580	18	0.132	3.74	.653	9
10. Profit made similar projects	0.641	18	0.530	3.63	.895	10
11. Project duration	0.382	18	0.702	3.58	.902	11
12. Ability fulfill tender requirements	0.254	18	0.795	3.58	1.305	12
13. Building relationships with key parties	-0.091	18	0.929	3.47	1.264	13
14. Availability of basic infrastructure	-0.094	18	0.926	3.47	1.219	14
15. Work client carries frequent	-0.388	18	0.739	3.42	1.017	15
16. Experience familiarity similar project	-0.283	18	0.780	3.42	1.216	16
17. Construction site conditions	-0.382	18	0.707	3.42	.902	17
18. Maintain long term relations with market	-0.492	18	0.628	3.37	1.165	18
19. Rigidity of specifications	-0.641	18	0.530	3.37	.895	19
20. Contribution to increase firm identity and brand	-0.760	18	0.457	3.32	1.057	20
21. Number of competitors with qualifications	-0.694	18	0.497	3.32	1.157	21
22. Competitors bid and win	-0.643	18	0.592	3.32	1.250	22
23. Penalty conditions	-1.042	18	0.311	3.26	.991	23
24. Bid preparation duration	-1.042	18	0.311	3.26	.991	24
25. Improve firms staff expertise	-1.223	18	0.237	3.21	1.032	25
26. Financial situation of company	-.791	18	0.436	3.21	1.584	26
27. Economic health and stability	-1.157	18	0.262	3.11	1.487	27
28. Subcontractors and materials suppliers	-1.564	18	0.311	3.11	1.100	28
29. Similar project size management	-1.564	18	0.311	3.11	1.100	29
30. Required qualified materials	-1.326	18	0.202	3.05	1.471	30
31. Required qualified labor	-1.586	18	0.131	3.00	1.374	31
32. Political stability and sensitiveness	-1.541	18	0.141	3.00	1.414	32
33. Required plants and equipment	-1.638	18	0.119	2.95	1.471	33
34. Consultant construction works	-2.516	18	0.022*	2.89	1.049	34
35. Technological difficulty	-1.821	18	0.085	2.89	1.449	35

Notes: ^a Mean score based on valid n = 19 (list wise), df = degrees of freedom, *Significant at the 95 per cent level ($p < 0.05$).

The top five ranked bid or no-bid factors from the perspectives of the foreign contractors included (1) Financial capability of client, (2) Terms of payment, (3) Client payment history, (4) Project type and (5) Project size. For ease of discussion, only the top quartile ranked bid and no-bid factors as well as the least ranked are included in these discussions.

Financial capability of client

A number of studies have acknowledged that, the ultimate goal for a contractor to undertake construction projects is to earn profit which results from payment. Therefore, “Financial capability of client” was the highest ranked and also statistically significant ($t(18) = 8.721, p = 0.000 < 0.05$). This finding also suggests a strong indication of the impact of client payment capability as none of the contractors would want to work with a client who will end up not paying them due to their financial incapability. For instance, Oke *et al.*, (2020) identified the reputation of the client as the most prominent factor related to time performance that affects bidding decisions, whereas the other Nigerian study by Oyeyipo (2016) also identified financial capability of client as the most highly ranked factor in bid no bid decision

“Terms of payment” and “client payment history” were the second and third ranked factors as shown in Table 4. The factors were also statistically significant ($t(18) = 3.172, p = 0.005 < 0.05$) and ($t(18) = 2.817, p = 0.011 < 0.05$) respectively. These two factors are more associated with payments and these are also very important as they demonstrate the existence of payment risk and also a check as to whether the client has put forward clear payment terms and what has been his payment history in previous projects. Bageis and Fortune, 2009; El-Mashaleh, 2014 had comparable findings in Saudi Arabia and Jordan top contractors.

Project size

Project size or size of project has been regarded as part of the Construction business environment broader factors and ranked highly among the indigenous contractors in developing countries such as Nigeria (Olatunji *et al.*, 2019). However, in Tanzania, despite the foreign contractors accounting for only 2.4% of the total number of all contractors including the local contractors still account for the half of contractors within the Class I category (Kikwasi and Escalante, 2018). Class I contractors are thus allowed to bid for projects of unlimited value. Therefore, project size was ranked fourth however, the result was not statistically significantly different ($t(18) = 1.873, p = 0.083 > 0.047$). This finding was equally ranked high in previous studies in developed economies (Shash 1998; Ahmad and Minkarah 1988, and Shokri-Ghasabeh and Chileshe 2016).

Project type

Project type was ranked fifth but with equal mean scores to project size which had a lower standard deviation (1.129) thus showing more consensus amongst the respondents with regards to the importance of this decision factor. However, the factor was also statistically significant ($t(18) = 2.133, p = 0.005 < 0.047$). The study noted that similar Nigeria study by Oyeyipo *et al.* (2016) ranked this factor 13th with a mean score of 4.16, whereas El-Mashaleh (2013) had project type with a mean score of 4.36 The implication emergent from this finding is that both foreign and local contractors highly consider this factor before they decide to bid. Despite the foreign contractors, and predominantly the Chinese operating in Tanzania having a bigger share of the contracts obtained by value, they equally require the knowledge on these factors to consider the project type and size for the appropriate allocation of resources (materials, labor and plants) to meet contractual requirements stipulated by the client.

In the lower quartile, required qualified labor, Political stability and sensitiveness, required plants and equipment, consultant construction works, and technological difficulty ranked 31st, 32nd, 33rd, 34th and 35th respectively. As shown in Table 4, with

the exception of consultant construction which was statistically significantly different ($t(18) = -2.516, p = 0.022 < 0.05$) the rest were not significant.

CONCLUSION

Despite the fact that numerous studies have been conducted on identifying significant factors influencing the bid no bid decision, limited studies have been undertaken within the African context. Besides, majority of the existing studies are heavily skewed towards local contractors. Therefore, in order to bridge the knowledge-gap, this study aimed at investigating the factors influencing the foreign contractors on the bid no bid decision in the TCI. Ranking and frequency analyses were used at identifying the criticality of the 35 bid and no-bid factors identified through the manually reviewed and search of the literature. The overall ranking indicated the following top five as highly ranked factors: (1) Financial capability of client, (2) Terms of payment, (3) Client payment history, (4) Project type and (5) Project size. In contrast, the following were identified as the least ranked factors: required qualified labor, Political stability and sensitiveness, required plants and equipment, consultant construction works, and technological difficulty. The results of the one sample t-tests indicated that except for five (out of 35) identified bid and no-bid factors; there is no statistically significant difference in the perception of the foreign contractors operating in Tanzania. However, the results as obtained are similar to those conducted in other developed and developing economies. What is nevertheless notable is that the ranking of these factors varies from country to country. This implies that the list of bid no bid decision could be the same across the globe, but the significance of each factor varies depending on the uniqueness of each contractor, project nature, client and country.

Whilst only one data collection approach was undertaken, some emergent contributions are evident. The first is through the identification and ranking of an ordered grouped set of bid or no-bid factors for the Tanzanian foreign building contractors. Another significant contribution of this paper is that it sheds light and provides insights, knowledge and understanding of the factors that influence bid or no bid decision factors to contribute to the growth of building contractor in Tanzania. Such knowledge would enable future international construction organizations seeking to operate within the Tanzanian environment on how to be more effective when deciding to bid for projects. Finally, the study expands the efforts of studying and evaluating the bid or no-bid factors across sub-Saharan countries sharing similar economic conditions, particularly within the (East) African context. Most importantly, the point of departure of our current study is that, whereas previous studies have mainly focused on local contractors, by exploring the factors influencing the bid no bid decision of foreign contractors based in Tanzania, which is the genesis of our study, would also be used as comparator of best bidding practices with the local contractors. The main limitation of this study was the small sample size ($n=19$) of the existing foreign contractor in the TCI. Future studies should include a larger sample of the foreign contractors, and a comparative study of foreign contractors bidding practices could be undertaken with other developing countries. Also, relationship between specific firm characteristics and bid/no bid decisions should be further explored in future.

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GENERAL TRACK

AN INVESTIGATION OF PERFORMANCE GAPS IN THE DESIGN OF UK HEALTHCARE FACILITIES

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The ‘design performance gap’, a situation in which design fails to meet user expectations, has been increasingly discussed in recent decades. This research concerns the design of healthcare facilities and ways of improving it, through the comparison of designers’ performance and the satisfaction level of users. A literature review is first presented of existing work on the assessment of design performance, performance gaps and ways of closing them, with a particular focus on the key issues in the design of healthcare facilities. The data collection involved two questionnaire surveys and fourteen interviews. The surveys encompassed Likert scale and open-ended questions that were assigned to designers to explore their awareness and response to important problems encountered in the design of healthcare facilities. This was followed up by in-depth interviews with selected designers. The second survey questioned the satisfaction of healthcare users about aspects of the design of their healthcare environment. Two situations emerged: (1) where designers are aware of the issues, think they are addressing them, and users are satisfied; and (2) where designers are aware of the issues and believe they are addressing them, but users are nevertheless dissatisfied. The conclusion is that designers have insufficient information on certain user requirements. Better user information is paramount for better design decision-making and for the quality of healthcare facility design. A conceptual framework and matrices were developed that could raise awareness of this and help in improving design decision-making through improved Post-Occupancy Evaluation.

