THIRTY-THIRD ANNUAL CONFERENCE 2017
September 4-6
Cambridge
WORKING PAPERS
FOREWORD

It has been twenty years since the ARCOM Conference took place in Cambridge, at King’s College in 1997. We return in 2017 with the theme, Brutally Innovative Construction, inspired in part by the venue Fitzwilliam College. Fitzwilliam began in 1869 as a non-collegiate institution, providing Cambridge education to undergraduates unable to afford membership of a college. Fitzwilliam College received its Royal Charter in 1966, 3 years after moving into its new premises on its present Huntingdon Road site. The College has been decorated with several architectural awards, including the two buildings used for the ARCOM 2017 Conference – Fitzwilliam Hall and Central Building (designed by British Brutalist Architect, Sir Denys Lasdun, and built 1960-1963) and the auditorium (built in 2004).

This year’s conference attracted 345 submissions in January 2017. Following three rounds of double-blind peer-review, a total of 113 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 89 members of the extended Scientific Committee. Thank you to all involved in the peer-review process.

This is the second year in which the ARCOM Conference is themed. There were also 10 thematic tracks proposed for the conference, covering a range of issues from service innovation to novel research methods for studying innovation in construction. There were also a number of tracks relating to the social aspects of innovation, including corporate social responsibility and social procurement in construction. These thematic tracks now form an important part of shaping the papers received and accepted and, we hope, of steering the conversations at the conference. As expected in a conference on innovation, we received a number of papers on the development and use of technology. Digitisation of the construction industry continues to be a significant theme, with several authors examining how information modelling is transforming the people, professions and practices in construction. Another significant area in this year’s conference is the focus on environmental sustainability, with authors addressing questions around low energy and low carbon construction.

It is also encouraging to see authors becoming more explicit about and experimental with the theories informing their studies of innovation in construction. Social network theory, actor-network-theory, institutional logics and institutional work, and even critical discourse analysis inspired by a smattering of Marxist thinking are some of the lenses used by authors to study the innovations that are radically transforming and disrupting the construction industry. Construction management researchers can be seen to mature from a relatively atheoretical field to one that is actively trying to put theory to work. It is therefore appropriate that the first keynote speaker is by Professor Chris Ivory from the Lord Ashcroft International Business School in Anglia Ruskin University, Cambridge; Chris will be provoking us to think about the role of theory in innovation in construction.

There is also a mixture of different epistemological positions found in the papers accepted for this year’s conference. A number of authors are also researcher-practitioners, and it is good to see such engaged forms of scholarship as action research featured in some of the papers. Innovation is also a collaborative endeavour, often involving actors across the value chain from supply networks to clients and end-users. It was not so long ago that collaboration was seen in the construction industry as an innovation itself, and while there is still much room for improvement, it is also interesting to see so many papers refer to collaboration as a source of innovation. To this end, we have scheduled four early-career
researchers (incidentally, all women) to be featured in the Langford Spotlight. This spotlight scheduled for the morning of Wednesday 6 September seeks to showcase research on collaboration through different theoretical lenses.

In such an applied field as construction management, collaboration between academic researchers and industry practitioners seems appropriate. We are delighted therefore to have a second keynote led by the programme team, including Nicolas Caille, David Coulet and Simon Evans, who are delivering brutal innovation within the New Safe Confinement Project at Chernobyl. This is a 36,000-tonne structure that is due to complete by the end of 2017 to cover the accident site in Chernobyl. For more information about this project, please see http://www.ebrd.com/what-we-do/sectors/nuclear-safety/chernobyl-new-safe-confinement.html. This second keynote will also be followed by an Industry Panel Discussion on Disruptive Innovation in construction.

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. In times of rising nationalism, there is a need to ensure that knowledge benefits many and not just a few elites. To this end, we will also organise a Knowledge Café to discuss how construction management and built environment researchers can contribute to the production of knowledge around the pursuit of the Sustainable Development Goals. This Knowledge Café will be convened on Tuesday afternoon, 5 September, by Alex Opoku from UCL and Christian Thuesen from the Technical University in Denmark.

Following the successful ‘Meet the Editors’ session in ARCOM 2016, we will run this session again at the ARCOM 2017 Conference. Editors from the ASCE Journal of Management in Engineering, Building Research and Information, Construction Management and Economics, and the International Journal of Building Pathology and Adaptation will discuss what constitutes novelty in the field of construction management research. In a world dominated by performance metrics, it is hoped that the editors will discuss how various publication metrics are helping (or hindering) progress made in finding the novel in the field.

Whether loved or loathed, the use of publication metrics is likely to intensify. Nevertheless, this should not distract researchers from doing high-quality studies. ARCOM has always been intended as a forum for supporting and developing researchers. To this end, we introduced two types of papers for the ARCOM 2017 Conference: the working paper and the published paper. Although working papers and published papers go through the same rigorous peer-review process, working papers are not indexed in the ARCOM and Scopus databases. This allows authors of working papers to extend their paper into a journal publication without diluting their publication metrics.

Last, but not the least, I also wish to show my sincere appreciation to a number of key individuals for their support and help over the past year, including the ARCOM Committee, Cath O’Connell, Alan Pease, all the folk who helped us at Cambridge Conference (including Anita Macdonald, Emma Hilditch and Laura Webb), and of course, our ever-patient and increasingly overworked Conference Secretary, Chris Neilson.

Enjoy the ARCOM 2017 Conference.
Paul W Chan
Chair, ARCOM 2017
August
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The success of the Annual ARCOM Conference depends on the voluntary efforts of the Scientific Committee. We are indebted to the 89 members of the Scientific Committee who, together with the ARCOM Committee members, provided rigour and constructive feedback in the peer-review process.

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BUILDING INFORMATION MODELLING
THE INFLUENCE OF LEADERSHIP, RESOURCES AND ORGANISATIONAL STRUCTURE ON BIM ADOPTION

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Building Information Modelling (BIM) affects the construction processes and at the forefront of digital innovation. BIM allegedly carries benefits for better collaboration and less cost. BIM attracts the attention of numerous large and small firms that update their strategies to embrace this digital shift. However, construction firms face challenges to BIM adoption. There is a close relationship between BIM adoption efficiency and enterprise strategy, which is a key BIM adoption driver. After studying three Dutch and one Finnish firms to understand their BIM adoption history and strategies; enablers and barriers for business model innovation due to BIM were observed. Drawing upon empirical data and organisational, and innovation theories, this paper discusses points for BIM business model innovation. First, leadership commitment was decisive for attaining BIM adoption goals. Second, small firms did better than large firms in BIM adoption, as they met their financial goals and growth with less risk. Third, flexible organisational structures were resilient to meeting BIM changes. The study outlines implications for policy-makers and enterprises who have or plan to adopt BIM and adds to the knowledge base of BIM innovation adoption.

Keywords: BIM adoption, innovation, strategy, leadership, business models

INTRODUCTION

While there is no universally acceptable definition of Building Information Modelling, it can be defined as tools, processes, and technologies that are facilitated by digital, machine-readable, documentation about a building, its performance, its planning, its construction, and later its operation (Eastman et al., 2008). BIM has been considered a solution to construction industry fragmentation, inefficiencies, poor project coordination and information management problems (Eastman et al., 2008). In a BIM-based project delivery, input from the various design disciplines, contractor, suppliers and subcontractors can be sought early in the design process, visualised and the potential coordination problems could be detected and resolved. This process requires close and continuous collaboration among project actors. The promise of BIM and its associated technologies and processes, is that it can integrate the team and facilitate high-quality work. Despite the acclaimed benefits, the level and rate of adoption of BIM by construction actors vary across professional disciplines and countries. Generally, the implementation of any technology largely depends on issues such as change management within the organisations adopting it (Thong et al., 1994). In this regard, Tornatzky and Fleischer (1990) suggested that enterprise management-related issues, e.g. organisation issues such as leadership, human resources management, corporate vision etc., would

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impact technology adoption rate and success by companies and the impact would be different for large and small-medium sized (SME) organizations (Prananto et al., 2003). Kimberly (1976) argued that availability of specific resources is a better way of understanding adoption decision and progress instead of organizational size. The extent to which firm size would impact the capabilities to innovate has also been a subject of discussion in both construction management (Dainty et al., 2017) and diffusion of innovation literature (Rogers, 2003, Barrett et al., 2008).

In their critical review, Dainty et al. (2017) suggested that BIM uptake is 'likely to be more problematic for smaller firms without the resources and capacity to invest in the technology'. Arayici et al., (2011) argue that SMEs have little to gain from BIM. For Jaradat and Sexton (2016) construction management research has favoured BIM adoption in large practices and megaprojects. It appears that BIM is only suitable for large organisations. However, there is little empirical evidence to support this. Meanwhile, the role of SMEs in diffusing BIM innovation is crucial for the integration of the supply chain and productivity across the industry as they are involved in every stage of facility life cycle including operations and maintenance. Given that SMEs account for a large proportion of the construction firms in many countries, the need to consider SME’s perspective in BIM policy effort has been advanced by researchers (Dainty et al., 2017).

From technology adoption theory, innovation diffusion theory and economics perspective, the role of SME in innovation is complex and needs further exploration especially in relation to BIM. This study will contribute to the debate in this area by examining enterprise management and organisational issues influencing widespread and best practice adoption and implementation of BIM, beyond organisational size. At the same time, the influence of the external environment on the enterprise management will be highlighted to provide context.

THEORETICAL FRAMEWORK

Adoption Trends of BIM as an Innovation

BIM is an innovation for construction industry (Arayici et al., 2011) and various scholars are problematizing around its diffusion across countries (Wong et al., 2010, Dainty et al., 2017). There is anecdotal evidence that BIM adoption is still rather patchy despite the growing public sector mandate in many countries. Ramilo and Embi (2014) identified technological, financial, organizational, governmental, psychological and process barriers to BIM-related innovation in firms. Although, BIM brings a promise of a new way of doing things effectively, it could expose the firms adopting it to risk of business failure, as they would need to change their processes (Ramilo and Embi, 2014). Through this process of change, the firms’ capabilities are challenged and tend to be below expectations. Apparently, BIM adoption would not immediately translate into more business (Khemlani, 2004). In the absence of large enough immediate gains, adoption attitude and investment would depend on long term corporate strategy and vision, which could in turn influence commitment, and investment in- and development of- BIM capabilities. BIM visions may entail BIM use to achieve automational, informational or transformational effects (Fox and Hietanen, 2007). Automational effect is the substitution of digital technology for labour to improve productivity, whereas informational effect is the capacity of BIM to collect, store, process and transmit information (Ibid.). Transformational effect is strategic and is the use of BIM to innovate and transform business and the supply chain to gain competitive advantage (Ibid.). For the reasons above, BIM adoption decisions may vary between large and small firms.
Scholars linked the differences between BIM adoption by large and SMEs to the notion of 'digital divide' in which Information Technology (IT) implementation is seen to be hindered by motivation, material access to technology, lack of skills, and lack of usage access in terms of getting opportunity to work with the technology and these are seen to be creating a gap in adoption rate between the SMEs and large firms (Dainty et al., 2017). The gap can also be explained by resource-based theory which suggests that when compared to large firms, small firms are constrained by resources to innovate but this could be compensated for by the agility and flexibility of small firms which promotes innovation due to the ability to identify and meet customer needs in a difficult business environment (Chen and Chen, 2013).

However, if such innovation is incremental - that is through small improvements (Abernathy and Clark, 1985) - it may not give SMEs any competitive advantage and may be costly, inefficient and short lived. Using current firm resources may be risky and lead to failure. Nevertheless, Chen and Chen (2013) discovered that small firms that continuously utilize and invest in innovation resources, can gain competitive advantage and in turn secure further external resources (investment) to mobilise next into differentiating their product or services. In the context of BIM, it would appear that only a strategic and transformational BIM agenda can benefit small firms on the long run and may be a determinant of significant investment in BIM. However, Acar et al., (2005) concluded that attitude towards IT is not different between large and small construction firms because IT is often not considered as strategic. For these reasons, it is likely that BIM adoption would be influenced by interaction between leadership, innovation resources, and organisational structure.

Drivers of Innovation Adoption

Diffusion of Innovation (DOI) theory (Rogers, 2003) and Technology-Organization-Environment (TOE) framework (Tornatzky and Fleischer, 1990) are two relevant and developed for explaining the drivers and dynamics of innovation at the organisational level. Rogers (2003) DOI theory identified four elements of innovation: (1) the innovation itself, (2) communication channels, (3) time, and (4) social system. Considering innovation as an idea, practice, or project that is perceived as new to the organisation there is need for knowledge and persuasion about the innovation before it can be adopted. Diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system (Rogers, 2003).

When looking at BIM as innovation, communication channels within and across firms and organizational structure would influence its adoption. The DOI theory further identified five forces that influence the rate of innovation adoption (1) relative advantage (2) compatibility (3) complexity (4) trial ability (5) observability. During diffusion process these forces decrease uncertainty about the innovation. Relative advantage is the extent to which an ‘innovation is seen as being better that the idea it supersedes’. Complexity is ‘the degree to which an innovation is perceived as relatively difficult to understand and use’. Compatibility is the ‘the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of adopters. For example, the compatibility of a firm’s existing and innovative software and BIM software may influence BIM adoption decisions and rate. Trial ability is the ‘degree to which an innovation may be experimented with on a limited basis’. For example, firms that implement BIM on pilot projects, learn over time and BIM adoption rate increases. The
trials may also lead to reinvention or modification of organisational processes and technology.

The Technology-Organization-Environment (TOE) (Tornatzky and Fleischer, 1990) identifies three contextual aspects that could affect technology adoption process and decision-making: technology, organization, and environment. Technology entails internal and external technologies available to the firm. Technology itself is merely a physical tool, humans have to interact with it to know the purpose of using it, how to operate the tool, and the impact of using it (Arpaci et al., 2012).

Internal technology is already natural to the firm, while external technology is available in the market. Technology availability as well as the features of the technology themselves can influence its innovation adoption process. External technology could provide the organization a vision about what is possible and could impact the adoption process. There may be external technological innovations that could produce incremental or disruptive changes (Tushman and Nadler, 1986). Incremental innovations (small improvements) are least risky as they present little change for the firm. For example, the change from paper-based designing to AutoCAD was incremental as it did not disrupt the existing processes. With BIM, adapting to both new BIM tools and workflows is needed.

Disruptive change leads to fundamental change in the organizational processes, workflow and culture. The ‘organizational’ context of TOE framework refers to the characteristics, resources and descriptive measures of an organization such as firm size, organizational structure (complexity of managerial structure of the top management), the quality of its human resources, and the amount of slack resources. It also includes informal decision making and communication process between employees. Formal and informal mechanisms that link units within an organization would facilitate the communication and knowledge sharing about new innovation.