Keywords: healthcare facilities, performance gaps, post-occupancy evaluation

INTRODUCTION

The apparent inability of buildings (either because of their design, or because of the way they were constructed) to meet the needs of their users has been noted by numerous critics. As well as the more obvious failings, such as defects (Josephson and Hammarlund 1999, Forcada *et al.*, 2016, Kraus *et al.*, 2017), there are performance miscalculations and misconceived designs that are simply not fit for purpose (Somboonwit and Sahachaisaeree 2012, Driza and Park 2013, Smith 2016, Van den Brom *et al.*, 2018). This is made worse by the disconnect between designers and users in terms of meaningful feedback (Kujala 2003, Steen *et al.*, 2007, Jensen 2011, Andrade *et al.*, 2012, Caixeta *et al.*, 2013). In this study the focus is on the design of healthcare facilities. Like all buildings, healthcare facilities should be well

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designed, be constructed with no defects and provide a healthy and suitable environment for their users. In the case of healthcare buildings (HCBs), these users include patients, medical staff, and administrators. HCBs are particularly complex because of the variety of activities involved in their design, construction, and use. Architects and other designers have an important role in ensuring that what they design is adequate for care delivery (Caixeta and Fabricio 2013). HCBs may include general hospitals, specialised hospitals, and clinics, in addition to other facilities. People who receive healthcare may be inpatients and outpatients. Their needs and those of other users such as clinicians, nurses, and ancillary staff, including those responsible for the running and upkeep of the building (e.g. facilities or asset managers) may be affected negatively if the building is not well designed. For simplicity, this group is referred-to here as ‘user-stakeholders’. The challenges faced include environmental comfort, sound insulation, and other aspects of space design (Bartley *et al.*, 2010) all of which designers need to recognise. This is, in theory, achieved by post-occupancy evaluation (POE), which helps the design team produce better designs (Nemeth and Cook 2007) by ‘feed-back’ that improves designs and avoids the repetition of mistakes (De Jager 2007). The research reported here leaves aside the aspect of defective construction (albeit an important issue) and focuses on the suitability of building design. For the purpose of this study, design is architectural design of the layout spaces and components that create a coherent, aesthetic and functional structure. To address the problem of design suitability and the satisfaction of healthcare users, it is well established that feedback from post-occupancy evaluations (POE) can offer significant benefits to design decision-making (Preiser, 2001; Preiser *et al.*, 2015; Hadjri and Crozier, 2009). If designers are able to take advantage of the post-occupancy evaluation (POE) and access feedback of the needs of user-stakeholders, these will be more likely to be met (Foulds *et al.*, 2013, Johnston *et al.*, 2016, Hay *et al.*, 2018). The research aim is to investigate on the performance gaps in the design of UK healthcare facilities through a literature review and a mixed-method approach that leads to develop a conceptual framework for the design of healthcare facilities based on users’ needs. The concept is informed by the post-occupancy assessment of experienced users and builds upon the current awareness of healthcare facilities designers. The research focuses on the design of HCFs in the UK, specifically on the design of hospital inpatient wards. The research uses responses from healthcare designers and healthcare users (which includes staff and healthcare allied professionals). Although they may be relevant, it does not include the views of patients.

LITERATURE REVIEW

Joseph and Rashid (2007) argued that failure to follow the design principles could impact adversely on the design, hence patient safety. Although the principles of good HCF design have been rigorously laid out in Health Building Notes’ (HBNs), research has shown design problems. Phiri (2014) discussed a set of design principles that should be considered in the brief of the design including daylight, air quality, acoustic and noise, thermal comfort, artificial lighting, and fall prevention. Other design principles such as infection control, scalability, adaptability, flexibility of the space, medication errors, isolation of rooms and beds, privacy and dignity and colour used in space have been highlighted (Reiling 2006, Clancy 2008, Phiri 2014). HCFs are complex buildings that include complex mechanical and electrical systems (Fiset 2005). For example, hospitals demand high rates of air changes to control infection, and this is one of the notable issues to be addressed by their designers. Infection

control has governed the design of wards since the 1930s, where designers started to design smaller bed bays to increase patients' privacy and mitigate infection (Hughes 2000). According to Hughes (2000) the default (Nightingale) ward design - a simple configuration of layout that included open ward with 30 beds - was based upon medical orientations (limitation of infection through high-ceilinged wards cross-ventilated by windows) and social orientations (interactions between patients in same ward). However, such designs lacked privacy and were noisy. In the design of hospitals, flexibility and adaptability of the space is a major issue. Fiset (2005) explained that hospital design needs to suit different medical practices, emerging technologies and new developments. For this, the design must respond to the need for adaptability (i.e. "the possibility of using the same space for multiple functions") and flexibility ("the ability to change internally and to grow externally, and to replace parts that have become obsolete"). Designers need to follow a set of guidance and references to design HCFs, and this to ensure the optimal delivery of projects and their ability to meet the users' requirements. Douglas and Douglas (2005) discussed design indicators for healthcare facilities and divided them in external and internal indicators. These include wayfinding, internal signage, lighting, ambience and control noise levels and acoustics, temperature control and ventilation. In addition to access to and from transitional spaces, entrances, reception, social spaces, ward environment, views and natural outlook, washrooms/hygiene facilities, personal space and ownership, privacy and dignity, nurses station/staff contact, safety and security, homely facilities, accommodation for relatives, catering facilities, leisure and recreational facilities, shops and personal services and telephone, television and Internet. Besides the external indicators that are accessibility and transport, integrated public transport, parking facilities for staff and parking facilities for patients/visitors. Others include on-site traffic and pedestrian movements, wayfinding for directional aids based on named roads and buildings, landscaping and green areas with access from internal areas, noise reduction services, safety and security in and around hospital grounds.

Design 'performance gaps'

De Wilde (2014) exposed several performance gaps that included indoor air quality, thermal comfort, acoustic performance, daylighting levels, and other criteria related to quantifiable aspects of the building. Van den Brom *et al.*, (2018) have argued that the discrepancy between the calculated and actual energy in the building, is called the "energy-performance gap", i.e., the difference between the actual and theoretical levels of energy consumption (Van den Brom *et al.*, 2018). In addition to the performance gap, which can occur between the design expected to be realised and the building performance due to construction mistakes, failure in the design, management or unclear use of building (Loftness *et al.*, 2009). Less tangible issues have been highlighted by other authors. For example, Devlin and Arneill (2003) drew attention to three problems: patients' involvement with their healthcare (i.e. the role of patient control); the ambient environment (light, sound); and the emergence of specialized building types. Furthermore, Joseph and Rashid (2007) discovered that design issues such as air quality, lighting, and room design impact the health and well-being of patients in terms of nosocomial infections, patient falls and medical errors. Van de Glind *et al.*, (2007) discussed the benefits of single patient rooms by investigating an extensive literature review and using six outcome measures that are privacy and dignity of patients, noise and quality of sleep, patient satisfaction with care, hospital infection rates of MRSA, patient safety: fall accidents, medication errors and patient recovery rates, complications and length of stay. This was supported by Alfonsi *et al.*,

(2014) who regarded “the most significant reduction of nosocomial infection is due to the introduction of single rooms instead of multiple bedrooms”. Other research work by Alalouch and Aspinall (2007) has raised the issue of privacy in hospital multi bedrooms by emphasising that the design of multi bedrooms affects this aspect but it can still be positive in terms of choosing lower integration and control values. Thus, although the use of single rooms reduces the infection rate, noise and medication errors, as well as increasing the privacy aspect it remains controversial (Ugboma *et al.*, 2011).

The table below shows a thematic representation of extant research and the research gaps to support the problem statement, objectives and knowledge gaps.

Table 1: The gaps of research in literature review

Key references	Ref 1	Ref 2	Ref 3	Ref 4	Ref 5	Ref 6
	Phiri (2014)	(Rashid 2013)	Ulrich <i>et al.</i> (2008)	(Li and Zhang 2013)	(Hay <i>et al.</i> , 2018)	(Andrade <i>et al.</i> , 2012)
Research core	The design issues and design principles	Benefits of implementation of EBD in HCFs	Outcomes of EBD on patient’s safety	Importance of knowledge in designing HCFs	Use of POE in their research	Users’ perception from HC buildings
Knowledge Gaps	The update of guidance	Limitation of EBD	Shortage of evidence	Lack of sharing the knowledge	Lack of capture of lessons learnt	Lack of involvement of users

RESEARCH METHODOLOGY

The study employed a mixed method sequential design to achieve the research objectives. This began with an online survey of HCF architectural designers to identify key design issues in hospital wards. Although other designers (for example Building Services or Structural) are involved in healthcare facility design, it was their architectural design that best fitted the context (i.e. wards) and the overall responsibility for their performance. Of the 165 architectural practices contacted (based on the RIBA register of healthcare facility specialists) 29 responded in full. This phase was then followed with 14 semi-structured recorded interviews to identify the type of data and information that should be captured and used as a reference for future projects to help improving design decision making. The final phase was an online survey of healthcare practitioners (i.e. nurses, clinicians and allied healthcare professionals) identified through contacts in the healthcare environment in hospitals and academia. The objective was to compare their responses and their satisfaction with those of the architects. A total of 47 complete responses were received, 27 were currently working as healthcare professionals and 20 were experienced healthcare professionals but had moved into academia or the third sector. The quantitative data were thematically analysed to produce descriptive statistics using SPSS and the qualitative data, after transcription were subjected to content analysis using NVIVO.

RESULTS

From the survey of designers several key design issues were identified. These were: Avoidance or reduction of the spread of infections, medication errors, and falls; fire escape strategy; the balance between daylight and artificial light, between light and shade, and between the need for isolation and visual and acoustic privacy against the need for visibility of patients and space availability. Other related criteria were air quality, noise, scalability, furniture placement, and the use of colour in the design space. The follow-up interviews with designers added greater detail to the survey

responses and confirmed earlier findings from the literature. The work of Devlin and Arneill (2003) on design and its impact on the patient’s healing was confirmed in the interviews with designers who mentioned that patients need a healing environment through a better design. Designers pointed out that the visual and acoustic privacy could be achieved through the design of single bedrooms that offer privacy, dignity and confidentiality for patients besides of preventing the spread of infection control. Sometimes, however, design was compromised by inappropriate use. Designers agreed that location of ward furniture was an issue in better patient safety but said this could depend on the moving of furniture by the staff around the room. Regarding the preference of Van de Glind *et al.* (2007), Alfonsi *et al.*, (2014) and other researchers for single rooms, they noted that single bedrooms can have an adverse effect on patient psychology. Additionally, open wards help in monitoring all patients at the same time rather than travelling from one room to another and most designers conceded that the design of wards requires a mixed use of single and multi-occupant rooms. The findings indicate that designers need an update of the design guidelines, besides some requirements and feedback while designing the ward or after the building is in use. These should be given by the users such as continual user engagement, cost issues, space required, brief establishment, design follow up, user choice in design. According to one of the designers who stated that “all of the issues are equally important, and a design has to balance all of these things within guidelines, costs, time to meet the demographic [sic] of the patient and staff groups”.

Table 2: The comparison of responses of designers and healthcare users

Common issues	Recognition		Implementation	
	Evidence derived from Designers’ surveys and Healthcare Surveys		Evidence derived from Designers’ surveys (open-ended questions) + interviews and Healthcare Surveys (open-ended questions).	
	Designers	HC users	Designers	HC users
Privacy	24.1%	31.9% Disagree	Designers’ survey and open-ended quest and interviews	Healthcare survey
Comments	Healthcare users agreed on the privacy and dignity of patients being maintained but disagreed that the patients have enough privacy in patient areas. Yet, designers in the open-ended questions section and the interviews argued that they are trying to do their best to keep the privacy of patients despite the difficulty to achieve it, while balancing the observation and monitoring of patients at the same time.			
Noise (e.g. by effective sound insulation of the space)	37.9%	48.9% disagree	Designers’ survey and open-ended quest and interviews	Healthcare survey
Comments	Although designers said that they focus on the sound insulation in the design, HC users disagreed that it was sufficient.			
Sightline	Not ranked	40.4% disagree	Open-ended quest	Healthcare survey
Comments	Although, designers and healthcare users agreed on the raised issues, HC users felt this was not implemented in practice, and evidence for this is shown above.			

Comparison of the Responses of Designers and Healthcare Professionals

When compared to the responses of healthcare professionals, there was clear agreement on the importance of the key design issues, yet when it came to

implementation (i.e. whether the issues were being addressed) there was a marked difference of opinion in three important areas. These were privacy, sound insulation and noise reduction, and visibility and lines of sight.

A Conceptual Framework

From the findings of the study, a conceptual framework was produced that could be implemented on a live project in order to improve design capabilities and design decision-making. Its aim is to raise the level of awareness of HCF designers regarding the users' needs and their satisfaction. The conceptual framework (Figure 2) has been developed based upon the analysis of data collected from healthcare HC users and designers (via the surveys and interviews), on how these compare to the prevalent observations derived from the literature review, and from the suggestions offered by the experts during the process of validating the framework. The framework is unique amongst existing frameworks because of the type of data and the way it was collected. Additional features of the framework were extracted from the literature review such as "General Design Problems".

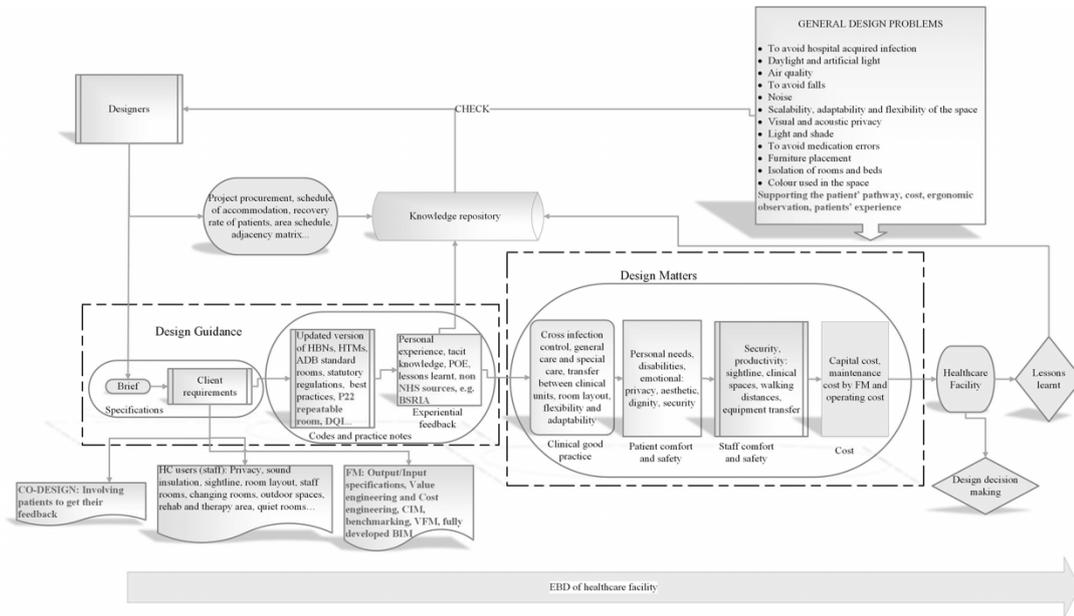


Figure 2: The conceptual framework

The conceptual framework consists of two parts; design matters and design guidance and includes designers and clients (i.e. healthcare users HC, facility managers FM, director of hospital or government). At the beginning of the process, designers meet with the clients during the brief to set their own needs. These include project procurement, schedule of accommodation, recovery rate of patients from previous healthcare settings, area schedule and adjacency matrix. During the brief meeting, clients also discuss their requirements that could be privacy, sound insulation, sightline, room layout and others. These two steps: brief and client requirements are called specifications, which is then followed by the use of designers for the codes and practice notes (i.e. health building notes 'HBNs', health technical memoranda 'HTMs', activity database 'ADB' standard) and others. When designers do not get the requirements and feedback that they need from the specification step or the design regulations, they compensate it with their experiential feedback that could involve personal experience, POE, lessons learnt and tacit knowledge. Some of these lessons learnt could be encapsulated within the knowledge repository of their system. The

design guidance is then followed by the design matters that consists of the design issues designers need to pay attention to and address properly. These include clinical good practice, patient and staff safety and cost. The design guidance and matters would help in achieving the healthcare facility project, which improves the design decision making and the lessons learnt. At the end of the design phase, designers need to check the general design problems such as (infection control, daylight, artificial light...etc.). The lessons learnt from the project will then be fed back to the knowledge repository that feeds back the designers before the brief of the next project.

Matrices for Pre-Design Requirements and Post-Design Evaluation

The research also contributed to the development of designers’ requirements and healthcare users’ needs in matrix format in terms of designing healthcare facilities in the UK. The matrices for Pre-Design Requirements and Post-Design Evaluation for any healthcare project in the design of inpatient ward.