It is reasonable to expect that smaller organization may find it easier to adapt to change process when compared to larger organizations. Of course they may be constrained by other factors such as lack of resources. Larger organizations would require more formal links to facilitate the communication and knowledge sharing about the new technology. It is also likely that organic and decentralized organizational structure (with least hierarchy) would progress more quickly in the adoption process (Lam, 2011), as there is lateral communication across such firms. This means that the role of top management in creating an organizational context to support adoption is critical for success.

Top management has to support change; communicate the need for change as well as motivate the entire organization into change and define the organization’s vision for the change. They need to make resources available for implementing change including the building executive team to support the change at all levels. In the literature, there is inconclusive evidence to suggest that organizational size and availability of slack resources (unutilized resources) influence adoption (Rogers 2003). Kimberly (1976) argued that availability of specific resources is a better way of understanding adoption decision and progress instead of organizational size. The external ‘E’ ‘environment’ context of TOE framework assumes that to adopt a new technology an organization needs to interact with other external elements including business partners, clients, the industry, competitors, regulations, and relationships with the government. Drawing upon the afore-described forces for diffusion of BIM innovation and the TOE framework, this study used empirical data from firms engaging in BIM innovation to respond the question: How do enterprise management aspects, such as leadership, resources, and organisational structure influence BIM adoption by firms?
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METHOD

The study followed an interpretive approach to understand how firms adopt BIM. The line of reasoning was inductive, by gathering and analysing a number of data sources to make sense of the relation between enterprise management and BIM adoption. Primary data were obtained from face-to-face interviews of eight individuals from four firms in the Netherlands and Finland about BIM adoption history and experience. Secondary data were collected about the firms’ history and identity. The firms were part of a larger pool of twenty construction industry firms in North-west Europe, recruited from a snowballing technique, which were studied for the same objectives. Thus, the case selection was purposeful and these four cases were selected for having a push approach towards innovation, and for evidencing various elements of leadership, resources, and organisational structure. These firms (cases) were diverse in size, services offered, and context. Table 1 shows their key features and research settings:

Table 1: Firm characteristics, interviewees, and context of the study.

<table>
<thead>
<tr>
<th>Country</th>
<th>Firm A</th>
<th>Firm B</th>
<th>Firm C</th>
<th>Firm D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td>Architectural</td>
<td>Contractor firm</td>
<td>BIM Consultants</td>
<td>Lifecycle Consultants</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>Large</td>
<td>SME - 50 staff</td>
<td>SME - 50 staff</td>
<td></td>
</tr>
<tr>
<td>The Netherlands</td>
<td>10 years</td>
<td>360 years</td>
<td>9 years</td>
<td>23 years</td>
</tr>
<tr>
<td>Interviewee 1</td>
<td>Founder</td>
<td>BIM Specialist</td>
<td>BIM Architect</td>
<td>Director/owner</td>
</tr>
<tr>
<td>Interviewee 2</td>
<td>Founder</td>
<td>BIM Manager</td>
<td></td>
<td>BIM Consultant</td>
</tr>
</tbody>
</table>

The primary data were collected through semi structured interviews of 90-120 minutes, which were later transcribed verbatim. The interview questions were about the identity of the firms, their history, challenges and strategy of BIM adoption, progress and future vision for BIM. The secondary data included observations of the firms’ work practice, firm policy documents, company websites, press, and slides by the companies. The analysis of the interviews was based on thematic analysis (coding) of the transcripts. The content of the interviews was examined for meaning and themes were identified through interaction between data and theoretical framework.

FINDINGS

Corporate Vision and Strategy

The four firms had varying visions and strategies for BIM adoption. Firm A was an architectural SME, established in 2007, only working in BIM. All projects are in BIM whether or not it is required by the client. Although the founders have worked in other firms using 2D, they envisioned BIM as the future of design tool and process. To them, BIM does not change the time for completing a project but changes the way the time is used on various activities over project life cycle. According to the founder, “we started our company and made BIM part of how we work. For us we wanted to make sure that we take into account future of design as process and tool and our objective is also to improve our process”. Because they were proactive of clients’ request, their vision could be characterised as transformational, informational and automational. Firm B, a large company with 25 subsidiaries, specialising in various projects, had a vision to use BIM on only large and especially integrated projects. As subcontracting had become an important aspect of their projects, they envisioned that information management would become their core business. In their vision statement BIM is an object-oriented communication
BIM Adoption

and information platform. The BIM specialist stated: “we wanted a good platform for information sharing”, which relates to informational and automational BIM vision. Firm B focused on small and incremental changes enabled by IT with no significant change to existing inter-organisational roles.

Firm C, an Architectural and Structural design SME, started using BIM by accident while helping another firm to prepare drawings for a project. Their client (another architectural firm) demanded for it and during the exploration process they discovered the benefit and made BIM their mainstream practice. A BIM vision was articulated and written down. They used BIM to capture information from the client and throughout the project lifecycle. They wanted BIM to improve the design quality delivered to clients and they had an unintentional and transformational BIM vision.

Firm D, a lifecycle consultant SME, envisioned BIM as an approach for transforming the building process and their business. They wanted to make a difference by using BIM for integrating their modelling with their cost management expertise. The intention was to develop a more efficient building process and get ahead of other players in the market. They envisioned the use of BIM collaboration to satisfy client’s needs and secure business. The have trialled a new business model with BIM. The Director said: “We wanted to do things differently and be ahead. We wanted to marry our modelling knowledge and cost knowledge together. We wanted to share knowledge through 3D models instead through people’s head”. This was a transformational, informational and automational BIM vision.

Leadership commitment

The two founders of Firm A started using BIM in late 1990s and early 2000s. While the company was not built around BIM, they committed to using BIM as the only way of working right from the outset of the new firm. BIM knowledge is the major criterion for all new recruits. The founder stated:

…we employ only those who are BIM ready. We engage those who have used it on projects and it paid off. Although, we have a few who have not used it a lot but we put them in the midst of large number of people who are very proficient with it and so we don’t have to worry

The BIM vision of Firm B was written by the Board of Directors. Despite being hit by recession; they were committed to making BIM a culture among 2500 employees. The Board set up a BIM Centre - the only initiative within the company centrally funded by the board. Firm B also established a steering group with directors from the 25 subsidiaries. The group develops yearly plans, then consolidated in one by the BIM Centre. Prior to that, BIM implementation was decentralised across 5 locations, which was proven inefficient.

For Firm C, although BIM use was unintentional, in 2007/2008, they committed to its full adoption. Disregarding staff resistance, a top down approach was adopted whereby all employees were required to use BIM within 3 months. Upon realising this was utopic, the management focused on those that are willing to work (10%) with BIM and progressively expanded BIM adoption to other employees.

The director and owner of Firm D has been working in construction for 45 years as cost manager. Originally, the core business of the firm was cost estimation and management. In 2006, to differentiate their business, 3D modelling expertise was added to its core business which is then used to extract quantities for cost estimation.
**Investment in innovation resources**

The firms had varying approaches to investing in BIM. Firm A only hired employees with BIM experience in real-world projects. They did not charge clients extra fees for BIM use on projects. They were also proactive in green building certifications. They partnered with another firm, collocated in the same building, on virtual reality to enable concurrent design and communicate it to the clients via 3D glasses.

Firm B invested €650,000 yearly on their BIM Centre for coordinating BIM company-wide. With 8 staff, the centre focused on R&D, methods, manuals, guidelines, developing information exchange protocols, and discussions about information structure such as standardization company-wide, and staff training across her 25 subsidiaries. They also invested in laptops and connecting all sites to firm’s network. The BIM Centre is involved in national and international BIM initiatives. They have collaborated with major software developers to drive the development of new BIM applications. They led 40 other firms (private and public) to work on object library together with industry and public government.

Firm C replaced their existing software and invested in BIM tools. They invested in research and training of staff using external trainers for design and early-stage cost estimation. An innovation team of 5 people was established to drive the BIM vision. At the outset of BIM adoption, temps were employed on contract basis to work on traditional projects, while permanent staff were working on BIM. In Firm D, an innovation manager eased the adoption process. An in-house BIM manager was hired to manage the BIM process. They also developed and now sell their own online tool for linking 3D models to cost to other BIM authoring software in a less complex way. Cost libraries, and databases as well as methodologies for modelling and work requirements were developed. Staff were trained in-house. To facilitate the subcontracting process, an integrated online platform was created so that each sub-contractor can upload their models online. Because of their vision to transform the building process free workshops were organised to train clients and business partners about BIM. The firm leads industry initiatives on BIM.

**Organisational structure for innovation diffusion and Informal Aspects**

Firm A consciously retained a small firm size, as they believed that it facilitates BIM adoption. It was easy for them as an SME to find knowledgeable staff to train others. Firm B has 25 subsidiaries in various locations. Decentralising BIM adoption into five branches was found to be inefficient. Thereafter, a centralized approach was adopted by establishing the BIM Centre to cater for the BIM adoption needs of all subsidiaries. Firm C unsuccessfully adopted a top down BIM adoption structure at the outset. Then, they adopted a flexible and organic approach whereby staff are first trained in BIM and then embedded within the firm. The BIM Architect stated:

> If management does not support it, don’t do it and even if management order it and want it and staff don’t want it, don’t do it. You must have a good mix. Some people must be ready to use it

Prior to BIM era, Firm D had a top down management structure and while introducing BIM, they introduced a lean organizational structure. To them, BIM adoption work best with a flat structure that inspires proactive behaviour.

**The influence of context**

Firm A is situated in Finland while firms B, C, and D are located in the Netherlands. Finland has a deeply entrenched collaborative culture as opposed to Netherlands which is both collaborative and competitive because of the financial crisis. While BIM has been
largely mandated by the public sector in the Finland with a lot of BIM development and cross-organisational knowledge exchange initiatives, BIM mandate in Netherlands is not as forceful. Organisations in Netherlands actively seek BIM knowledge exchange beyond their firm (Firm B and D). In Finland, knowledge exchange became cultural because of their collaborative culture and the aggressive nature of the governmental BIM mandate. The Dutch building agency responsible for managing government assets has mandated BIM but in a slow, measured and non-aggressive fashion when compared with the Finnish authority which actively promotes and coordinate all BIM adoption efforts across the industry. The downturn in the Netherlands had mixed effects on BIM adoption depending on firms’ views, corporate vision and strategy. The transformational BIM vision by Firm D is purposely to stay ahead, transform the building production process and offer clients new way of producing better buildings, cheaper and faster in the face of the downturn whereas BIM was not conceived by Firm B and C as a means of navigating the downturn.

BIM Implementation outcomes

Firm A is rather successful with BIM, as all projects are now done with it, but at various levels depending on clients' needs and requirements. Firm B has not been so successful, despite the leadership commitment and funding available for BIM adoption company-wide. The firm size appeared to have hindered adoption effort. Although Firm B has some characteristics that should enable in-house learning of integrated BIM and to transform the industry they only managed incremental and small change with BIM despite their financial commitment to it perhaps because of their large size, rigid organisational structure and deeply entrenched organisational culture. Meanwhile, Firm B became insolvent and was restructured. Firm C now uses BIM on all projects but at different levels. They have been transformed to a BIM consultancy. They have seen failure cost reduced by 10%-20% and ahead-of-time project completion because of BIM. Firm D now works with BIM on all projects. With their current BIM capability tested on projects, they foresee a future where they will be able to manage projects with a limited contractor role. They have developed a new commercially available BIM methodology and online software tool.

DISCUSSION

Leadership - It appears that BIM vision and strategy have mixed impact on the success of BIM adoption depending on other issues. Although firms with no clear vision for BIM appear to struggle (Firm C), leadership and commitment rectifies the lack of clear vision. Firms with a transformational vision exhibit stronger leadership and commitment (Firm D) than those who see BIM only as an information exchange tool (Firm B), which is in accordance with (Fox and Hietanen, 2007). Firms with transformational vison tended to be proactive in investing in long-term BIM prospects rather than just immediate gains (Firm A and D). They seek new services to meet clients' needs (Firm A and D) and are committed to redefining construction business (Firm D). Having a transformational strategy is compatible with informational and automatial strategies. Others appear to be more focused only on in-house development of BIM rather than seeking new offerings to clients (Firm B and C).

Resources - Whereas firm size can influence the ability to invest in innovation resources (Firm B), it might also be a liability. Large firms face the dilemma of choosing between top-down and bottom-up as well as centralised and decentralised approaches to adopt BIM (Lam, 2011). While a decentralised approach can facilitate organisational culture change (Lam, 2011), it makes change effort cumbersome and inefficient (Firm B). On
the other hand, centralised approach is counterproductive when seeking change in organisational culture; it is slow and rarely company-wide. The findings confound some existing concern about BIM adoption and small firms (Acar et al., 2005, Dainty et al., 2017). It appears that the difficulties faced and success of BIM adoption by small firms depends on corporate vision, leadership support, and commitment rather than limitations of resources. After all, the risk and impact of failure of BIM adoption is less for smaller than large firms. The adoption history and the outcomes of BIM implementation across the 4 firms perhaps show that disruption and new business models to change construction production process might come from SMEs with transformational vision and leadership commitment (e.g. Firm D). After all, SMEs are generally more competitive in the supply chain and able to utilize their resources in an agile manner. Firm D continued to invest in BIM innovation and the firm commitment has yielded new innovation (a software firm).

Structure - Large firms with established clientele may resist change especially when BIM is not required. While they have the slack resources to implement change, they may have inflexible organisational structure to maintain their market position amidst disruptive change and are exposed to risk (Chen and Chen, 2013). Any gains from disruptive change are not immediate to offset the initial investment of large firms. When BIM is not required, firms can implement change in a non-disruptive fashion to improve internally (Firm B). Small and flexible firms require less slack resources to implement change and subsequently carry less risk than large firms.

Firms with flexible structures can later upscale rather quickly and in turn induce greater change. With transformational BIM vision and continuous investment in BIM resources, the likelihood of SMEs, start-ups, and flexible firms disrupting the industry depends on their ability to find large clients who are attractive to their newly discovered business model (Firm A and D). They may be able to implement BIM with great success on the long run when compared with large and established firms (Firm B and C). We expect the interaction between size, resources and leadership to be similar in industries such as manufacturing. However, there might be some differences depending project type specialisation. Firms specialising in prefabricated buildings might be able to implement BIM quickly with greater success since the supply chain is standardised, whereas those specialising in unique projects might find it challenging because of the ever changing nature of the supply chain they have to engage across projects.