The first matrix “Pre-design Requirements”, consists of designers’ requirements that have been identified in the interviews. These requirements were the missing data/information that designers would like to receive from the facility managers and clients. The second column is assigned to the facility managers and clients who will notify designers with the availability or unavailability of the requirements needed as illustrated in figure 3.

Designers Req FM evaluation	Schedule of accommodation	Recovery rate of patient	Area schedules	Adjacency matrix	Material choice	Material lifespan	Fire&management policy	Transports	Patients' Measures	Ground conditions	Project procurement
Availability	X			X	X				X		X
Unavailability		X	X				X			X	

Figure 3: Matrix of Pre-Design Requirements

The second matrix “Post-design Evaluation”, consists of Healthcare users’ requirements that have been identified. The second column is assigned to designers who will evaluate the tasks ‘requirements’ as achieved, unfinished or failed as illustrated in figure 4.

HIC users Req Designers' evaluation	Privacy	Sound insulation	Sightline	Room layout same handed	Room layout inbound	Staff rooms	Changing rooms	Outdoor spaces	Rehab & therapy area	Quiet rooms
Achieved	X			X	X		X			X
Unfinished		X	X					X		
Failed		X	X					X		

Figure 4: Matrix of Post-Design Evaluation

CONCLUSION

The empirical research in this study was conducted entirely in the UK. The study explored designers’ awareness of the key challenges and problem areas that exist in the design of healthcare facilities. In general, their awareness accorded with the literature on these issues. The study also compared designers’ evaluation of their performance with the satisfaction of healthcare users. There were many instances where users were satisfied, though this was not the case in certain areas. In general, it appeared that designers were somewhat complacent about their performance, the methods they use, particularly the adequacy of their experience and tacit knowledge. According to designers, facility managers do not get involved at the early stages of the design. This lack of feedback at an important stage represents unexploited

knowledge. Where FM feedback does exist, it can be conflicting at times and can change during the whole process. Designers would benefit from more systematic and explicit knowledge based upon post-occupancy feedback. Similar approaches could be taken with other respondents beyond those that were considered in this study such as FM, patients and visitors within other spaces in HCFs that could include clinical areas, outpatient or others. Evidence-based design is critical in the design of healthcare facilities (Alfonsi *et al.*, 2014), as it can reduce: the spread of infection in hospitals, stress and injuries on medical staff, and improve the healing of patients. To maximise the impact of evidence-based design and thus improve user-satisfaction, there is a need to capture lessons learnt from occupied projects. Such evaluations could be stored in a database or a knowledge base using digital (BIM-type) technologies. The conceptual framework presented in this study could form a basis for a knowledge-based repository that would inform new designs. The conceptualised framework would represent a basis for its live implementation in the future by incorporating the emerging technologies, such as BIM. Further works could also include developing enablers of real-time and rapid feedback (for example, electronic touch screen tablets) that are accessible by healthcare users to notify facility managers 'FM' with the problem area (that were identified in the designers' survey) in the ward and/or the patient room. The notification of the problem area would allow FM to fix the problem and send the lessons learnt to designers. The research can be extended to other countries based upon the design guidance and regulations implemented. Another factor to consider for further research would be cost, time that would ultimately mediate the performance of designers and the final outcome.

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AUTOETHNOGRAPHIC WRITING AS A STRATEGIC TOOL IN A MEDIUM-SIZED CONSTRUCTION COMPANY: A STRATEGY AS PRACTICE APPROACH

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In this qualitative study, I demonstrate how autoethnographic writing can be used to develop and refine a midsized construction company's business strategy. As owner of a construction company, I am in a unique position to explore a business environment autoethnographically. This includes writing extensive fieldnotes about my experiences and observations as well as reflecting on them. These fieldnotes and subsequent reflections resonate well with a strategy as practice approach. Drawing on a vignette about a conflict demonstrates how autoethnographic writing and a view of strategy as practice helps practitioners to develop and implement a strategy in business practice. This contributes to the debate about practice-relevant research and practitioner research. Using the researcher's thinking, I problematise what I see and gain insights to begin to amend my own strategy. This approach is very similar to insider action research. Utilising personal experiences of business practice demonstrates how ethnographic writing - in other words, qualitative material - can be used to develop and refine a construction company's business strategy. Ethnographic research has been employed to research business strategies in different fields. Yet, neither ethnography nor autoethnography has been applied to develop business strategies in the field of construction management. Additionally, the use of autoethnographic research in construction management is a further contribution to the efforts to relate research to the construction management practice. Although the exploration is limited to a unique case, lessons can be transferred to other companies and offer valuable new insights to researchers seeking collaboration with the construction industry and beyond.

Keywords: Autoethnography, strategy, practitioner research, strategy as practice

INTRODUCTION

The focus of this paper is the extent to which autoethnographic writing can assist managers in developing and implementing strategies in their respective organisations. This is an issue of personal interest as I pursue autoethnographic research while running my own construction business. To address this question, I initially explored the fieldnotes I had collected previously, while researching autoethnographically in my business. A strategy of practice perspective was used, which has recently gained increased interest. From this perspective, a strategy is a process manifested in the practices of the actors involved. It is, therefore, a research perspective close to

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managerial practice and is concerned with practice relevance. However, I want to take it a step further and seek to employ it as a managerial tool. Hence, I not only try to understand the micro-processes of strategizing but also to enhance the process of strategizing in my business.

Firstly, this paper is connected with the strategy-as-practice research. Secondly, the process of collecting the autoethnographic material is described, followed by a vignette created from fieldnotes. This vignette is used to demonstrate how the writing had an impact on the strategic decisions and how they were enacted in practice. The paper also considers the micro-perspective of day-to-day decisions and explores the effects on long-term strategies, drawing on further fieldnotes and reflections.

Strategy as Practice

This paper connects to the ‘Strategy as Practice’ approach outlined by Golsorkhi *et al.* (2010, 2015). This approach focusses on the daily business of managers rather than taking a resource-based approach to strategy. It is “a more comprehensive, in-depth analysis of what actually takes place.” (Golsorkhi *et al.*, 2010: 1). It looks at “micro-activities that [...] can have significant consequences for organizations” (Johnson, Melin and Whittington 2003: 1) These micro activities manifest to a large extent what organisations are. In this sense “strategy is more than just a property of organizations; it is something that people do” (Whittington 2006: 627). Focussing on “practice as a philosophy” highlights the “value of understanding practice as constitutive of reality” (Orlikowski 2010: 30). The reality of strategizing rests, therefore, on the interaction of the strategist with others - inside and outside of the organisation. To Rasche and Chia (2009), ethnographic methods are better placed to yield insights into organisational activity than interviews and questionnaires.

The study of Sage, Dainty and Brookes (2012) is an example from the construction sector which uses Strategy-as-Practice approach to elucidate how strategic goals and measures are translated and mistranslated in practice. Exploring a lean implementation, they showed how site managers were brought on board by making them “understand why” different practices should be adopted and hence experiencing the “benefits”. The strategy-as-process thinking is of particular importance for construction managers since the projects, the people on the project and the respective conditions are continuously changing. A strategizing as process approach is more suitable to the “unfolding” of a project as it progresses as it is adaptable to change (Johnson, Melin and Whittington 2003).

Sage, Dainty and Brookes (2012: 226) demonstrated how a strategy as practice approach yields practice-relevant knowledge. Cunliffe (2015) urges researchers to share this with practitioners. To this end, she proposes even more in-depth collaboration with practitioners. However, it is difficult to convey research findings to practitioners in an accessible way. Bartunek (2007: 1326) criticizes researchers’ methods of communicating to practitioners: “implications are typically suggested in a decontextualized, distant way. Some of the advice would appear to many readers to be contradictory, and some of it is simply hortatory.” Antonacopoulou (2010: 222) addresses this problem to academics, whose “research tends to be geared towards the generation of new knowledge, while that of business executives tends to be geared towards resolving a specific (usually short-term) business problem or attending to financial targets.”

Yet this concern could be addressed in two complementary ways. The first is through a focus on micro strategizing since it deals with “day-to-day stuff of management. It

is what managers do and what they manage.” (Johnson, Melin and Whittington 2003: 15). The second is through more collaboration. Antonacopoulou (2010: 220) suggests “[p]ractice-relevant scholarship promotes ‘re-search’ as a common practice that scholars, business executives and policy-makers all perform in their own way, as well as collaboratively.” Bartunek (2007) goes one step further and proposes interchange research and practice. In other words, managers become researchers and vice versa. This approach would undoubtedly take “the dual hurdles of relevance and rigor” and so produce research “that is more penetrating and insightful” (Van De Ven 2007: 35).