CONCLUSIONS

This study examined how organisational management aspects influence the adoption of BIM innovation. Drawing upon empirical data from four construction firms in North-western Europe and innovation and organisation theories, several key aspects were identified, namely leadership, resources and organisational structure were found critical for successful BIM innovation adoption. The study adds to research and knowledge base on BIM adoption from an intra-organisational perspective and offers new insights into the discourse about which firm size better supports BIM adoption. The data and the reflection of these four firms who adopted BIM a few years back should be of interest to practitioners who have or plan to adopt BIM and transform their practices. The paper outlines implications for policy-makers as numerous features apart from firm size might influence BIM adoption. Correspondingly, varying incentives schemes could support BIM adoption and macroscopically its diffusion in the industry. Future research will revisit the study of these firms (and the larger sample) in a longitudinal study to reflect on the strengths of leadership, resource availability and organisational structures for successful BIM innovation adoption.
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THE POTENTIAL COMMUNICATION AND COOPERATION BETWEEN CHINA AND UK BASED ON THE APPLICATION OF BIM IN THE CHINESE MARKET

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Since the publishing of “The 2011-2015 Development Guideline for the construction industry digitalization” by the MOHURD (Ministry of Housing and Urban-Rural Development) of the People’s Republic of China in 2011, the idea of BIM (Building Information Modelling) has been officially established by the Chinese government and quickly became one of the trendiest words in Chinese construction industry. The goal of this research is to analyse the current situation of BIM development and application, in terms of application situation, barriers and the market in China. Also, various wider potential opportunities of communication and cooperation can be provided in the Chinese market through comparative study between China and UK, which is regarded as one of the fastest developed countries in implementing BIM. The methods used in this research is via questionnaire and interview with leading professors, managers and engineers from colleges and AEC (Architecture, Engineering and Construction) industry from Ningbo, Shanghai and Chengdu, respectively. The results indicate that there is still a large gap on the development and application of BIM between UK and China, which is still in its preliminary stage. Some communication and cooperation strategies are presented in the educational, normative and commercial aspects.

Keywords: BIM, Chinese market, communication, cooperation, AEC industry

INTRODUCTION

In recent years, Building Information Modelling (BIM), which represents one of the most promising technologies in the global architectural, engineering and construction (AEC) industry, is pushing worldwide AEC firms to implement an innovative revolution for the conventional industry. BIM not only brings technical breakthroughs in multi-dimensional visualization and real-time synchronization, but also realizes multi-disciplinary collaboration and comprehensive management for a building project lifecycle, which consists of several main phases including planning, design, construction, operation and maintenance (Eastman et al., 2011). As one of the fastest BIM adoption and development in Europe, the UK government and industry associations are playing positive roles during the process of native BIM development (Eadie et al., 2013). They state, that BIM can improve the overall efficiency and bring other benefits across the project lifecycle.

Compared with the UK, China, the largest AEC market in the world, is currently undergoing a number of development of BIM application. Due to the outdated structural system and lack of BIM experience, China’s AEC industry is still at an initial level of BIM proficiency (Jin and Tang 2015). In 2012, a market survey by the China Construction Industry Association (CCIA) indicated that less than 15% of in total 388 Chinese contractors claimed that they have adopted BIM (CCIA 2013). Another China’s

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survey in 2012 from Shenzhen Exploration & Design Association also indicated that over 90% of design firms had heard of BIM, 54% of them claimed that their BIM applications still stayed in the experimental stage for small-size projects (SZEDA 2013). Like the UK government, China’s central government also had introduced related policies and standards to support the development of BIM application during the past 12th Five-Year Plan period (2011-2015) (Jin and Tang 2015), such as the 2011-2015 Development Guideline for the Construction Industry Digitalization, the Announcement of Publishing the 2012 Engineering and Construction Standards, Request for Proposal on BIM Application in the Construction Industry, Proposals on Enhancing the Development and Improvement in the Construction Industry, etc. (Jin and Tang 2015). In the next five-year period (13th Five-Year Plan, 2016-2020), BIM is also a key to promote the development of digitalization and upgrading of industrial structure (MOHURD 2016). A guideline by the Chinese Ministry of Housing and Urban-Rural Development (MOHURD) stated that by the end of 2020, the BIM usage in projects of large and medium-sized buildings needs to meet 90% target (MOHURD 2016). It can be predicted that the future demand for BIM application is enormous in Chinese market.

In this research, the current situations of BIM development and application in China are analysed and discussed by using a scientific research methodology, which is based on empirical and comparative study. The analysis results also indirectly reflect the differences between China and UK. This paper aims to propose some potential communication and cooperation between China and UK in the future.

**METHODOLOGY**

![Methodology flowchart](image)

*Figure 1: Methodology flowchart*

As the Figure 1 shows that questionnaire and interview are two main methods applied in this research and the literature review is for comparing differences of BIM development and application between the UK and China. In general, respondents and interviewees were selected from three AEC industrial conferences held by D-CiTi Lab² in Ningbo,

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² D-CiTi Lab: Digital City Infrastructure and Technology Innovation Laboratory, a multi-million-pound living lab that integrates research and innovation on BIM and Smart City development located in the University of Nottingham Ningbo China.
Shanghai and Chengdu, respectively. BIM contemporarily develop and apply in these three typical cities, can be considered to be representative of China’s current situation.

The questionnaire is focused on the investigation of application BIM in China. Over 390 attendees who work in AEC companies, governments and universities were asked to complete the questionnaire. To make sure that the results only reflect the situation of China, responses from overseas companies should be neglected. After adjustment, 283 valid responses have been collected in total.

The interview is to verify and improve the results that come from the questionnaire. Questions in the interview are based on the questionnaire and the background for each interviewee. Ten guests who have more than ten years working or research experience in AEC industry were invited as the interviewees. It is believed that their opinions can represent the understanding of Chinese BIM pioneers. To protect interviewee’s individual privacy, their names and profession details would not be shown in this paper and they are marked from letter ‘A to J’ for distinction. Because each interviewee has multi-career background, seven background factors are listed in Table 1 and the specific background for each interviewee are shown in Table 2.

<table>
<thead>
<tr>
<th>Table 1: Profession background factors</th>
<th>Table 2: Interviewee’s background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background Factors</td>
<td>No.</td>
</tr>
<tr>
<td>Project manager</td>
<td>1</td>
</tr>
<tr>
<td>Engineer</td>
<td>2</td>
</tr>
<tr>
<td>Local government consultant</td>
<td>3</td>
</tr>
<tr>
<td>University professor</td>
<td>4</td>
</tr>
<tr>
<td>Company general manager</td>
<td>5</td>
</tr>
<tr>
<td>International institute member</td>
<td>6</td>
</tr>
<tr>
<td>Regional president/chairman of international institute</td>
<td>7</td>
</tr>
<tr>
<td>Chairman of Chinese industrial institute</td>
<td>8</td>
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</tbody>
</table>

The valid opinions were extracted from the summary of collected interview content. Each of these valid opinions has been indicated or agreed by at least three interviewees. Finally, through the combination of the results from questionnaire and interview and the comparison between the application and development situation in UK, multiple communication and cooperation methods between China and UK are suggested in Discussion.

According to the data, 55% of respondents have not applied BIM in their current or previous projects. Rest of them, as the Figure 2 shows that are more focused on the design phase and construction phase. However, there are limit applications in operation and maintenance phase, project management and collaboration phase. Based on the further investigation, although the results show that the most widely application of BIM is in design phase, the real number of the application in design phase should be less due to the limited understanding of BIM for some of the respondents and they believe that the changing of 2D drawing to 3D model is the full application of BIM in design phase.
RESULT AND ANALYSIS

The Situation of BIM Application in China

In terms of the situation in the UK, according to the National BIM report, 54% of respondents are using BIM in 2016 and the percentage in 2017 is 62% (NBS 2017). With respect to respondents in this research who have experience in BIM application, 45% of them have very lower application rate which is less than 25% of their total projects in the past year. Only 15% of them got quite frequent application and the application rate is more than 75%. However, according to the National BIM report in 2017, 18% of their respondents in UK use BIM in every project and 29% of them apply BIM in 75% of their projects (NBS 2017). According to the statistics, 55% of respondents in this research who have experience in BIM application indicated that there are just beginners in BIM. Only 10% of them believe that their master at applying BIM. However, 55% of respondents in UK are confident in their knowledge and skill in BIM while only 23% of them are not confident. The difference between China and UK is obvious. However, interviewees indicated that the BIM applications are relatively better in some first-tier cities such as Beijing, Shanghai and Shenzhen and there are several typical case studies including Shanghai Tower, Disneyland and CITIC Tower. In general, even though there are various outstanding projects of BIM application, it is undeniable that the application of BIM in China still in the stage of beginning comparing with the situation in UK.

The Barrier of Development and Application of BIM in China

For 54% of those respondents who have not applied BIM before, they believe that lack of understanding in BIM is the severest barrier to apply BIM in their projects. 13% of them believe that the excessive costs of applying BIM including the hardware cost, software cost and training cost are the severest barrier to apply BIM. 27% of them believe that the severest barrier for them is the limited demand for BIM and they indicate that the traditional pattern and technologies have already satisfied their requirement. Rest of them have different opinions of barriers such as lack of BIM standard, long training period of BIM and lack of guidance from the local or central government. Several interviewees have some similar but deeper understand in barriers of BIM application and development

Lack of BIM understanding
Four of interviewees believe that insufficient of BIM capability including the understanding and technical skills is the one of most significant barriers in China. Many
managers or engineers even treat BIM as a tool for 3D visualization. Poor capability inhibits the deeper application and development of BIM and it can lead the superficial application of BIM. Some interviewees indicate that to fulfil the bidding requirements of the owner, many companies only create 3D models by using BIM software independently and follow the traditional work pattern to complete their projects. In these companies view, BIM become independent encumbrance.

*Lack of BIM standard*

The superficial application of these companies can also reflect the imperfect standard system of BIM in each process. Until 1st July 2017, the first BIM national guiding standard named Unified Standard for Building Information Modelling Application is published by MOHURD. In terms of UK, in order to promote the native BIM development, relevant policies and mandates have been announced in the UK since 2007, such as User Guide by Construction Project Information Committee (CPIC), British Standard BS 1192 by British Standards Institution (BSI), Publicly Available Specifications (PAS) 1192 sponsored by Construction Industry Council (CIC) and other BIM technology protocols by AEC (UK) team. As the interviewees indicated that the clear and detailed standard or policy is of importance for everyone in the industry. Some of the experts also believe that for the Chinese companies, apart from the Chinese local standard, they should also understand some international standard in order to improve their competitiveness. Interviewees pointed out that several domestic companies have failed overseas bidding because they cannot fulfil the requirement of standards in the country.

*Return on investment*

In questionnaire survey, most respondents who have BIM experience did not answer the question about the investment return. It is speculated that the investment return has not been evaluated by them. However, interviewees state that the benefit of BIM can be embodied through the whole lifecycle of the building but the investment in the beginning usually much higher than old pattern and therefore the return period will be extended. The actual profit for the company is hard to evaluate therefore many companies are still on the fence. The delayed investment return is another battier of BIM development and application.

*Organisation barrier*

Organisation barrier referring to the traditional organization culture and structure that is not suitable for BIM working flow. Interviewees believe that BIM is more than a technology and it interacts with organization culture and structure. A successful BIM adoption needs the support from the aspects of management and organization culture. Interviewees indicated that Chinese AEC industry prefer to solve problem or increase productivity through utilization of massive man power, instead of applying innovative technologies or increase efficiency of current resources. They also believe that those phenomena mainly caused by the cost of Chinese labour force is relatively lower and more attainable compared with innovative technologies. Besides, Traditional Chinese managers are proficient in manage manpower instead of modern technologies. With the increasing further application of BIM in management, the change would be gradually imbedded in the culture and structure.

*Animated market in China*

Although the situation of BIM application in China is unsatisfactory and there are many barriers of BIM development, the benefits of BIM and positive prospect of BIM are still accepted by most of respondents. According to the statistics, 70% of respondents believe
that BIM will have very positive effect on Chinese AEC industry and 80% of respondents who have not applied BIM before will prepare to apply BIM in the future. Meanwhile, 40% of the respondents indicated that they obtained the BIM knowledge from self-study, 46% of the respondents obtained from industry-oriented training and only 14% of respondents learnt BIM from school education. It can show the strong willing of Chinese AEC industry to adopt BIM and meanwhile reflect a huge demand on BIM education.

Interviewees indicated that the direction of the market follow the policies from central government. Since April 2016, centrally procured construction projects in UK are required to achieve BIM Level 2 (NBS 2016). That means all project and asset information, documentation and data should be electronic and integrated into a collaborative 3D model. This policy strongly pushes the development of BIM in UK and the importance of BIM is also mentioned in ‘13th 5-year national plan’ by China MOHURD. Therefore, the willing and demand for the BIM will increase rapidly in the next few years. With the rapidly development of Chinese AEC industry, the market will not only focus on the first-tier cities of China. The larger market will open with increasing need of accommodation, entertainment and consumption in the second or third-tier cities.

DISCUSSION

Based on the results and analysis, the communication and cooperation opportunities between the UK and China based on the application of BIM can focus on three aspects as followings:

Educational Aspect

Education is the fundamental for an industry especially for those that are experiencing the innovation and reformation (Stadler, 2012). Without strong reserve of talents and promotion of knowledge for BIM, the speed of development will remain sluggish. As the interview and questionnaire indicated, the cognition and basic skills of BIM for respondents were limited. In recent years, some of the top universities such as Tongji University, Tsinghua University and the University of Nottingham Ningbo China started to set BIM courses in related majors. However, comparing with British colleges, the curriculum system still needs improve. Many Chinese and British colleges have already had a series of communication and cooperation patterns such as summer school, student-exchange program, united training program and Sino-foreign cooperative University etc. (Hancock, Tang, Jin, and Ligt 2017). Based on those patterns, more BIM cooperation can be developed to fix the blank of the BIM knowledge in many courses of Chinese universities and colleges.

Also, various international competitions which are related to BIM can be held by government or enterprise for collegiate students such as the Solar Decathlon competition which is held by China National Energy Administration and the Department of Energy (DOE, USA). It is a good platform that not only can improve the BIM skill for students but also convenient for communication between each government, enterprise and school in UK and China based on the BIM education.

Meanwhile, there is also a huge market on industry-oriented training. According to the results, nearly half of respondents have industry-oriented training experience. Different from the school education, industry-oriented training is provided for different professions and some of requirements such as the brief period and practicality should be satisfied. The incomplete training system can lead unilateral cognition. Many people treat BIM as a software because most of industry-oriented training in China only focus on the software
operation. The design for curriculum system should be comprehensive and it is a good opportunity for both Chinese and British AEC industry, universities and profession training institutions to develop a systematic social BIM training base on Chinese market.

Normative Aspect

Chinese government plays an essential role on guiding and accelerating the BIM development by releasing guiding policies and leading the formulation of standard.

In the 13th Five-year Plan, BIM is considered as a fundamental technology in the development of informatization and digitalization of AEC industry. However, this document still stays on the guidance level and lack the specific mandate. Meanwhile, the first BIM standard of China will be applied after 1st July and the Chinese BIM standard system will be extended and improved in the future.

Comparing with China, UK have approximately complete standard system based on BS and PAS and it provide the foundation for British AEC companies to follow the mandate of UK government which is the requirement for the application of BIM Level 2 in all centrally-procured government projects since April 2016 (Bew 2016). The UK government set a good example in using government power to make BIM happened (BIS 2012).

Considering the communication and cooperation between Chinese and British government at all levels, the bilateral forum is an available and efficient method. Depend on research results, the forum can be focused on several topics for example, how to drive BIM application in companies and how to improve the standard system etc. It is expected that the experience and knowledge sharing will benefit for both British and Chinese participants. For the Chinese government, it is an opportunity that can provide multiple perspectives for several departments in Chinese government to enhance the understanding of the BIM development in the further. For the UK government, it is a good opportunity to cooperate with Chinese government and provide more favourable polices for British AEC companies under ‘One Belt One Road’ development strategy.

Commercial Aspect

The commercial corporation and communication between each company in UK and China can be considered in the aspects of management and project. Managers in Chinese AEC companies should be clear that the trend towards BIM application is irreversible and the investment is indispensable. As many British companies in the AEC industry have extensive experience in BIM application, the understanding of the investment, management, organization culture and structure based on BIM can be improved through the communication with British companies. For the Chinese companies, various problems can be avoided and solved.

Meanwhile, with the popularisation of BIM, the demand for high quality BIM consulting and projects will increase rapidly. Due to the limited cognition and skill of Chinses AEC companies on BIM, a gap between demand and supply in Chinese market is expending. It is an opportunity for UK BIM companies to eliminate the gap with the corporation with local companies and government. Currently, there are many participations for foreign company in several projects of landmark building such as Shanghai Tower and Disneyland.

In addition, currently foreign companies mainly focus on the market in first-tier cities of China. However, the opportunities in middle and western part of China are neglected. For example, Wuhan and Zhengzhou which are located in the middle part of China aim to
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become national centre cities with the authorized by National development and Reform Commission. Guangxi province, which locate in the Southwest of China, is one of the first batch of province that announce to facilitate BIM development. The BIM adoption rate in the government-funded projects is required to achieve 90%. All the evidences announce that there is huge market in the middle and western part of China. Various commercial opportunities are waiting for explore through the further communication between Chines and British companies.

CONCLUSIONS

The investigation is based on the three high-level conferences in Ningbo, Shanghai and Chengdu respectively. The current situation of BIM development and application in China can be reflected from educational, normative and commercial aspect. In general, the BIM development and application in China are in the preliminary stage compared with the situation in UK. According to the result analysis, the Chinese BIM market is animated and many communication and cooperation opportunities between China and UK are presented in terms of the BIM education, company cooperation and standard setting. In the future, more related industrial surveys will be carried on in more Chinese cities to further investigate the Chinese BIM situation and set strategy and vision for the mutual market growth for both China and UK.

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LEARNING ECOLOGY FOR DIGITAL TRANSFORMATION IN CONSTRUCTION PROJECTS

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Industries are going through digital transformation journey, and construction is no exception. Building Information Modelling (BIM) is a technological innovation in the construction industry that can be used to deal with the digital world to resolve complex problems through multidisciplinary solutions. Digitalisation is not just a process, but deals with decisions related to people. Therefore, making connections is vital for a successful digitalisation; however, identifying and creating a suitable learning ecology through these connections is challenging, especially in project-based industries such as construction. Learning ecology emerges from a unique configuration of activities, materials, resources, relationships and integrations. The aim of this study is to examine the aspects of learning ecology in BIM construction projects. Data has been collected from two case studies on educational BIM construction projects which fall in the £30-£60 million bracket. The study explores how learning is taking place differently than earlier in BIM construction projects by demonstrating how tasks are completed. The findings suggest that to cope with digitalisation, construction projects need to be transformed into self-adaptive systems to enable the connection between people which will improve the way in which they align with project goals and to configure the right workflow.

Keywords: Building Information Modelling (BIM), digital transformation, learning ecology

INTRODUCTION

Digitalisation is a step change in the move towards technological innovations which help to reduce the demands for routine and manual tasks (OECD, 2017). Many industries are already benefiting through the adaptation of digital technologies; however, the construction industry is slow in adopting these technologies and embracing new opportunities in order to improve operations in construction projects. According to the Construction Industry Council (2014), intelligent apparatus and systems are still at their initial stage of development in the construction industry. However, the ongoing technological evolution in construction is expected to improve productivity, building quality, safe working conditions, environmental compatibility and reduce project delays (Geno and Clay, 2016). On the other hand, technological innovations are challenging for construction when they lead to skills deficiencies due to underdeveloped technologies (Lee, 2010), to an overall decline in employment due to automated technologies (OECD, 2017) and the introduction of new job roles (Berger and Frey, 2016). In contrast, critics argue that the industry as a whole is unlikely to be automated due to the variability of the tasks within each process (Autor and Handel, 2013). Nevertheless, the overall aim of technological innovation in the construction industry is for it to evolve from its traditional analogue-based artefacts and processes to a new and more connected digital state.

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In recent years, the construction industry has started to focus on Building Information Modelling (BIM), which is a new technology to integrate processes throughout the project lifecycle (Aouad and Arayici, 2010). BIM can be described as a computer-aided modelling technology for managing and generating building information, with the related processes of producing, communicating, and analysing building information models (Eastman et al., 2008). The fundamental concept behind BIM is to store the relevant data connected to a project in a single Federated model and then apply the relevant details into the digital environment when needed. Data involved in this centralised BIM model are used to increase productivity, efficiency, quality and to achieve competitive advantages in the global market to attain their set targets. A number of BIM benefits are explored in construction studies (Eastman et al., 2008; Arayici et al., 2011); however, there are also barriers and hindrances to adopting BIM for construction projects due to a lack of skills and learning (Succar and Sher, 2014; Abdirad and Dossick, 2016; Chae and Kang, 2015). Therefore, to deal with this issue construction project teams should develop a comprehensive digital learning strategy. To achieve this we should explore the learning that happens in BIM construction projects from a different perspective in order to help the team members to achieve their full potential.

LEARNING IN CONSTRUCTION PROJECTS

Learning in construction projects and organisations is gradually becoming more complex compared to previous approaches due to the rapidly changing technologies. This increased complexity not only affects interpersonal relations, information co-ordination and learning in projects, but also causes project failures and low success rates.

The learning that takes place within projects has been explored by several researchers. Organisational learning (OL) in the project environment generally occurs through past experience, experience from others, thinking, knowledge recombination and experimentation (Sethi and Farooq, 2014). OL motivates and provides inputs for learning, but knowledge sharing, innovation, competitive advantages and lack of business confidence are some of the challenges related to it (Tennant, 2013). Situational learning, on the other hand, is an instructional approach which motivates people to learn by actively participating in the learning experience (Lave and Wenger, 1990). However, providing authentic contexts, authentic activities, access to expert performance and opportunities to investigate multiple roles and perspectives are drawbacks to this learning approach (Herrington and Olive, 1995). Constructivism is another learning approach, which is based on a learners’ experience and reflection on it. In this situation, even though knowledge is personal, learners construct their knowledge by interacting with the physical world, and by collaborating in social settings and in a cultural and linguistic environment. Critics consider that constructivism is subjective, fails to break away from a traditional empiricist view and does not accurately portray the practice of science (Osborne, 1996). On the contrary, the theory of social constructionism suggests that learning happens through the social context of people’s knowledge and the social processes of knowledge construction. However, criticism levelled against social constructionism argues that it only concerns epistemological claims and neglects ontological ones (Andrew, 2012).

In these approaches there has been very limited consideration for the connections and relationships between entities within the learning environment, which are crucial for the information world. Learning is interactional and is constantly changing, so there is a need for systematic and structured learning to connect the entities and their interactions within the project environment to achieve successful project outcomes. One of the ways
to improve learning within projects is to generate a suitable learning environment that allows a connection between the project entities and their interactions. An ecological view of learning describes the nature of interactions that occur in learning. Furthermore, it suggests that learners have access to a suite of facts, concepts, tools, practices and people distributed across time and space which provide the context (Jackson, 2013). Therefore, embracing a learning ecology lens would allow people to access and connect with all the entities in a project environment.

**LEARNING ECOLOGY**

Learning ecology is a relational concept which refers to how and why people are learning, and their complex and comprehensive set of relationships with the environment the entities connected (Jackson, 2013). The Learning Ecology concept has been applied in various contexts, and some of the viewpoints explored by scholars are shown in Table 1. Generally, people use learning ecology to construct, organise and interact with the content; nevertheless, people’s learning and behaviour is currently changing due to the introduction of new technologies. This has altered the environment in which they learn, which has become networked and has expanded beyond the physical walls with the use of technologies. There is hence a need for effective learning ecologies in this digital world. This study proposes a learning ecology view as a potential approach for the modern information world to address complex and dynamic issues in a scalable and efficient way.

Collectively from the above perspectives and aspects, learning ecology is a vast and intricate network of systems, which is formed as a result of the interactions with the world to achieve certain goals. However, it includes different tools, understandings and relationships, which change according to the process of imagining, designing, constructing and implementing certain goals in a particular situation. Therefore, framing a learning ecology is important in order to understand how the world works and to help connect the relationships with other people, including the physical, emotional and cognitive behaviours which occur in relation to specific environmental contexts and situations. Since the components are connected within the ecology, a change in one part affects all of the other components. The construction industry has recently seen the introduction of various technologies (i.e. BIM) in order to attain its time- and cost-related goals. Therefore, the concept of learning ecology needs to be understood by the project team members to work with these new technologies.

**RESEARCH APPROACH**

Two BIM construction projects were examined to explore the learning ecology in which project team members were engaged. According to Flyvbjerg (2001), case studies are a versatile way of examining human learning which is open to public scrutiny. These case studies were selected as the researcher was allowed to access the design meetings in BIM construction projects in ‘natural settings’. Case study one is a 100,000 square foot extension to a previous building built in 2015. This is a £31 million project which caters for over 3,000 students and members of staff and features more than 650 rooms, a student hub and lecture theatres, a new library, and teaching and IT spaces. This high-tech university project has used Level 2 BIM for its delivery and detailed planning and completion is anticipated in September 2017, in time for the new academic year. Case study two is a £57 million project featuring a 9,000 square foot design for media and art students, with the purpose of teaching, rehearsals and state of the art performance spaces. This building includes excellent facilities, such as a jazz club, a 500 seat conference hall, an intimate 150 seat recital hall, a 100 seat practice and rehearsal hall, an organ studio and
complete AV digital interconnection. This project has also adopted Level 2 BIM and will also be completed in September 2017.

Table 1: Different perspectives of Learning Ecology

<table>
<thead>
<tr>
<th>Authors</th>
<th>Perspectives</th>
<th>Aspects</th>
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<tbody>
<tr>
<td>Bronfenbrenner</td>
<td>Learning Ecology is viewed as a whole system that comprises different</td>
<td>Relationships and communication with people, and their interaction with</td>
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<tr>
<td>(1994)</td>
<td>components to interpret human development.</td>
<td>the immediate environment and institutional patterns of culture such as</td>
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<td></td>
<td></td>
<td>economy, customs and bodies of knowledge.</td>
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<tr>
<td>Gitterman</td>
<td>Learning ecology is viewed from a human ecological perspective, which</td>
<td>Space involves people's physical, social and virtual environments; in</td>
</tr>
<tr>
<td>(1994)</td>
<td>involves people in their physical, social and virtual environments as a</td>
<td>particular, cultural and historical contexts.</td>
</tr>
<tr>
<td></td>
<td>unitary system living within a particular culture and historical context.</td>
<td></td>
</tr>
<tr>
<td>Brown (2000)</td>
<td>Learning ecology is viewed as an open, complex adaptive system comprising</td>
<td>Open, complex adaptive system;</td>
</tr>
<tr>
<td></td>
<td>elements that are dynamic and interdependent.</td>
<td>dynamic and interdependent.</td>
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<tr>
<td>Zimmerman</td>
<td>Learning Ecology is viewed as the process of creating and handling</td>
<td>Self-regulation; a continuous process that starts with imagination,</td>
</tr>
<tr>
<td>(2000)</td>
<td>situations that emerge over time and need to be self-regulated.</td>
<td>planning and decision making, action/performance and self-reflection</td>
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<td></td>
<td></td>
<td>on action/performance.</td>
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<tr>
<td>Barab and Roth</td>
<td>Learning ecology is viewed from an affordance network perspective, which</td>
<td>Connection in terms of facts, concepts, tools, methods, practices,</td>
</tr>
<tr>
<td>(2005)</td>
<td>extends the time and space and comprise perceptual and cognitive</td>
<td>commitments and people, people's intention and capabilities.</td>
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<tr>
<td></td>
<td>affordance that collectively form the network for particular goal sets.</td>
<td></td>
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<tr>
<td>Barron (2006)</td>
<td>Learning ecology is viewed from a positivist point of view and defines it</td>
<td>Connections, relationships and interactions between activities and</td>
</tr>
<tr>
<td></td>
<td>as a combination of a unique configuration of activities, material</td>
<td>material resources.</td>
</tr>
<tr>
<td></td>
<td>resources, relationships, and the interactions that emerge from them.</td>
<td></td>
</tr>
<tr>
<td>Siemens (2007)</td>
<td>Learning ecology is viewed as the space in which learning occurs.</td>
<td>Adaptive, dynamic and responsive, chaotic, self-organising and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>individually directed, alive, diverse, structured informality and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>emerging space.</td>
</tr>
<tr>
<td>Eraut (2009)</td>
<td>Learning ecology is viewed from a capabilities point of view, which is</td>
<td>Capabilities comprise complex sets of skills, qualities and attitudes,</td>
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<td></td>
<td>mediated by judging the appropriateness of what has been done, how well</td>
<td>forming new relationships and resources.</td>
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<td>it has been done and effectiveness in achieving goals.</td>
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</table>

In both educational buildings, level 2 BIM has been used from the beginning of the project for coordination, collaboration, clash detection and clear scheduling. The cases were chosen because of their compliance with level 2 BIM requirements and the access to day to day activities and tasks, decision making meetings, individual interviews and project documents. The data within the case studies were obtained through observations,
semi-structured interviews and project documents between August 2016 and March 2017. The formal interviews were conducted with the project members who were using BIM in their projects. The interview protocol focused on the interviewees’ role and understanding of BIM, issues faced while working with BIM and their learning experience in BIM construction projects. This allows the researcher to explore the key aspects related to learning ecology. The following section outlines the findings on the aspects of the learning ecology in BIM construction projects.