Elsewhere, examples can be found in which practitioner-researchers make use of ethnographic approaches as business tools (Denny and Sunderland 2014). Some even demonstrate how to develop and implement strategies (e.g.; Morais 2014). However, to my knowledge, regarding a strategy as practice perspective, research is only pursued from the researchers’ perspective and not that of a manager developing and implementing a strategy. This is the case for strategy as practice research in general and particularly for strategy as practice approaches in construction management. This paper offers an alternative perspective to strategy as practice research and construction management research as it is written by the owner of a small construction business.

This paper focusses on single clients and single projects and demonstrates how strategy is adapted and revised. It emphasises the learning and the situatedness of doing strategy and moves away from a formal process (Mintzberg 1994). This is more relevant for smaller business (which make up the majority of construction companies by turnover and employee numbers).

Autoethnography

The autoethnographic approach provides a way of being both research and practitioner. There are few examples of autoethnographies written by managers in the construction industry (e.g. Kanjanabootra and Corbitt 2016, Whaley 2016) and beyond (e.g. Kempster and Stewart 2010, Verkerk 2005). However, it is usually academics writing about their experiences in different contexts and seldom management practitioners writing about their work (Kempster and Stewart 2010). Kempster and Stewart (2010) connect this lack of managers’ autoethnographies to concerns about confidentiality or issues surrounding publication and to practitioners’ difficulties in reflecting on experiences and related knowledge. I would like to add that managers have to see the benefit for themselves - academic reputation might not be enough. Perhaps research is more concerned with rigour than with practical relevance and this makes it unattractive to practitioners to conduct endeavours? This is probably the reason why practitioners so seldom engage in autoethnographic writing, in addition to the argument of Kempster and Stewart (2010). Therefore, I would like to explore how autoethnographic writing helps managers to develop and implement strategies - to do strategy-as-practice.

I have been writing fieldnotes about managing my own construction company since 2013. The business employs 35 staff members and builds concrete and brickwork structures. The job requires frequent interaction with clients, architects, engineers, suppliers and subcontractors as well as with my own staff. Often, I take brief notes or voice recordings after an interaction (or any other event) and develop it later in the evening into a fieldnote. The writing itself is not a straightforward process but is a meandering (Adams St. Pierre 2002) between the actual event, recollection of earlier events and reflections. For this paper, I explored my fieldnotes (collected in cloud-

based software) about a conflict I had had to manage. I chose this event because it contradicted and questioned my business strategy. During this unfolding conflict, which stretched over almost two years, I frequently sat down in the evenings and wrote fieldnotes. There were, of course, periods when nothing significant happened, followed by a couple of days of intense action. Although, I wrote about what happened in my business on an almost daily basis, this particular conflict reappeared in my fieldnotes whenever something interesting happened.

These fieldnotes were studied and put together in order to create a narrative which was, of course, revised and edited. Within this process, details were added from memory where it seemed appropriate and omitted if regarded as irrelevant. This is not a straightforward process but a back and forth between writing, reading, and rewriting. This produced the following vignette:

Spider's web

One day I got the message that there were cracks in the other face of a building we were about to hand over to the client within the next days. During the months before, we had built a detached house in the northern suburbs of Berlin. It was a reasonably simple and robust construction of concrete and sand-lime bricks. The house had been insulated with a so-called "external thermal insulation composite system" - a layer of insulation panels fixed with mortar to the walls, reinforcement mesh and finishing plaster. My workers had fixed the insulation boards to the walls' months before, and a subcontractor had done the reinforcement layer and the finishing.

A couple of days before, all had looked perfect but now the finishing was full of cracks and was hollow underneath.

None of the parties involved could understand why this had happened. However, since this was quite an expensive insulation system, everybody knew that this would be very costly in the end. As we started to investigate the problem, otherwise hidden issues came to the surface. We had used the right material, but it was sold under a different trademark, the way the insulation was fixed to the wall wasn't in complete accordance with the technical approval, furthermore the approval hadn't covered the particular finishing (colour and type of mortar). A technical consultant of the producer had given some wrong advice. Yet, none of these inconsistencies proved to be the ultimate reason for the fault.

It was terribly messy. The client was understandingly disappointed. The supplier with whom I had worked for years had bought a system from the industry which did not work and had sold it to me. A small and long-known subcontractor did the finishing that now looked like a spider's web. And we (my site-managers and me) had failed to fulfil our due diligence.

There was no single right way forward.

At first, when we started to investigate the issue, the mood was quite friendly - given the circumstances. Although we hoped to get an answer, the investigations from the producer's laboratory and an expert for external thermal insulations (which we jointly called in) did not determine the cause of the cracks in the facade. Both producer and expert were similarly perplexed. They said they did not know why the system had collapsed and, hence, would not recommend using the same product again because "as long as we don't know what went wrong, we don't know how to do it right."

However, I had promised - by signing the contract - to deliver this system. It was clear that the client could insist that I deliver what I promised, and if I wouldn't deliver, he was entitled to claiming damages. So, the client was - from a contractual perspective - in a rather comfortable position. Yet, everyone else was not. Nobody knew who was accountable and what proportion of the bill each had to carry.

As the investigation went on, we sought to convince the client and the architect to use another insulation system. We negotiated about different options and about possible compensations, but still we couldn't get their approval, and no progress was made. At that point, I saw no other option than to instigate a court-ordered examination by an expert witness, which is the first step in litigation. Taking this step surprised and upset some parties involved.

Again, plodding progress and the examination, only yielded inconclusive results. At a time when I had already lost faith finding a settlement, the architect made another attempt. After long negotiations with the different parties, we reached an agreement without going into formal litigation.

Reflections

Going through the fieldnotes, I found shifting interpretations of the different actors in this game. At first, I had some sympathy for one person; later I believed this person to be responsible for undermining a possible solution and in the end, when the solution was found, I changed my mind again. Along with these shifts in interpretation of each individual's actions, my emotions towards these actors changed too. This all had an impact on the strategy which governed my actions. And seeing myself changing my mind about a person can cause a fair deal of self-doubt. It is this doubt about myself, my strategy and its implementation which led me to pick this event among others.

My lawyer and I agreed that this was not the only example where the wrong person was accountable for the problem. Developing and executing a strategy is marked by not knowing, by assumptions and interpretation. These assumptions and interpretations are based on partial vision, on limited sources, and selective perception. Hence, they are always incomplete. Incomplete to an unexpectedly large extent. It is as if understanding and so-called "truth", slip through one's fingers.

Strategy as Practice

Within this shifting understanding, I see part of my company's strategy as acting as a reliable partner to clients, design teams, suppliers and subcontractors, as well as staff members. Yet this situation was messy and unfathomable and, furthermore, quite significant losses were looming. In this situation, I felt the urge to act in self-defence which would mean letting someone down. Instigating formal court proceedings did not go down well with anybody involved. However, I pursued this path, based on the interpretations I made at the time. Formulating and implementing my strategy involved a constant learning process (Mintzberg 1994).

Everyone involved proclaimed to be searching for a way out of the impasse, but then meetings got cancelled at the last minute with no explanation, aggressive emails circulated, and everyone started blaming others for the failure. I perceived contradictory information and confusing cues from all angles, and it seemed impossible to understand the aims of all the parties. And, I was no exception - my actions also contradicted what I had said and done before.

Micro view

Autoethnographic writing helps to understand these processes. As Johnson, Melin and Whittington (2003: 4) write, “sustainable advantage must lie in micro assets that are hard to discern [...]. Profit, not only the devil, lies in the detail.” The micro assets were my notes and the reflections on the events as they unfolded. There was a clear aim: getting the issue settled at the lowest cost (for everybody involved). Yet the way to get there was not clear at all. For a long time, I could not decipher the interests of the various actors. Hence, the strategy that I employed had to fit an unfolding understanding. Yet, even in retrospect, I do not know whether these decisions were the best decisions I could have taken, although we reached the desired agreement in the end. Writing fieldnotes was “action research for the individual [manager]” (Ellis 1999: 677). This notion resonates with Cunliffe’s call for intersubjectivist research on strategy as practice - for “action-research and collaborative and co-constructed methods” (2015: 443). Autoethnographic writing - in one or the other form - addresses this call.

Yet, Cunliffe wants ethnographers to observe and write “in an unmediated and unfiltered way” (2015: 443). In doing so, they “can focus on their personal sense of what is significant.” (Emerson, Fretz and Shaw 2011: 24). Most managers gain some experience in their job, so in contrast to conventional ethnographers, as described by Hammersley and Atkinson (2007: 79) they are not “necessarily a novice”. When I started writing fieldnotes, I had been in business for 14 years. I had already formed an understanding of how the construction industry works. Still, I sought to write about everything I encountered. Nevertheless, conflicts and often negative experiences grabbed my attention (Illouz 2015). My writing is therefore probably not so much theoretically as emotionally and economically filtered because I write about things that touch me and impact my business. The vignette above is just one example among many that I find in my fieldnotes.