**FINDINGS AND DISCUSSION**

It is crucial to maintain connections between entities within the project to ensure successful implementation of BIM. This study has therefore used an ecological approach to understand the holistic view of the connections in these selected BIM construction projects. The following five features identified in BIM learning environments show the aspects of learning ecology within the projects. The findings show learning within these BIM projects are mainly driven by digital technologies.

**Common space for learning**

BIM implementation in both the case studies has created a common space for people to learn and engage within the construction projects. This is in line with Siemens' (2007) learning ecology view, where space for learning is considered as the main concept. Supporting this, Barab and Roth (2006), from an affordance network perspective, also agree that learning ecology is an extension of time and space, which includes perceptual and cognitive affordance collectively to achieve the set goals. Data collected from the case studies indicate that the common space created in the BIM construction projects is centred on the federated BIM model which is accessed by key project team members.

For example, in case study one cable trays coming down from the acoustic panels were identified as an issue in the BIM model. In response to this problem, the BIM coordinator identified all the team members involved in the issue and invited them to a design meeting. In the meeting all the related issues, such as the materials used for the cable trays and the way they were constructed, were discussed with the use of federated model. After the discussion, the architect decided to change the cable tray design and add boxing to it to avoid clashes with other building elements. Even though people learned in this project through sharing their experience and interacting with each other, the federated BIM model motivated the BIM project team to learn within a common space, in this case the design meeting, to resolve the problem. Similarly, in case study two pipes running behind the toilet cubicles went directly through the wall, which created a clash between the wall and pipeline, which was identified in the BIM model. To solve this problem, a team including the contractor, M&E consultant, BIM coordinator and architect arranged an informal meeting to discuss alternative ways of positioning the pipelines. In this situation, active participation with the use of the federated BIM model allowed team members to interact and learn in the projects. Overall, these observations show adaptive and responsive features of learning ecology through the connected common space. These observations show that a connected common space created through the use of BIM has acted as a platform for learning to be delivered, applied, created, communicated and used for decision making.

**Self-adaptive and self-organised learning network**

Observations and interviews in the case studies indicated that self-adaptive and self-organised learning networks within the projects helped to handle continual changes and newness. BIM construction projects are typically complex and dynamic due to the changing BIM model, unpredicted components and diverse stakeholders. According to
Salehie and Tahvildari (2012), self-adaptive systems are about evaluating one’s own behaviour and changing performance when the evaluation indicates that it is not achieving what the software is intended to do, or when better functionality is possible. On the other hand, self-organisation is a process where a system reproduces with its own logic and components. Brown (2000), Zimmerman (2000) and Siemens (2007) believe that self-adaptation and self-organisation are key aspects of learning ecology which create and manage unpredicted situations. In these projects, the nature of self-adaptive and self-organised learning is observed in the structural relationships and search for alternative approaches, and through feedback loops, management of unplanned activities and interaction between the project participants regarding decision making.

For example, in case study one the project used Naviswork for clash detection and then self-adopted the BIM 360 field because the collaborative project team believed it was more accurate and beneficial in terms of maintaining the level of detail compared to Naviswork. This situation shows that the learning environment itself, by identifying alternative ways of working, has self-adopted a suitable tool to maintain a high level of detail which is not usual in traditional construction projects. In another situation, in case study two, design conflict between a column and duct pipe was identified by the BIM coordinator in the clash detection process. In this situation the column was close to the steelwork, therefore the project team, after self-organising their learning through feedback from project team members and referring to several alternative ways in the BIM model, decided to remove the insulation. These findings from the case studies reveal that self-adaptive and self-organised learning networks in BIM construction projects are initiated and encouraged through digital technologies to connect people and allow them to evolve and adapt to constantly changing environments.

Open mind-set
In general, project team members remain in silos within construction projects and only focus on the work allocated to them. In contrast, several situations observed in BIM construction projects show that project team members are ready to accept and learn changes within the projects. Siemen (2007) concurs with this structure of allowing an ongoing diversity of openness with minimum control and refers to it as ‘structured informality’. For example, in case study one windows located upstairs were combined with blinding according to the architectural model. However, other members who attended the design meeting after analysing the centralised BIM model indicated that using separate blinding does not make any difference. The quantity surveyor from the contractor’s team also supported this view and mentioned that it was cost effective for the client to install the window without blinding. The effect of changes was visually explained to other team members in the BIM model. An open discussion then unanimously led to the decision to install the windows without blinding. These aspects of diversity and openness in structured formality in BIM construction projects are encouraged through people’s open mind-set and it they are developed and nurtured through individuals having trust in the feedback they receive from other team members. This aspect is crucial for managing multiple viewpoints and contradictory views from different people involved in the construction project.

Conversely, in some situations, due to different individual viewpoints and considering several factors at a time, people resist thinking openly, contradicting Siemens’ (2007) structured informality view, to solve issues in BIM projects. For example, a large duct underneath the stair core which was going out to the canal side was identified in the BIM model. After arguing about different views, such as changing cable trays, creating additional route for the pipes and shifting the cable trays, the project team members
ultimately created confusion in the decision making process. Therefore, rather than considering alternative ways, the project team immediately agreed with the change suggested by the BIM coordinator, which was to shift a cable tray to the right by 431mm. This situation illustrates that even though project team members are open minded about considering open and diverse options to resolve identified problems in BIM models, it is sometimes challenging to manage complex situations.

**Imposed multi-disciplinary learning**

Germain and Gitterman (1994) and Barab and Roth (2006) emphasise that the participation of people is one of the key features of learning ecology. Both projects selected for this study support this view, being formed of multidisciplinary teams with a group of the client's project team and the supply team members, consultants and specialist suppliers. It has been noticed that BIM construction projects have created opportunities for multidisciplinary learning, in which people learn each other’s trades and educate themselves from each other to perform the task better than before. Moreover, early involvement of this multi-disciplinary team, which is different from traditional construction projects, was beneficial to resolve the problems collectively and to share the risks, especially when a team member has not come across a similar issue or worked in a particular manner.

In case study one, the project team members were trying to make a room larger by using a panel with the different material. This situation in this BIM project was handled by gathering together all the project team members related to the problem to finalise the decision. During the meeting, team members discussed about suitable materials, dimensions and the maintenance of different panels, with the aid of a BIM model. After actively communicating and learning from each other, the team consulted a professional expert to make the final decision. Similarly, in case study two, low duct work below the ceiling was identified in the model at the design stage, so different options were discussed by the architect. On the other hand, alternative designs were also proposed by the structural engineer and the M&E consultant during the discussion. At the end, the team, after learning and understanding each other’s alternative ways, agreed with the design proposed by the structural engineer. Finally, the architect was instructed to remodel it. From these situations it is clear that the BIM technology adopted by the entire project team fostered multi-disciplinary learning to help complete each task successfully by making efficient decisions. This multidisciplinary learning imposed from the early stages of the project has helped to tackle the dynamic nature of the project through communicating with people and connecting with other components in the project, including maintaining trust and openness between the project team members.

**Infoxication**

One of the major challenges faced in both the case studies is that the people involved in the BIM construction projects were overloaded with information. According to Eraut (2009) and Barab and Roth (2006), learning ecology is about capabilities and affordance. They believe that what individuals/organisations bring into the project allows them to think, interact and perform. Therefore, information should not exceed needs. Observations from these projects indicate that information is overloaded into people through the volume of emails, models and project documents. Due to this, project team participants struggled to understand what was needed for the project and make effective decisions at the right time.

In case study one, information about floor boxes was shared with relevant project team members through a number of emails and project documents. However, these email
conversations and documents contained more information than was needed. This is evident from the building service manager’s statement in a design meeting: “we are not sure about what information to use...”. Similarly, in case study two the lighting specification kept on changing. Therefore, each time specification changes were made, project team members were loaded with information via emails and models. This caused confusion among the relevant team members regarding use of the correct information. Compared to traditional construction projects, BIM models include a high level of details and visualisation facilities, which allow people to think and analyse problems in depth. In many situations this has provided unwanted information to other team members. This shows the chaotic characteristic of BIM construction projects and emphasises that BIM is not always an easy solution as portrayed by several software vendors.

CONCLUSIONS

The construction industry has started to realise the importance of digitalisation and is going through a technology-led revolution in its move towards a new digital age. The findings from this study show the embedded aspects of learning ecology in BIM construction projects such as common spaces for learning, self-adaptive and self-organised learning networks, open mind-sets, imposed multidisciplinary learning and infoxication. The new digitalisation is mainly enabling connection between project entities. Common spaces for learning in BIM construction projects allow the people, resources and tools involved in the project to maintain connectivity between them. On the other hand, self-adaptive and self-organised learning networks in BIM projects enable the project team members to evolve and to be adaptive and responsive to the constantly changing environment. The structured informality observed through people’s open mind-sets in the BIM environment has promoted continuous learning and improved performance. On the other hand, connecting people and other entities in the project through imposed multi-disciplinary learning has helped to tackle the dynamic nature of the project. Therefore, to work in this new digital age with these new technologies, it is essential to embrace a learning ecological perspective. This transforms the learning environment into a connected self-adaptive system which could enhance people’s understanding of the project and improve the way people align with project goals.

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ORGANIZING FOR DIGITIZATION IN FIRMS: A MULTIPLE LEVEL PERSPECTIVE

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This paper explores how an established organization in the AEC industry is responding to radical, potentially disruptive, digital technologies. As the pace of digitization accelerates, so the ability of firms to adopt technologies effectively is becoming increasingly important. Evidence from other industries shows that radical technologies can create significant disruption in industry structures, institutions, and organizations. This paper draws on a multiple level, longitudinal analysis of the process followed by one incumbent firm in developing digital capabilities. Data covers a 15 year period and charts the implementation of BIM at institutional, organizational and user levels. Findings suggest that organizing for digitization in firms is a process involving these multiple levels and that alignment between them enables the adoption of technologies.

Keywords: digital technology, disruptive innovation, technological change, BIM

INTRODUCTION

The AEC industry has experienced substantial technological change in the last 50 years (Gann, 2000). As a number of recent reports have emphasised, the pace of technological change influencing the industry is accelerating substantially and coming from a diverse set of interdependent technologies (see for example ICE, 2017; Farmer, 2016; HM Government, 2015). While many other industries have also experienced rapid digitization, the AEC industry’s low profit margins and productivity rates make it ‘ripe for digitization’ (McKinsey, 2015). The process of digitization involves the transformation of:

…existing socio-technical structures [that were] previously mediated by non-digital artefacts or relationships into ones that are mediated by digitized artefacts and relationships with newly embedded digital capabilities (Yoo, Lyytinen, Boland, and Berente, 2010: 7).

Experience from other more highly digitized industries shows that established high-performing firms often fail in the face of radical technologies, such as those being adopted in the AEC industry (Christensen, 1997). Radical technologies can give rise to disruptive digital innovations that change existing industry architectures (Henderson and Clark, 1990). In the face of accelerating technological change that threatens to disrupt the AEC industry, how then are firms responding? The capability to use and implement technologies effectively is becoming a key competitive differentiator between firms and will determine whether technologies disrupt or sustain organizations and industry architectures (Christensen and Overdorf, 2000).

Scholars of technology and organizations have moved away from technologically deterministic views to place emphasis on the context of use (Orlikowski, 1996),

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recognising that the individual user is central in enacting technological change in organizations (Orlikowski, 1992). Recent studies adopting this perspective in the AEC industry find that the diffusion of digital innovations in firms is non-linear, influenced by changes in the innovation and firm context (Shibeika and Harty, 2015). The interplay between institutional actors, the socio-cognitive environment, and the market and production environment all influence the adoption and use of ICTs (Jacobsson, Linderoth, and Rowlinson, 2017). While these studies shed light on the critical issue of why firms are often unable to realise the benefits of technological change (Gann, 2000), the nature of the relationship between the factors influencing technological adoption in firms operating in the AEC industry remains unexplored, despite the growing importance of organizations developing such capabilities.

This paper addresses this gap by providing a multiple-level view of one firm’s efforts to adopt a new technology. It does so through longitudinal case of an established, firm’s adoption between 2000-2015 of Building Information Modelling. This data is presented at multiple, embedded levels - at institutional, firm and user levels - in order to explore the relationship between them. It contributes to a growing body of studies looking at the implementation of BIM in organizations (for example Jacobsson and Linderoth, 2010; Jacobsson, Linderoth, and Rowlinson, 2017; Linderoth, 2017). This paper proceeds as follows. It reviews digitization in the AEC industry, and the application adoption of these technologies or how they are used in context. It then presents the case study and discusses the findings from this case. The findings add support to studies showing the importance of the institutional environment in influencing technological implementation in firms. It extends these studies by unpacking the nature of this relationship, suggesting that mutually constitutive relationship exists between institution, firm and users whereby they change and are changed by each other.

**Digitization of the AEC industry**

The products and production of the built environment have experienced extensive technological change since the mid-1900s (Gann, 2000). On one hand, technology has extended the art of the possible: from Sullivan’s Chicago skyscrapers of the late 19th century, made realisable because of the availability of steel frames and elevator technology, to the complex infrastructure and building forms of the present day. On the other, the production of the built environment has also experienced a transition along the innovation spectrum, from incremental to more radical digital innovations, a term used in this paper following Slaughter’s definition of an innovation as the application of a new idea (1998).

From the transition in the 1980s from paper-based drawing to Computer Aided Drafting (CAD) to create visual representations, to 3D CAD applications (Gann, 2000), to the ongoing adoption of BIM technologies, like other industries and consumers the AEC industry has experienced substantial technological change in the last 50 years. Today the industry is moving towards radical, and potentially disruptive digital technologies. This is reflected in a number of industry reports published in recent years which identify additive manufacturing, artificial intelligence and robotics, automation of knowledge work, advanced materials, advanced manufacturing, Internet of Things; big data and complex analytics, virtual and augmented reality, advanced applications of BIM, mobile devices, energy storage and renewable energy and Blockchain as digital technologies driving the process of digitization.

Building Information Modeling (BIM) is the latest group of technologies to be introduced to the construction industry. Drawing on parametric modelling techniques widely used in
other industries, the use of these technologies enables an accurate digital model to be developed. Information is embedded in every object in the model, thus the digital models is commonly described as a “database with drawings”. This common model forms a knowledge repository or manual of the built asset and can be used for its entire life cycle, after maintenance for operation purposes.

**Technologies in use**

While the consequences of digitization in the AEC are not only positive, indeed the recent move to adopt BIM has revealed its ‘dark side’ (Davies and Harty, 2012) and current debates abound around cyber security risks presented in the digital built environment, the accelerating rate of digitization appears inevitable. Positively the emergence of novel digital technologies present opportunities to create digital innovations, created through the application of technologies (Slaughter, 1998). However the application of these technologies has often proved a challenge for the AEC industry and its firms, and to realize the promised benefits of technological change. Early research notes that the outcome of firms’ efforts to implement ICTs was far removed from the benefits envisaged (Salter and Gann, 2003). A comparative study between the adoption of CAD and virtual reality technologies found that the lack of end user involvement in firms’ implementation processes hinders take up (Whyte and Bouchlaghem, 2002). More recent studies of BIM adoption develop these findings. BIM is viewed as an “unbounded innovation” requiring collaboration between many firms for implementation to be successful (Harty, 2005), its use demands, rather than creates, greater collaboration between its users (Dainty et al., 2017).

In an industry that continues to struggle with collaborative working, this is a key challenge in using BIM and a major contributor to the industry’s sluggish rate of adoption. Institutional and industry setting is vital in considering BIM use (Jacobsson et al., 2017). Actors’ sensemaking is central to their use of BIM, which is in term highly influenced by the institutional environment (Linderoth, 2017). Recent theoretical papers have argued that the adoption and use of ICT in the industry is a result of the interplay of related factors including the socio-cognitive environment, institutional actors and the market and production environment, suggesting that the outcomes of the interplay between these factors can be aligned or misaligned with the ICT (Jacobsson et al., 2017). This paper provides an empirical study of this theory; study the adoption of a potentially disruptive technology by an incumbent organization in the AEC at multiple levels.

**METHOD**

In keeping with the aim of this paper, the data presented is drawn from a single, embedded case study, suitable for developing a detailed understanding of a process of change (Van De Ven and Poole, 1995). Through this research method “thick descriptions” (Geertz, 1994) were generated, strengthening the transferability and reliability of this study, thus addressing a potential weakness of single case study designs (Lincoln and Guba, 1985). The selection of the case was crucial and driven by the ability to “shed empirical light about theoretical concepts or principles” (Yin, 2009: 40). The case study firm presented in this paper, referred to henceforth by the pseudonym Design Partnership, is a large and mature multidisciplinary design consultancy. This leadership position is apparent in the considerable size of the firm and the breadth of its work. Because of this, the firm has significant influence across the construction industry and its supply chain.
Design Partnership has a strong reputation for creativity which is apparent in its innovative approach to using digital technologies at organisational and project level (see for example Criscuolo, Salter, and Sheehan, 2007). This study was developed in collaboration with Design Partnership meaning data were collected through deep access to the firm. The author was able to collect data on the process of BIM implementation at Design Partnership over a 15-month period, between July 2013 and September 2014. During this time, she was embedded in the organisation as a researcher, spending one or two days per week in Design Partnership’s UK head office. In order to build a longitudinal view of the process of BIM implementation at Design Partnership over time, she collected contemporaneous and retrospective data. In collecting retrospective data, she maintained a critical awareness of the validity and accuracy of the data gathered. The recollections of informants regarding BIM implementation gathered during semi-structured interviews, was particularly vulnerable to “informant inaccuracy” (Bernard, Killworth, Kronenfeld and Sailor, 1984).

Such informant inaccuracy potentially has significant detrimental effects on the quality of data collected (Bernard et al., 1984). In order to minimize the impact of potential inaccuracy, she collected data from a number of sources, following Pettigrew’s advice for conducting longitudinal studies using retrospective data (1990). Thus she achieved data triangulation and increased the credibility of the case (Lincoln and Guba, 1985). Data were collected using qualitative research techniques and drawn from a number of sources including interviews, archived information, internal meetings seminars and regularly updated field notes, as shown in Table 1. Semi-structured interviews form the central source of data collection. Interviewees were purposefully drawn from a variety of professional disciplines. They came from a range of roles and seniority levels in the firm. Additional external data were collected to correlate Design Partnership’s implementation process with external events. The sources of this data included semi structured interviews with 9 external individuals instrumental in setting institutional policy, and regulatory standards for BIM implementation, external media, websites and relevant conferences.

<table>
<thead>
<tr>
<th>Number of interviews</th>
<th>Meetings / seminars</th>
<th>Archived information</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Partnership</strong></td>
<td>34</td>
<td>Launch of BIM strategy in UK</td>
<td>Background reports</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Meetings of BIM strategy team</td>
<td>DP journal.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Others</td>
</tr>
<tr>
<td>Industry</td>
<td>9</td>
<td>Conferences</td>
<td>Regular field notes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External media and website</td>
<td>External reports and academic papers</td>
</tr>
<tr>
<td>Other firms</td>
<td>11</td>
<td>Websites</td>
<td>Internal documents</td>
</tr>
</tbody>
</table>

**Table 1: Data sources**

RESULTS

Founded 70 years ago, Design Partnership employs some 11000 staff working from 38 countries. It is a multidisciplinary professional services firm, employing staff from various backgrounds whose work involves high levels of collaboration across disciplines, professions and organisations. It is sufficiently flexible to meet the demands of dynamic environments and has the capabilities needed to create complex products. It developed these capabilities through its highly skilled and innovative workforce. The institutional
and organizational context for considering BIM implementation at Design Partnership is illustrated in Figure 1. This presents an overview of technology implementation as a long-term process at Design Partnership, from 2000 until 2015. Three temporal stages in the implementation process are evident which were identified through significant events that serve as temporal breakpoints. The time period of the longitudinal study covers a significant period the implementation of BIM across the UK and global construction industry.

**Phase 1: Islands of automation**

The first phase identified in this study starts in 2000 and extends to 2005. It marks the initial adoption of BIM in the built environment industry and at Design Partnership. Externally awareness in the potential of BIM was emerging. In 2000, BIM was being used on real world projects (Grilo and Jardim-Goncalves, 2010). Government funded research projects explored the use of collaborative digital technologies in live projects. These research projects demonstrated the potential that BIM held for improving the efficiency of work and quality of output in the UK built environment industry. However, they also hinted at the scale of the disruption that BIM-enabled working would bring to the industry. As well as learning to use new and complex software, behaviour, cultures, standards and processes would need changing.

![Figure 1: Three phases of implementation of BIM at Design Partnership and industry](image)

Before 2000, Design Partnership had adopted new technologies with minimal organizational intervention. For example, the transition from paper based to digital drafting, using Computer Aided Drawing, was achieved through evolutionary methods. Based on this past experience, the firm initially took a similarly hands-off strategy to implementing BIM. It employed a bottom up approach that foresaw individual BIM
enthusiasts driving BIM implementation across Design Partnership. As a member of the current BIM implementation team recalls:

We had an evolution about 10 years ago to 3D drawing but it was still only physical objects that we were looking at. So it was a relatively easy transition and one born out of necessity: if you were doing something really complicated it made sense to do it in 3D. We thought that the evolution to BIM was going to be similar.

During this period, use of BIM in the firm remained resolutely the domain of the technological enthusiasts. The dominant perception of BIM in Design Partnership was that BIM is an irrelevance: as one senior business leader at the firm explained, “most people felt that BIM was nothing to do with what Design Partnership does”. During this initial phase, a lack of engagement amongst leaders and practitioners in Design Partnership led to minimal progress in implementing BIM. Without the organizational and institutional structures in place, the isolated innovations of technological enthusiasts working in islands of automation were unable to advance technological implementation. The hands off approach adopted by leadership proved insufficient to progress implementation of BIM.

Phase 2: Learning to implement

During Phase 2 (2005-2013) implementation of BIM in Design Partnership remained patchy, limited to “pockets of people who could see the light” - a growing group of practitioners who began using BIM in their everyday work. During this time, BIM attracted significant institutional attention as policy makers, business and industry leaders realized its potential but also the challenges that adoption presented and the scale of change needed. Early in this phase the industry experienced the impact of a major economic recession. Understandably, BIM implementation took a backseat during this time, but attracted attention once again with the publication of Government’s 2011 construction strategy. In it, Government uses its position as procurer and client of 40% of the Built Environment industry to drive through BIM adoption by mandating its use on public sector projects from 2016. It also draws attention to the cost and time savings that could be generated through the use of BIM. In an industry struggling with profitability and efficiency, this was an attractive proposition. The effects of this mandate can be seen at institutional level.

At Design Partnership, technology was permeating almost all aspects of work. Interest grew in the use of new technologies and their potential to aid design processes and outputs. Designers at the firm were seeing opportunities to begin using BIM in their work. External studies provide a detailed accounts of Design Partnership’s development of an electronic knowledge management system, or an expert ‘yellow pages’ (Criscuolo, Salter and Sheehan, 2007). Dodgson et al’s study the use of simulation technologies in Design Partnership, and show how these technologies can foster innovation in inter organizational projects (Dodgson et al., 2007). The proliferation of technology at work made the challenges of adopting BIM more apparent. It was clear it required more deliberate organizational intervention than previous technological change and involved changes reaching far beyond the IT department. As a Director in Design Partnership explained, the magnitude of the change and level of disruption to the organization meant that:

Almost every member of staff needs to be told what it [BIM] means and that it’s going to change their job description - it is that disruptive.
Phase 3: Infrastructure of support

The third phase of BIM implementation at Design Partnership occurs between 2013 and 2015. During this time, BIM implementation at the firm aligned with institutional changes. The Government mandate was laid out in the GCS report in 2010. Institutions began publishing policies and standards that were formed during Phase 2, facilitating the use of BIM. Standards were introduced with the publications of documents such as PAS 1192-2 that laid out the specific requirements for achieving Level 2 BIM. The professional institutions aligned their routines with the use of BIM: for example, in 2013 the Royal Institute of British Architects published a new Plan of Works to accommodate BIM-working in its project stages; the Construction Industry Council also published similar guidance in 2013.

Reflecting this, a step change occurred at Design Partnership in its approach to implementing BIM. Its Chairman launched its current strategy at the firm’s AGM, indicating clearly that the implementation of BIM had become a key strategic issue for the business. The objective of the strategy is to standardize BIM across Design Partnership with all work being routinely undertaken in a “BIM fashion” by 2014. This strategic shift indicated that BIM was no longer the domain of a few technical enthusiasts but involved every member of staff in the organization. A range of mechanisms provided this infrastructure of support.

For example, users were provided with information and guidance, explaining the abundant terminology that surrounds BIM and detailing guidance in using BIM. Focused training was delivered that caters for different disciplines and levels of seniority. Existing organizational routines were adapted to incorporate BIM working, for example virtual design reviews are added into standard project reviews; extensive guidelines are available on producing BIM execution plans as part of the briefing process. Measurable targets and being established that link to individual and business performance and reward. Targets include the number of projects with BIM execution plans and virtual design reviews, and rates of staff training. A survey has been developed, based on the BIM Project Execution Planning Guide developed by Pennsylvania State University’s Computer Integrated Construction Research Group, which measures various dimensions of BIM use on projects. Human Resources are developing individual performance measures of BIM relating to different job functions, production, management and leadership, which will be used for future recruitment and performances reviews.

DISCUSSION

This study presents a detailed view of how an established firm in the AEC industry responds to technological change and implements new technologies in its everyday work. Three phases show the mutually constitutive relationship between users, the firm, and institutions operating in the AEC industry. This finding builds upon past research that establishes that diffusion of innovation in firms is influenced by changes in the innovation and firm context (Shibeika and Harty, 2015) by demonstrating how the relationship between institutional, firm and users influences implementation efforts. Use of technology is enabled by alignment between these levels, and constrained when they are misaligned. For example, during Phase 1 a few technological enthusiasts in Design Partnership were using BIM. The firm invested limited resources in implementation, opting instead to take a hands-off approach and rely on evolutionary change to effect implementation.
During this time use of BIM is isolated, confined to individual BIM enthusiasts. Phase 2 is a transitory stage, during which time Design Partnership learns about BIM. During Phase 3, alignment is created between institutions, the firm and users of BIM in Design Partnership. An infrastructure of support is created which affords widespread use of BIM technologies in the firm. In this phase, adoption of BIM is a key business issue for Design Partnership, as shown by strong senior leadership support, investment and strategic direction. The firm acts as a filter between users of BIM and the wider ecology, influencing and responding to changes at both levels. It achieves this by offering targeted training that acknowledges the variety of users, by diffusing information and by increasing involvement with industry and institutional bodies. Attempts are made by Design Partnership to open discussions between producers of BIM software and its practitioners. During Phase 3 users of BIM are becoming increasingly innovative and confident in using BIM. Their skills in using BIM are growing, both technically and with regards to the organizational routines needed to use it in everyday work. Learning is cyclical and often extends beyond organizational boundaries.

An important limitation of this study relates to its research design. While the single case study used here was suitable for the study’s topic and theoretical approach, single cases have limited generalizability (Yin 2009). This is addressed by playing close attention on increasing the transferability of the study by generating thick descriptions (Lincoln and Guba, 1985) and through careful selection of the case. However this limitation does raise a number of possibilities for future research. For example, how does a smaller, less influential firm organize for digitization?

Whyte argues that the peripheral position of SMEs disadvantages them in the adoption process (2013). Similarly, Dainty and colleagues argue in their recent paper that existing SMEs have been disadvantaged in the recent adoption of BIM as they do not have the resources to dedicate to technological change (2017). As this study shows that the process of adopting new technologies involves firms responding to and affecting external change and support internal practices, large incumbents have the resources and often the influence to affect wider institutional change and are able to devote considerable management resources to internal implementation efforts. Is this situation changed as digitization brings more radical technologies? Are SMEs better placed to respond to future technological change?

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CLIENTS AND INNOVATION
Public Procurement for Innovation (PPI) is expected to leverage demand-side innovation in sectors such as transport and infrastructure. However, to make that happen, public clients must be willing to apply PPI. How does a public client of the construction industry come to choose for, develop and apply particular PPI procurement approaches? To explore the rationale for PPI from a public client's perspective, the reasoning behind a client's first application of a PPI-like procurement system is reconstructed in a case study. Assuming that the particular features of this system ultimately are related to overall strategy, two major concepts are used to guide this reconstruction: strategic alignment and procedural rationality. The results show how in this case PPI is triggered by, and across multiple levels of strategy is aligned with, ministerial strategy. An additional gain of this study is that it suggests how strategic alignment between a particular procurement system and overall organizational strategy could be achieved in a deliberate manner. The client is commonly viewed as an important driver for innovation. Observing that construction management literature on PPI is limited, the creation of an in-depth insight in a public client's rationale for PPI contributes to the further understanding of the client's role in innovation.