This may lead some to claim autoethnographic research may amount to “naval gazing” (Allen-Collinson 2013: 282) and is “self-indulgent” (Sparkes 2002: 210). Yet, it can make strategy as practice more accessible to managers reading such work because it offers an engaging account (Richardson and Adams St. Pierre 2005). It is essentially “a narrative account of [my life] to make a point.” (Wolcott 1999: 174).

During the conflict described above, I was - as Cunliffe describes - “making sense of the situations from within the activity itself.” (2002: 40). I could only see the business owner’s perspective. The writing offered me a way to capture these thoughts and process them. I wondered why the architect acted in such a way and I wondered what his intentions were. To some extent, I could distance myself. This was not of course, a detached view but was a slightly different perspective - a review of my actions, experiences, and how my strategy had worked so far. But the risk remains that one might “become so involved as to make observation itself virtually impossible” (Wolcott 1999: 48). One may argue that co-created or collaborative ethnographies offer an additional reflexive lens which a single researcher-practitioner by default cannot offer. Nevertheless, as a sole researcher, I discussed my understandings with professional and academic peers. These conversations forced me to reflexively examine my views and interpretations and helped me to produce a less tainted view of the events. Still, it is not going to become unbiassed account. It should, therefore, be judged on whether it is reflexive and credible representations of my research (Richardson 2000).

Writing as a Tool

I initially only wrote in the interests of research, but I soon realised how powerful this tool was. I could examine what I was doing as a manager and assess my strategy. Yet the uncomfortable truth was that I saw myself compromising my own principles. I wanted to act like a reliable partner, but I felt the need to defend myself - hence, commencing a court-ordered investigation. My own strategy is not what I say I do but what I actually do. Hence, the problem here is probably best described by notions of “espoused theory” and “theory in use” (Kemmis and McTaggart 2005: 561). What I proclaimed to be my strategy was one thing: but what I actually did was wholly different. Instigating legal procedures compromised the picture of a reliable partner that I wanted to convey.

The link to strategizing is that repeated problem-solving leads to a wider view - one can zoom out and understand the bigger picture. Managing a construction company with its daily ups and downs puts strategy to its practice test. Writing about managing is recording or capturing personal experience. This is not doing numbers but making meaning of a strategy. What is lying beneath the problem one is faced with? Usually, autoethnography is very much focussed on detail. The autoethnographer has to step back. The researcher needs to deliberately enter the meta-view in order to understand. Yet repeated entrance into the meta-level and again submerging into the daily business - this being thrown (Heidegger 1927) into managing construction projects over and over again - made it possible and necessary to constantly reformulate my understanding and subsequently my strategies. Hence, autoethnographic writing does neatly fit the notion of strategy-as-practice. It is an ongoing hermeneutic process of creating and recreating an interpretation. Following Orlikowski (2010), autoethnography as a research strategy constitutes the social reality it seeks to explore.

What follows is a deeper questioning of professional practices. Reflection then departs from simple problem solving - or single loop reflection - to a deeper questioning or multiple loop reflection. It might be interesting to ask how to solve the conflict above - that is the obvious question for the practitioner. However, adopting the researcher’s way of wondering (Antonacopoulou 2010) and beginning to search for the problem behind it, is even more fruitful. Why am I unable to understand what is going on? Is it really a problem not to know the hidden agendas of the other parties involved?

Long term impact

My autoethnographic writing always considers myself as an entrepreneur. It clarifies what I am able and willing to implement as strategy. It captures and seeks to explain subjective issues which may otherwise be neglected, such as how I felt about certain events and decisions. Autoethnographic writing made me reflect on my strategy and its implementation. This manifest itself in my shifting interpretations and the subsequent actions. This insight was only possible through continuous fieldnote writing about events. Slowly but continuously, writing about oneself and one’s experiences makes a difference. It shifts attention. One draws on previous interpretations to make sense of newer experiences. One develops routines not known before and becomes more aware of the questions beneath the surface. For instance, do I appear as reliable as I would like?

I found one particular reflection in the fieldnotes, regarding another dispute I had lived through and written about years before. I wrote that I felt much calmer and more distanced about the ‘spider’s web’ than in the conflict years before. I had learnt to

distance myself. Hence it made it possible for me to detach myself, to have a look at the problem from a distance and to not be too emotionally engaged. I was better able to manage this conflict and to develop a strategy than before. Conflicts are recurring; they come back again and again. Autoethnography is a means to deal with them as an action-orientated method and so to learn from problems and issues.

SUMMARY

This paper attempts to explore how autoethnographic writing can assist managers in developing and implementing strategies. It shows how autoethnographic writing is a way to improve strategic practice. For one, it made me aware of the nitty-gritty details when trying to solve a conflict. I cannot say that I made one particular, outstanding decision. I did not pivot; there was no single game-changer. Instead, there were numerous little conversations, actions and moves that apparently led to the desired outcome. This resonates well with the strategy as practice approach. It also demonstrates how local adaptation (Sage, Dainty and Brookes 2012) of a company's strategy unfolds. Hence, on the micro-level, autoethnographic writing helped - it assisted me in solving this particular conflict. Avoiding lengthy and costly litigation certainly had an impact on the mezzanine level. Finding a compromise and hence maintaining reasonably good relations with the parties involved also count on this level. Therefore, "micro-activities" (Johnson, Melin and Whittington 2003: 1) had an impact on the implementations of my strategy.

On a macro level, big changes (e.g. significant technical innovations or rapid economic changes) are beyond the scope of this study. Furthermore, autoethnographic writing rarely has an immediate effect on the long-term strategy of an organisation. However, long-term learning about oneself and one's business environment has a significant impact on developing and implementing strategy. It demonstrates from a practitioner's perspective how strategy is lived and done (Whittington 2006). Writing fieldnotes raises the questions practitioners often avoid asking. Perhaps, this could be a motivation for managers to engage in one or the other form of autoethnographic or journal writing.

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CHANGE IN PUBLIC FACILITIES MANAGEMENT ORGANISATIONS: THE CONNECTION BETWEEN EMOTIONS, HUMANS AND OBJECTS

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In this paper, the interest lies in increasing the understanding of how individual actors (both human and objects) within public facilities management organizations respond to the changes in their organizational context that is imposed on them, and how this is affecting their institutional work (IW). Data was collected through a workshop and interviews with officials from public facilities management organizations. Data was analysed using a framework that focused on the interaction between humans, emotions and objects. The findings present three types of objects, that have in common that they are used to reduce anxiety; past objects, used a 'soft blankets', future, imaginary objects used for concretizing the future perfect and current objects as shields to prevent 'reality' from being managed. The findings further indicate that humans believe that they conduct institutional work to create new practices in public facilities management organizations, when they are in fact maintaining current practices, for example by relaying on future imaginary objects to solve current problems. The paper complements previous research that has shown how individuals engage in creating new or disrupting old practices if the current situational order threatens their psychological wellbeing. Instead, it is argued that people engage in activities that maintain the institution of public facilities management when their psychological wellbeing is threatened.

Keywords: emotions, institutions, Public Facilities Management, sociomateriality

INTRODUCTION

Research has focused much on technical solutions related to current challenges for public facilities management organizations (PFMOs) while less has been researched on organizational aspects related to current challenges and changes in operations (Nielsen *et al.*, 2016; Galamba *et al.*, 2016). Specifically, not much has been written on how human's emotions and work practices are affected by the current situation and how this in turn impact practices and institutional work.

In Sweden, many public buildings were built during the so called 'million program' during the 60's and 70's. Due to the fact that local governments have lacked necessary overview of their building stocks as well as the organizational capabilities to manage them, there is now a large amount of buildings that need to be managed: the vast majority of these need extensive renovation (Jensen and Due, 2008; Hartmann *et al.*, 2018; Junghans 2013). In order to manage this need for mass-renovation and in some cases even replacement of buildings, PFMOs need organizational change. This

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change includes new organizational arrangements, both between PFMOs and organizations they collaborate with, as well as changes within PFMOs' own organizations. For example, PFMOs in Sweden are moving away from organizing their operations focusing foremost on facility management to become 'project-based organizations', responsible for both facilities management, extensive re-building projects and new construction. At the same time, PFMOs are facing increased demands on sustainability, financially sound operations and increased collaboration with stakeholders. Thus, today's public facilities management is placed within an increased complex organizational context in which individual actors (such as facilities managers and facilities strategists) need to 'travel' between different organizations levels to a larger extent than before (Gluch and Svensson, 2018) together with managing several different logics and perspectives in practice (Svensson, and Löwstedt, 2019).

Research has indicated that there is not enough flexibility in many of the PFMOs to combine these different perspectives (for example energy efficiency and financial aspects in renovation or renovation and new construction); instead some perspectives are overrunning others in practice (c.f. Thoreson 2015). Moreover; research has also pointed toward that the institutions connected to PFMOs are hard to change (Andrews and Johnson 2015). Hence, many PFMOs do not meet the criteria for a healthy organization, i.e., organizations that have the capacity and ability to, in a flexible manner, meet the changing demands imposed on them (Schein 2013). Within such organizational, individuals are likely to experience feelings of anxiety and stress.