Keywords: procedural rationality, public procurement for innovation, strategic alignment

INTRODUCTION

According to public policy literature, Public Procurement for Innovation (PPI) is expected to leverage demand-side innovation in sectors such as transport and infrastructure (Edler and Georgiou, 2007). However, while the European Commission has long since been stimulating the use of innovation procurement by a range of supporting policy initiatives (see European Commission (2014) for an overview), it still observes a deficiency of innovation procurement applications. This seems to go for the construction industry as well. This study aims to create an understanding of how public clients in the construction industry come to apply PPI. Whereas literature sums up public policy rationales for applying PCP, such as economic growth, new employment, new firms, reduction of market failures and increase of quality of public services (Rigby 2016), an in-depth insight in the client's rationale is lacking.

Arguably, innovation is not a goal in itself for these clients. Instead, PPI must fit with the client's procurement strategy and higher level strategies. Therefore, application of PPI presupposes that a client in a given situation a) recognizes PPI as a relevant procurement option, b) prefers PPI over other options, c) generates a tender file to operationalize the PPI concept into a ready-for-use procurement system. So how does a public client of the construction industry come to choose for, develop and apply a particular form of PPI?

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This paper reports on an exploratory case study performed at ProRail, a major client of the construction industry in the Netherlands. Recently, ProRail has challenged the market to come up with innovative solutions that increase the safety level of passively protected level crossings.

It is ProRail's first application of a PPI-like procurement system. The study reconstructs the client’s rationale for applying PPI. This is conceptually approached by combining the theoretical concepts of strategic alignment (Baier, Hartmann, and Moser, 2008) and procedural rationality (Simon 1978). Assuming that in this case PPI did fit with higher level strategies, reconstruction of strategic alignment across multiple levels of strategy is expected to yield an in-depth insight into the client’s rationale. Procedural rationality is brought in to account for the possibility that some of this rationale may be difficult to uncover.

Both in construction management and public policy literature, it has been observed that the client is an important driver of innovation (Bygballe and Ingemansson, 2014). In the case of PPI, evidently the public client is a crucial actor, since application of PPI is dependent on action by the client. However, whereas construction management literature on PPI is scarce, a public construction client's perspective on PPI seems altogether absent. Therefore, the insights presented in this paper are expected to contribute to filling this gap. Also, the understanding of why a client of the construction industry would choose to apply PPI is expected to help practitioners consider this option more deliberately in future.

Since the case study concerns a particular form of PPI, which can be identified as pre-commercial procurement (PCP), the next section first shortly explains how PPI and PCP are understood here. The paper then moves on to the conceptual framework and research methodology as applied in this study. Next, the case is shortly described and followed up by case analyses and results. The discussion and conclusion sections shortly highlight the theoretical and practical implications of this study.

PPI AND PCP

In general, PPI is contrasted with 'regular procurement' where public sector organisations place orders for 'of-the-shelf' products. PPI has been associated with instances where public agencies act to purchase a product-service, good or system that does not exist at the time but could be developed within a reasonable period, in the sense that it requires innovative work (Uyarra et al, 2014). Therefore, in this paper PPI is used as an umbrella term to refer to an array of procurement systems targeted at innovation.

However, confusingly, PPI may also be used to denote a particular procurement system. In that sense, PPI is distinguished from Pre-commercial Procurement (PCP). While both target innovative products and services for which further R&D needs to be done, for PCP the commercial development phase is out of scope (Edler and Georghiou, 2007). The procurement system of this case can be identified as a PCP.

According to literature, in general PCP practices are managed in three steps (Edquist and Zabala-Iturriagagoitia, 2015; European Commission 2007):

1. Solution exploration phase (selection of offers from competing suppliers).
2. Prototyping phase (simultaneous solution development by the selected suppliers).
3. Testing phase (solution validation through field tests. At least two suppliers remain to ensure future competition).
Reconstructing a Public Client's First Application of Innovation

If a PCP is followed up by a regular procurement procedure, then the combination of the two overlaps with the phases of the general PPI process. Also, if further development is required, PCP may be followed by a PPI procedure instead of regular procurement. For these reasons, in this paper PCP is considered as a form of PPI.

CONCEPTUAL FRAMEWORK

To achieve an understanding of a single client's rationale for PPI, this study creates a reconstruction of the reasoning that apparently has taken place. This reconstruction is guided by two major theoretical concepts: strategic alignment and procedural rationality. In addition, two minor concepts are introduced to describe the public client’s procurement context: the procurement system selection and development processes.

Strategic Alignment

Literature holds that alignment between strategic goals and procurement practices is vital for achieving performance (Baier et al., 2008; Zimmermann and Foerstl, 2014). Alignment has been described as the degree to which priorities on strategic stances are consistent across different organizational levels (Andrews et al., 2012). Studies on alignment have mainly been of a quantitative nature, assessing alignment as a fit between particular constructs (e.g. Baier et al., 2008).

Instead, this study assumes that strategic alignment can be articulated in the form of means-and-ends relations, just like a causal map may represent a strategic plan (Bryson et al., 2004). Literature suggests to expect procurement strategies on multiple organisational levels (Hesping and Schiele, 2015). Therefore, the rationale behind the application of any procurement system is expected to be related to higher level procurement strategies, functional strategies, the public client's strategic goals and, ultimately, governmental policy goals. This implies that the client’s rationale can be viewed as a chain of reasons across multiple level of strategies.

Strategic alignment also includes decision making with regards to competitive priorities. These are managerial objectives, such as cost and quality that may be set on multiple organisational levels and for which simultaneous pursuit inherently implies making trade-offs (Baier et al., 2008). In this paper, competitive priorities are interpreted as trade-off decisions based on certain reasons.

Procedural Rationality

It is widely held in the literature that procedural rationality improves decision making quality (Kaufmann et al., 2012). Procedural rationality is defined as the extent to which the decision process involves the collection of information relevant to this decision and the reliance upon analysis of this information in making the choice (Dean and Sharfman, 1996). In this study, it is assumed that the explication of reasoning in strategy formation processes increases the level of procedural rationality.

Selection and Development Process

According to construction management literature, clients run selection processes that result in the application of particular procurement systems (Love et al., 2012). The term ‘procurement system’ only represents a concept. To operationalize the concept into a ready-for-use procurement system, public clients need to compose a set of tender documents. Moreover, to execute the procurement process, several subsystems, methods and tools are used, such as prequalification systems, contract award evaluation methods and past performance measurement tools.
For as far as these subsystems, methods and tools are selected out of a client's current portfolio (i.e. the set of procurement components released for use), the procurement system is only composed, not developed. However, if clients create new or bespoke procurement components, then a development process has been carried out as an adjunct to the selection process. The distinction between systems, methods and tools implies that this development process is not necessarily restricted to ‘contract design’ (Argyres and Mayer, 2007) only.

In conclusion, a client’s first application of a procurement system suggests that the client has run both the selection process (conclusion: no appropriate procurement system available in the portfolio) and the development process (result: new documents, methods and/or systems created). The reconstruction of a chain of reasoning should also account for these processes. However, since scholars point out that, in practice, these processes may be run intuitively and subjectively (Ballesteros-Pérez et al., 2015; Love et al., 2008), it may be expected that parts of this chain are not explicated (i.e. have remained at a low level of procedural rationality).

In conclusion, strategic alignment is interpreted here as the degree to which reasoning across multiple levels of strategy forms a coherent chain of choices in the form of trade-offs. This chain ultimately relates strategic goals to procurement system design. Similar to causal mapping, alignment implies that one can logically ‘ladder up and down’ (Bryson et al., 2004: 66) the hierarchy of reasons.

**RESEARCH APPROACH**

The exploratory character of the research question implies applying a case study approach (Yin 2014). It was assumed that a first-time application of PPI would require the public client to consider its rationale deliberately. If so, this would increase the chances of achieving a reconstruction. Therefore, a case was selected in which PPI is an innovation to the client's procurement practices.

**Sources of Information**

The client's reasoning is reconstructed by researching documentation, attending presentations on the project and interviewing key players in the project team (e.g. tender manager). The documentation included internal documents like the project plan, the contracting plan and the tender file, but also external documents (e.g. minister's report to the parliament) and websites reporting on the case (e.g. ministry's procurement expertise centre, national media). Data is identified as 'reasoning' if it explains why certain choices are made. For instance, where the PCP design involves an information session (choice), the argument that this 'session will increase the participant's understanding of the client's needs' is viewed as reasoning.

**Observing Implicit and Explicit Reasoning**

It was expected upfront that not all reasoning would be retrieved from documents only. Also, the retrieved reasoning would probably not automatically constitute a logically complete chain of reasons. Therefore, reasoning is labelled explicit if the reasoning is documented and logically connects a lower level of strategy to a higher level (completed reasoning, written out in project documents). Implicit reasoning is identified by the researcher by filling the gaps of the conceptual framework. This is done by checking the chain of means-and-ends on missing links (non-documentated or incomplete reasoning, retrieved by interviews or researcher's deduction).
CASE DESCRIPTION

Level crossing safety is a crucial issue for railway operators and infrastructure managers. Each year hundreds of fatal accidents at level crossings occur across Europe, which accounts for one third of all rail fatalities and 1.2% of all road deaths (Tey et al., 2011). In general, level crossings are either protected by active or passive systems. Active crossings are protected by automated warning systems (flashing light, boom barrier etc.). Passive crossings only provide a stationary sign, requiring people to stop and look left and right for train traffic.

In 2016, the Netherlands’ Ministry of Infrastructure and Environment started a program to target the passive crossings accident rate. The ministry formulated a twofold strategy. Firstly, the number of passive crossings is to be further reduced by removal or substitution by active crossings or overpass junctions. Secondly, because of budget restraints, innovative solutions to increase the safety of extant passive crossings is to be stimulated. Based on the philosophy that testing of concepts speeds up innovation ('from talking to testing'), the ministry defined a time frame for the testing of concepts.

The ministry commissioned ProRail, the public agency responsible for the railway infrastructure in the Netherlands, to carry out the program. Although ProRail maintains a broad portfolio of procurement systems, it was decided not to make use of any of these, but to develop a new system instead. The development process resulted in a three stage procedure called 'Proeftuin Nabo', which translates as 'experimental field for passive crossings'. The goal of this procedure was to come to ‘cost-effective (innovative) solutions that increase safety of present passive crossings’.

When writing this paper, the testing phase was not completely finalized yet. However, the procedure was already evaluated positively by its participants, ProRail and stakeholders and received both governmental and national media attention.

CASE ANALYSIS

According to the conceptual framework, the reconstruction of the rationale should result in the presentation of one integral hierarchy of reasons. However, because of page size limitations, this section presents the result in two parts: the rationale for 1) choosing to develop a new procurement system and 2) the design of that system. The first part represents the hierarchy of top level strategy down to the selection process. The second part represents the development process.

1. PCP Choice Rationale

Table 1 presents a summary of the reconstructed rationale. The reasoning (first column) illustrates the relationships between separate rows. The columns 'source' and 'organisation' indicate the primary document in which a specific part of reasoning was found and the level at which it has been formulated respectively. The elements marked * in the table are added by the researchers in order to fill up the gaps revealed by applying the conceptual framework.

2. PCP Design Rationale

Table 2 summarizes the rationale behind the PCP design in terms of the major design choices (first column), and the corresponding reasoning (second column) and trade-offs (third column).
Table 1: Rationale for PCP

<table>
<thead>
<tr>
<th>Reconstructed reasoning (* marks implicit reasoning)</th>
<th>Source</th>
<th>Organisation</th>
<th>Trade-off in competitive priorities (resource allocation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway safety (including level crossing safety) is a strategic goal</td>
<td>Ministry policy</td>
<td>Ministry</td>
<td>*Other strategic goals in transport sector</td>
</tr>
<tr>
<td>While in many respects safety levels are increasing, passive crossing (PC) safety is lagging behind. Create programme to target this problem.</td>
<td>Ministry program, contract plan</td>
<td>Ministry</td>
<td>*PC safety issues vs other railway safety issues</td>
</tr>
<tr>
<td>Given that programme budget is insufficient for applying conventional solutions at all PC's, it is worthwhile to allocate part of budget for innovative supply side solutions.</td>
<td>Ministry program, contract plan</td>
<td>Ministry</td>
<td>Conventional PC reduction vs chance of coming to new cost effective PC safety measures</td>
</tr>
<tr>
<td>Commission ProRail to carry out innovation program with a 'from talking to testing philosophy'</td>
<td>Contract plan</td>
<td>Ministry</td>
<td>*ProRail assignment vs other options</td>
</tr>
<tr>
<td>*Railway safety is a strategic goal</td>
<td>ProRail strategy</td>
<td>ProRail</td>
<td>*Other strategic goals (reliable, punchal and sustainable railways)</td>
</tr>
<tr>
<td>PC safety is too complex and risks are too high to tender for innovations directly. Apply a step-by-step market approach instead:</td>
<td>Contract plan</td>
<td>ProRail sourcing team</td>
<td>Risks related to single tender vs multiple tenders</td>
</tr>
<tr>
<td>*Develop a new procurement system, since no alternative in the current portfolio is appropriate</td>
<td>(research)</td>
<td>ProRail sourcing team</td>
<td>*Development process risks vs chance of creating successful approach</td>
</tr>
<tr>
<td>*Design procurement system by discussing PR of three procurement models</td>
<td>(research)</td>
<td>ProRail sourcing team</td>
<td>*Start from scratch vs select and customize model developed elsewhere</td>
</tr>
</tbody>
</table>

DISCUSSION

This study started off by questioning how a public client of the construction industry comes to choose for, develop and apply PPI. The results unveil how this client’s first application of PPI can be traced back to the ministry’s twofold strategy of continuing passive crossing reduction while also allocating part of budget to innovation. The ministry did not dictate how to achieve innovation. However, its basic philosophy of going 'from talking to testing' seems to have been a decisive factor. As far as could be retrieved, it was this philosophy that led the sourcing team to the conclusion that developing a new procurement system targeted at gathering, developing and testing innovative concepts - and to stop there for the moment - would be the best way to carry out the assignment.