The transition that PFMOs need to go through (and in some instances has begun) can be viewed as an 'institutional change', since the underpinning ideas on how PFMOs are operating will need to change/ is changing. In this paper, the interest lies in increasing the understanding of how individual actors (both human and objects) within PFMOs respond to the changes in organizational context that is imposed on them, and how this is affecting their institutional work (IW). To understand the practices connected to institutional change, the research stream on IW highlights different types of intentional actions taken by individual actors in relation to either creating, maintaining and/or disrupting institutions (Lawrence *et al.*, 2009).

Following a practice-turn in research, the IW construct has provided an opportunity to extend institutional research to also include interrelations between materiality and institutions (for example by combining IW with sociomateriality) respectively between institutions and emotions (see overview in Hampel *et al.*, 2017). For example, emotions have been shown to be a powerful device for and in institutional processes and affect human actions (Friedland 2018).

In order to increase the understandings of how institutions are maintained (disrupted and/or created) within the built environment, it has been suggested that researchers need to pay closer attention to practices and to the IW performed by (all) the actors involved in a process i.e., both humans and objects (Gluch and Bosch-Sijtsema 2016; Raviola and Norbäck 2013; Monteiro and Nicolini, 2015; Lawrence and Dover, 2015; Jones and Massa, 2013). A hand full of papers have investigated the role of objects in change processes within the construction management research. For example; in a study of a Swedish public housing company's energy efficient renovation process, Palm and Reindl (2016) found, by applying a practice theory framework, that existing technical infrastructure largely determined what issues came up for discussion at meetings, thus the technology itself was part of organizational processes and seen as a valuable player. Buser and Carlsson (2016) have highlighted the active involvement

of the house itself, during a renovation process. Gluch and Svensson (2018) highlighted how objects were part of the process to develop new organizational practices connected to new management practices in PFMOs.

However, while construction management scholars have focused on the effective means of acknowledging humans and objects inter-action in facilities management and renovation processes, i.e., focused on the value for accounting for all involved members of the process and their impact, they have not elaborated on the affective parts of such processes.

Informed by the theoretical concepts of IW (Lawrence and Suddaby, 2006) and the emotional sociomaterial practice perspective (Stein *et al.*, 2014), this paper aims to increase the understanding of the connection between humans, objects and emotion in PFMOs changing organizational practice.

THEORETICAL FRAMING

Combining IW and sociomateriality entails focus on the entanglement between the material and the social in practice (Leonardi 2013). The view on sociomateriality underpinning the research in this paper is that of so called 'weak sociomateriality' (Leonardi 2013) that is based in a critical realist ontology. This means that a) objects are acknowledged as having a material agency affecting human practice (and the relationship with humans) b) the actions that stem from this relationship becomes the interest of study and that c) objects and humans exist prior to their mutual relationship. However, it is through their inter-action that a certain phenomenon becomes interesting to study. More, the weak perspective takes an interest in the broader social context in which actions take place and how this affects the interaction between humans and objects.

In recent years, emotions have become widely researched in organizations studies. Nevertheless, little attention has been paid to emotions in relation to sociomaterial arrangements and IW; humans' intentionality is discussed purely in relation to goals and plans and emotions are not mentioned within the sociomateriality paradigm (Stein *et al.*, 2014). The emotional sociomaterial (practice) perspective alerts us to the idea that emotional practices are not only socially contingent but also materially contingent (*ibid*). Focus is on what humans (and objects) are doing when humans say they experience certain emotions. Thus, the theorising of emotions in this paper is inspired by Stein *et al.* (2014) who have elaborated on two approaches for including emotions in sociomaterial theorizing; one for 'weak' sociomateriality (based in critical realism) respectively one for 'strong' sociomateriality (based in agential realism).

Stein *et al.* (2014) introduces the concept of 'felt quality' of practice in sociomateriality research and thereby contend that; "context is not a neutral container, but an 'equipped context (Gherardi 2012 p. 174)". Thus, taking this into account means, for example, that the researcher is aware that negative emotions can stabilize around a particular sociomaterial assemblage and so make it extremely difficult for a productive practice to emerge. It also implies the importance to take into account the organizational setting and the emotions it brings with it. Moreover; emotions are treated as practices (i.e. something that we do rather than something that we simply feel as an afterthought of some even).

Some researchers have begun to include emotions into their studies on IW, however; most of them have been focusing on how humans deliberately use emotions to pursue their means (c.f. Suddaby and Greenwood, 2005). Others however have

acknowledged that human can act in certain ways, depending on their current emotional context. Voronov and Vince (2012), for example, emphasize the importance of paying closer attention to the interaction between emotions and cognitions of institutional maintenance, disruption, and creation. They postulate that agents engage in creating new or disrupting old institutions if the current situational order threatens their psychological wellbeing. In another study Zietsma and Lawrence (2010) noted that agents might engage in institutional disruption because they are 'dissatisfied with existing practices.

To sum up, combining an emotional sociomaterial practice perspective with an IW lens, provides a focus on and interest in the entanglement between the material and the social during times of change in PFMOs.

METHOD

In order to explore how the current organizational context influence humans and objects IW ten interviews with officials from different PFMOs, involved in change work and organizations working with PFMOs were conducted, together with a workshop.

Data Collection and Analysis

The interviews varied in length from 30 minutes to 1 hour and was conducted either by phone, face-to face or through Skype. The interviewees were chosen through 'snowballing' asking previous interviewees for connections to other municipalities and organizations working with PFMOs. The interviews focused on how the individuals experience the current situation, i.e., mainly the issue with the large building stock in need of renovation and how their work is affected by both the change that has already happened and the pressure to continue changing due to this large building stock in need of measures together with demands on sustainability and financial sound operations.

The workshop was a whole-day event and was attended by nine practitioners from different organizations, either PFMOs or organizations working closely with such organizations, plus one researcher that specializes in facilities management (FM).

The participants at the workshop were divided into three groups in which they were to discuss different aspects of current challenges for PFMOs and relate to their own organizations: What are the conditions for the current transition? Which actors are involved in the transition, what do they do and how is their work changing? How are your current work practices affected by the current situations for PFMOs? The discussion was based on a conceptual model developed by Gluch and Svensson (2018) that envisions the different organizational levels of current changes in PFMO.

The process of data analysis followed an abductive reasoning, meaning a continuous movement between the empirical data and the theoretical frame of reference. The notes from the workshop together with extensive summaries of the interviews was read through several times looking for patterns. The data analysis was divided into two phases. Firstly, the context of PFMOs was outlined, and the feelings this context bring with it. Secondly, the work of humans and objects were summarised in the findings.

The objects that were included in the analysis were selected based on the following criteria: They were somehow connected to the current context of PFMOs; thus, they were either created, wanted or used in specific relation to current challenges. They

were also shaping the actions in relation to current challenges. The type of objects identified were also apparent in more than one organization. Thus, they were used, adopted and understood similarly in and by different organizations (c.f. Friedland and Arjalies, 2020). After the objects of interest were identified, their interactions with humans were analysed.

The term sociomaterial has most often been associated with technology (c.f. Jones, 2013). However, objects in this paper may be both tangible and non-tangible (meaning both a document, an IT-system and expressions/concepts are objects). They are 'a thing outside' (the human body) (c.f. Friedland and Arjalies, 2020).

Frame for Data Analysis

The frame for the analysis of the relationship between emotions, humans and objects was inspired by Stein *et al.*'s (2014) framework for understanding emotions for socio-materiality based on critical realism (table 1). In sum, there are three important concepts to consider when theorizing emotions in sociomateriality: Affect, emotion and emotionology (ibid).

Table 1: Frame for analysis of emotions and the sociomaterial relationship (adapted from Stein et al., 2014)

(Conceptual) series of interaction between emotions, the material/objects and humans	Empirical observations
1.Organizational affect (humans and objects) ¹	1.Organizational situation in PFMOs generate increased complexibility
2.Subjective emotion	2.This complexibility in turn generates anxiety and stress
3.Emotionology	3."This organizational context is hard to manage; how can we deal with this? These negative feelings need to be reduced". "The complexity needs to be managed/simplified somehow".
4.Material affect ²	4.The objects functions (in various ways) to reduce anxiety and simplify the messy reality
5. Emergent felt quality of relationship between objects and the organizational context.	5. "We need to do something that will help solve our problems...."
6. The type of institutional work conducted and the implications for the institution of PFM ³	6. Practices maintained.

Empirical Setting and Context

The organizations and the individuals within them in this study have not come equally far through the change process. Some individuals had experiences from organizations that had been trying to implement new working practices whereas other had only begun to change their work practices. Yet other had not begun to change at all but had witnessed the change in other organizations. However, what the participants had in common was that they all felt that there is greater complexity imposed on PFMOs, with increased collaboration and increased timelines for planning. Moreover; both during the workshop and interviewees, it was mentioned that people experience stress and anxiety due to current (organizational) changes in PFMOs. The organizations and the individuals within them in this study have not come equally far through the change process. Some individuals had experiences from organizations that had been trying to implement new working practices whereas other had only begun to change their work practices. Yet other had not begun to change at all but had witnessed the change in other organizations.

For organizations that had begun to take action and comprehensively "do something" about buildings from the million program this had resulted in a need for increased cooperation between organizations as well as within the organizations;

"... For example, a project manager who would now be able to handle massive projects with lots of relationships with the contractor and tenants and everything. I discovered that these people were beginning to fall apart. Sleep problems, depression, those kinds of issues. If you had been a project manager at a school before, you have to change the roof... these are manageable quantities and known processes. But now it started to be about a hundred million and about 15 different groups to be coordinated, there are architects involved and then comes the politics and scream and then the company management that requires reports because now this is important... and by tomorrow you have to have a report on this etc. This in turn led to strong frictions between the various organizational units " (CEO, Private FM organization/ specialized in renovation of the million programs)

This complexity and organizational uncertainty in turn created anxiety among the individuals within PFMOs.

For an organization that has not prepared or has done this before, it is a crisis. Crises are about people as I see it. I see now how, I notice this anxiety that exists... many have clear anxiety... (CEO, Private FM organization/ specialized in renovation of the million programs)

Several PFMOs have gone from being a 'service' function to become active stakeholders in planning and decision making regarding both current and future public premises.

Within this new organizational situation, three type of objects distinguished themselves and will be presented below.

FINDINGS

Three Type of Objects That Work to Decrease Anxiety

Object as a 'soft blankets' to rely on - The usage of past objects for new situations

The current challenges for PFMOs creates a need to develop new practices and routines in several different areas. Once the organizations had managed to act and create new work practices and plans for one problem area, these plans were used for other areas. According to one of the participants at the workshop, (head of schools, public FM organization): The "ventilation-investigation" (a brief summary of the work that was done with ventilation measures) later was referred to in plenty of other occasions; "that you can read in the ventilation investigation" became a common expression to tackle diverse issues. The object can be seen as a functioning "soft blanket", and in moments of uncertainty it is easier to lean on this rather than to create more new practices/reports.

Objects as a shield - The usage of 'phrases' to avoid facing the truth

In several PFMOs, there are many buildings from the million program that are in need of extensive measures. One reason for why so little has been done with the facilities from the million program is according to one of the interviewees that the "label" itself has functioned as a mental barrier: "There is so much that needs to be done within them (the buildings in bad conditions), especially for the housing companies with million programs, and it is like the housing companies have made regular changes in many other areas, but when it is called million program it is almost like you dare not move. Then it becomes like a barrier." (Facilities Management, private FM)

organization, specialized in renovation of the million programs). Thus, the sweeping expression "million program" have prevented actors from thoroughly investigate each building. Rather measures in these areas have been postponed for the future. More; according to the interviewees it has become "praxis" to lie for oneself by referring to that the "million program" is too extensive and money consuming to even bother about. The anxiety and mental barrier prevent the actors from seeing the truth as it is. However, in reality though, several interviewees, claim that the variety is large between different areas within the million programs, and even within the same are in the million program housing areas. "All areas have their challenges but also their qualities". The interviewees conclude that the areas are not as bad as many thinks.

According to one of the interviewees who had experience from several PFMOs there is a tendency for the boards of municipal housing companies to 'pretend' to be in control. "Rather than acknowledging the truth, people state that: "we are working with this issues" - hence another sweeping expression. Once you get to ask a bit deeper, 'working with this issues' usually meant discussing the problems, not doing anything in practice".

Some also mentioned that although the creation of new concepts, such as 'strategic facilities management' initially can be used spur enthusiasm and optimism these can also be used to "hide behind". In this way, organizational members can overtly claim that they are using a certain concept, however in practice the practices they are adopting are not in line with the ideas behind these new concepts. Though stating that they are working according to these concepts help to claim both themselves and the managers /organizations.

Object as concrete vision of the 'perfect' future - The usage of future objects as a concretization of the future perfect

Solution for current challenges, including increased collaboration, were often put somewhere in the future, when certain things would be in place, that do not exist today. As one example; new educations were put forward as one solution to manage renovation of the million program: "we need to start a three- year education in order to renovate the million program?", a project manager from a private CM company asks his group rhetorically at the workshop. While there might be a need for new competencies to manage current challenges, this way of reasoning might lead to no real action in practice, and people wait for this program to become reality rather than acting in the present.

Also, the need for new "(IT)- systems" in order for strategic FM to become reality, was a common solution to frame the solution to current issues. However, what such system would include was not clear: "A lot of people talk about the need for a "new system" in order for PFMOs to be able to manage the million program, but it is very difficult to know what content is intended?" was a common reflection at the workshop. "While waiting for these systems many other things become "locked up"" says one participant (Head of FM of schools, Public FM organization). So, while not being able to work with certain issues due to waiting for these IT solutions, the belief was that once these new systems are in place "everything will get in order". Discussing and relying on this future system calmed the humans in the present and it appears as if they felt they were productive in discussing these systems. However, in practice nothing changed.

DISCUSSION AND CONCLUDING REMARKS

The increased complexity and organizational uncertainty in PFMOs create anxiety among the individuals within PFMOs. The urge to manage these negative feelings lead people to use different objects in their institutional work. Objects and humans interact and together maintain current practices. The findings present three types of objects and how they are used to pursue this; past objects, used a 'soft blankets' and future, imaginary objects used for concretizing the future perfect and, current objects as shields to prevent 'reality' from being managed.

It appears as talking about a future IT system calms the actors in the present and make them feel as if they have accomplished something. However, in reality nothing has happened hence practices are maintained. Likewise; using 'empty' phrases such as "we are talking about it" made people feel as if they were doing something constructive, but they were in fact avoiding doing real change in practice. These findings indicate that humans (may) believe that they are part of creating new practices in PFMOs, and are agents for change, when they are in fact maintaining current practices. Moreover: these findings provide insights into why organizational practices in PFMO are hard to change (c.f. Andrews and Johnson, 2015), by showing how actors engage in practices that maintain institutional practices when their environment become fragmented and difficult to comprehend.

Complementing previous research that has shown how humans engage in creating new or disrupting old institutions if the current situational order threatens their psychological wellbeing (Voronov and Vince, 2012), and/or engage in institutional disruption because they are 'dissatisfied with existing practices' (Zietsma and Lawrence, 2010) it is shown here how humans engage in activities that maintain institutions when their psychological wellbeing is threatened. The stories that this paper present shows that emotions affect humans in ways that are not always obvious and makes humans do things that have different consequences than was intended, in this case the maintaining of public facilities management practices. Thus, the humans did not use the emotions (in this case anxiety and stress) (c.f. Greenwood and Suddaby, 2005) rather the emotions were part of the context, that in turn affected the humans and the inter-action between humans and objects (c.f. Stein *at al.*, 2014).

In order for PFMOs to become 'healthy' organizations (c.f. Schein, 2013), that do not produce anxiety, it is essential that managers are aware of the different processes that are going on, that prevent change from happening and that, in the long run, produces more anxiety. Managers need to help people to face the 'reality' as it is, and the research presented in this paper can help them to discover and pay attention to the type of strategies humans use, together with objects. By lifting the functions of the objects, the present study advances the understanding of how humans and non-humans together enact institutional outcomes (Raviola and Norbäck, 2014, Monteiro and Nicolini, 2012), in this case maintaining current practices. The present study highlights the function of the objects for humans in PFMOs and the affective aspects in these processes, thus adding to Buser and Carlsson (2016) and Palm and Reindl (2016), expanding the view on objects role and function. In this paper it was researched on how anxiety and stress lead to actions related to the maintenance of institutional practices. However, within the institutional change that PFMOs are subject to, there are also other type of IW conducted and other types of emotions present. For future research it would be interesting to investigate how and if other

types of emotions in the context of changing PFMOs is both present and how they are affecting actions.

In this paper, the data was collected through talk that was converted into text; either at the workshop or by interviews. For future studies it would be interesting to collect other types of data. For example, one idea could be to follow/shadow a human or an object to be able to observe the emotions first-hand.

The paper has increased the understanding on organizational change in PFMOs by exploring the relationship(s) between IW, objects and emotions and highlighted how emotions derived from a certain context influences humans IW and their inter-action with objects. As such, the paper opens the black box of the relationship between emotions, humans, objects and institutional work (c.f. Stein *et al.*, 2014).

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