Interestingly, it appears that the European Commission’s innovation procurement policy reinforcement measures (European Commission, 2014) have had no (direct) influence. Considering that the ministry had not assigned ProRail to run a PCP either, this case qualifies as an example of the ‘autonomous bottom up’ approach to PCP, rather than the ‘top-down agency model’ (Rigby 2016). However, this qualification remains disputable. One the one hand, the results show that this PCP fits with the client’s strategic goals. One the other, the budget and philosophy for innovation came from the ministry.
Table 2: Rationale behind PCP design

<table>
<thead>
<tr>
<th>PCP design</th>
<th>Reconstructed reasoning (* marks implicit reasoning)</th>
<th>Competitive priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perform marketing research (desk research, consultation of similar public clients, market consultation, concept design)</td>
<td>1. To enable better formulation of the demand. 2. To identify potential suppliers. 3. To inspire and quickly inform the PCP participants on relevant current state-of-art-technology</td>
<td>*Staff resources vs expected level of PCP effectiveness and risks</td>
</tr>
<tr>
<td>Narrow down innovation area (search for solutions based on proven technology in two categories: 1. Alert road users to PC, 2. Alert road users to approaching train and include physical barrier)</td>
<td>Category 1: Innovations are expected to be cheaper, quicker to test and implement.</td>
<td>Solution feasibility vs scope of innovation opportunities</td>
</tr>
<tr>
<td>*Develop concise and easy-to-understand PCP tender documentation</td>
<td>*Make PCP procedure accessible to non-experienced tender participants</td>
<td>*Staff resources vs PCP effectiveness/risks</td>
</tr>
<tr>
<td>Ruta PCP phase 1: concept selection</td>
<td>Increase market attention beyond the 'usual suspects'</td>
<td>*Staff resources vs level of publicity</td>
</tr>
<tr>
<td>a. Attract attention in multiple ways (Next to TED also other forms of communication)</td>
<td>Increase participants' understanding of client's needs</td>
<td>*Staff resources vs PCP effectiveness/risks</td>
</tr>
<tr>
<td>b. Information session</td>
<td>1. Create a set of solutions, since no single solution will suffice for all PCs. 2. Select multiple participants to maintain post-PCP competition</td>
<td>*Staff and budget resources vs PCP effectiveness &amp; future opportunities</td>
</tr>
<tr>
<td>c. Select 2 x 6 innovative concepts (two page concept descriptions; award criteria: cost, innovation, safety, impact)</td>
<td>(Same as for PCP phase 1c.)</td>
<td>(Same as for 1c.)</td>
</tr>
<tr>
<td>Ruta PCP phase 2: prototype development</td>
<td>1. Secure legal aspects. 2. Reward participant efforts.</td>
<td>*Budget resources vs PCP effectiveness</td>
</tr>
<tr>
<td>a. Close PCP-contract and pay fixed compensation for prototype development</td>
<td>(Same as for PCP phase 1c.)</td>
<td>(Same as for 1c.)</td>
</tr>
<tr>
<td>b. Select 2 x 3 prototypes for testing (same award criteria as in 1c)</td>
<td>Reward participant efforts.</td>
<td>*Budget resources vs PCP effectiveness</td>
</tr>
<tr>
<td>Ruta PCP phase 3: prototype testing</td>
<td>1. Reduce uncertainties regarding solution feasibility, safety issues and stakeholder acceptance 2. Provide the supply side with client and stakeholder feedback on prototypes</td>
<td>*Staff resources vs PCP effectiveness</td>
</tr>
<tr>
<td>a. Provide test facilities</td>
<td>Gain valuable knowledge on why what works (or not) for potential future requirement specifications</td>
<td>*Staff resources vs PCP effectiveness</td>
</tr>
<tr>
<td>b. Pay fixed compensation for participant expenses</td>
<td>*Staff resources vs PCP effectiveness</td>
<td></td>
</tr>
<tr>
<td>c. Determine feasibility of solutions and (if applicable) develop requirements specifications</td>
<td>*Budget resources vs PCP effectiveness</td>
<td></td>
</tr>
</tbody>
</table>

Now that the rationale has been reconstructed, does it satisfactorily explain why this client came to apply PPI? Perhaps not. Potentially interesting additional insights may be generated by a) taking an innovation diffusion perspective (Abrahamson 1991) or b) interpreting the client's strategy in terms of exploration and exploitation (March 1991). The first seems logical because a client's first application of PPI can be seen as an innovation to the client's procurement practice (why now, how exactly did the 'Proeftuin' idea reach the sourcing team?). The latter seems sensible since a client's general strategy may be to first explore how such procurement systems work out in the client's particular setting, before exploiting these on a greater scale. The presence (or absence) of such a general strategy may influence the extent to which experimenting with innovations in procurement systems is stimulated.
The conceptual framework of this study has merits that go beyond the topic of PPI. Firstly, in purchasing and supply management literature the link between procurement practice and overall performance has been studied intensively (Zimmermann and Foerstl, 2014). However, while strategic alignment is central in those studies, to our knowledge, as yet it has been studied by using theoretical constructs, not by composing chains of empirical reasoning. Therefore, this paper presents one of the first detailed examples of links between high level strategy and detailed procurement system design.

Secondly, this study’s approach to investigating a client’s rationale for a particular procurement system deviates from construction management literature on the selection process (Love et al, 2012). While many procurement system selection methods have been proposed, as yet strategic alignment has not been used as a central concept. Since it is such a key concept both in strategic management and purchasing and supply management literature, it could serve as a fruitful perspective for reviewing current selection process methods.

Thirdly, the conceptual framework distinguishes a development process from the selection process within the client’s organisation. The case study results show that the choices made in this process may be equally relevant for success as those in the selection process. Therefore, this study suggests that the development process should be regarded as a process in its own right.

Two managerial implications follow from this study. Firstly, since the case shows how PPI can fit with a public client's higher level goals, practitioners are encouraged to consider the added value of PPI to their current portfolio of procurement systems. Secondly, the conceptual framework may help to deliberately create or assess strategic alignment in practice. While literature claims that creating strategic alignment is vital for performance (Baier et al, 2008), how it is created exactly remains unclear. This case provides a detailed example of how it could be done for procurement systems in a structured and explicated manner. In this vein, it strikes that the study unveils much non-explicated reasoning for the aspect of competitive priorities. This may indicate that it is easier to create a reasonably related set of choices than to explicate the corresponding trade-offs on potentially relevant alternatives per choice. However, based on the concept of procedural rationality, doing both deliberately will enhance the quality of the selection and design process, and thus, ultimately, may positively contribute to a client's overall performance.

CONCLUSION

Innovation is not a goal in itself for public clients in the construction industry. Public policy rationales for applying PPI may not be in the client's main interest either. However, this study shows that applying PPI can fit with the client's strategic goals. Therefore, public construction clients are encouraged to deliberately consider the potential added value of PPI to their current portfolio of procurement systems.

Observing that literature is unclear in detailing out how to create strategic alignment, an extra gain from this study is that it presents a detailed example of how creation of strategic alignment between procurement systems and strategic goals could be achieved. It also suggests that explicit consideration of competitive priorities may help to achieve strategic alignment in a more deliberate manner.

ACKNOWLEDGEMENT

The authors wish to thank ProRail for making this paper possible.
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Plantinga, Voordijk and Dorée


INNOVATION REALIZED? CLIENT'S CHALLENGES OF SUPPORTING SUPPLIER-LED INNOVATION AT THE PROJECT LEVEL

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The important role of the client in contributing to productivity in the construction sector by, for example, enforcing procurement strategies to support supplier-led innovation has been acknowledged by researchers; it is also now in the mission assigned to public clients in Sweden. Many have also highlighted the fact that project-based construction-client organizations need to manage both exploration (‘doing new’) and exploitation (‘doing better’). Yet little research has addressed how ‘the new and inventive’ is actually implemented and successfully managed in practice. The conventional project management approach tends to emphasize the use of reductionist techniques, especially objectivity and control, which tends to stifle innovation; project managers might thus find themselves challenged to stimulate innovation. This paper presents the first step in a longitudinal case study addressing a Swedish public construction client with the explicit mission and strategy of supporting productivity and innovation in the construction industry. Based on interviews with three project managers and a study of internal documents, the paper describes challenges that limit efforts to stimulate supplier-led innovation. It concludes that in the pursuit of stimulating innovation client organizations need to rethink current project management practices.

Keywords: client, innovation, infrastructure, project management, project-level

INTRODUCTION

The important role of the client in creating the right conditions for innovation has been acknowledged by Loosemore (2015) and Ozorhon (2012) and yet other researchers have highlighted for example the impact of contracts (Erikssoon 2013), project specifications (Blayse and Manley 2004), and project evaluation criteria (Loosemore and Richard 2015) on supplier-led innovation. Ozorhon and Oral (2016) studied drivers of construction innovation where they distinguish between project-, firm- and industry-related factors, and their findings suggest that project-related factors are the major driver of innovation. However, most research in this field has adopted an industry- and organizational-level perspective (e.g. Bygballe and Ingemannsson 2014; Ivory 2005; Loosemore 2015) while limited attention is given to clients’ active role in supporting innovation at the project level. In a literature review of construction innovation, Xue et al., (2014) suggest that more research is needed on how to manage innovation from a project level.

Researchers such as Erikssoon (2013) have also highlighted the fact that project-based construction-client organizations need to manage both exploration (‘doing new’) and exploitation (‘doing better’). At the same time it is suggested that conventional project management in construction may fail to sufficiently support, or even be in conflict with, the managing and implementing of innovation (cf. Keegan and Turner 2002, Toole et al., 2002). 

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2013). At the project level clients' project managers have the operative responsibility of realizing innovation as well as to manage the project from a client perspective; they make decisions, they supervise projects, and they integrate the work from different suppliers. Yet little research has explicitly addressed client project managers and how ‘the new and inventive’ is actually implemented and successfully managed in practice.

This paper presents the initial findings from an ongoing longitudinal case study addressing a large Swedish public construction client having the explicit mission of adopting the role necessary for stimulating long-term productivity and innovation in the industry. The purpose of the research is to increase our understanding of how client organizations manage projects in order to stimulate supplier-led innovation. More specifically, the aim in the first step of this research is to assess strategic efforts undertaken by the client organization to open up for supplier-led innovation and to illustrate and discuss the challenges that potentially limit efforts to stimulate supplier-led innovation throughout the project life-cycle, as described from the perspective of three client project managers.

**HOW TO OPEN UP FOR INNOVATION – SOME SUGGESTIONS FROM PREVIOUS RESEARCH**

At an industry level, it has been suggested that the fragmentation and project-based nature of construction creates challenges to implementing innovation (cf. Gann and Salter 2000). One practical way of overcoming the fragmentation of the industry and stimulating collaboration is through using various contracting methods. The use of Design-Build (DB) contracts has become popular among public clients (Nyström et al., 2016).

Theoretically, DB contracts enable innovation by reducing the fragmentation of the value chain through integrating the design and construction phases of construction. DB contracts are also supposedly advantageous for innovation by allowing contractors the freedom to propose different solutions; however, Nyström et al., (2016) (who studied the same public client as this case study) suggest that the studied client made no systematic difference in the degrees of freedom between DB and DBB contracts.

Likewise, Szentes and Eriksson (2015) found in their study that public construction clients still exert considerable control in DB contracts. One potential pitfall of DB contracts procured based on competitive tendering is the evaluation of lowest price. Eriksson (2013) suggests that if price is the only evaluation criteria, the contractor has no incentives to spend time and money on exploration. Loosemore and Richard (2015) conclude that lowest price selection has the merit of competition, but might not always be equal to good value; instead, encouraging collaboration and integration can lead to innovation and more value.

Furthermore, it has been suggested that clients can promote innovation by adopting performance-based specifications that allow contractors to explore new solutions (cf. Blayse and Manley 2004; Loosemore and Richard 2015). The rationale of using performance-based specifications is to make use of contractor's technical competence by allowing a contractor to apply e.g. new methods or materials. But Rose and Manley (2012), who studied innovation adoption in Australian road construction projects, suggest that the use of performance-based specifications is affected by clients' capacity to develop appropriate performance measures for the intended use; and are further limited by how trustworthy contractors are perceived to be by clients. The use of performance-based specifications implies the use of a contractor's skill to deliver and the client's capability to evaluate the performance. It also implies that clients need to have the capacity to
recognize, assess and assimilate alternative options proposed by contractors. But time pressure and limited resources during the tender stage can limit the assessment of alternative solutions, leading to risk aversion and a reluctance to look beyond conventional ‘non-innovative’ solutions (Rose and Manley 2012).

The nature of the construction industry, the one-off projects and the (to some degree) uniqueness of each project create a market structure where clients often have an active role in the design and production phases; thus some researchers suggested that innovation in construction needs to be market-led (e.g. Loosemore and Richard 2015). However Ivory (2005) suggests that the client-focused nature of the industry and the inability of clients to value innovation have created an industry where development in construction projects does not extend beyond reducing time, risks and scope. Both Loosemore and Richard (2015) and Bygballe and Ingemansson (2014) found that construction professionals viewed clients as overly fixated on price, which Loosemore and Richard (2015) tentatively suggest is the result of internal governance constraints and a lack of tools to value innovation. Gambatese and Hallowell (2011) concluded from studying ten construction projects in the US that measuring and tracking innovations were seen as important to the organizations; but the organizations acknowledged that their organization's ability to measure and track innovation was low. In a study consisting of 58 interviews with leaders in the Australian construction industry, Loosemore (2015) found that contractors viewed clients as risk averse. He stressed the importance of clients creating a market for innovation and suggested that construction firms do not rely on clients for innovating, but are dependent on them.

From a client perspective, Rose and Manley (2012) found that clients expressed a concern about opportunistic contractors, potentially leading to clients becoming cynical about a contractor’s ability, intention and integrity, e.g. to only propose cost-saving ideas that jeopardize the quality of a project. These ‘conflicting’ views of a risk-averse client and opportunistic contractor might be the result of the fragmented nature of the construction industry. Thus, collaboration and trust are commonly mentioned in research as essential to overcoming barriers to innovate in construction (cf. Ozorhon 2012; Xue et al., 2014). Kulatunga et al., (2011) analysed the ‘championing’ characteristics of clients in construction, i.e. their role in fostering innovation. They identified several characteristics (e.g. proactive involvement, early contractor involvement, effective communication and being a team player) which clients can adopt to minimize the fragmentation of stakeholders and positively influence innovative activities in construction projects.

Likewise Loosemore and Richard (2015) who conducted interviews with 46 business leaders and policy makers in Australia provide several recommendations for how clients can facilitate more innovation in the industry (e.g. being less prescriptive in dictating solutions up front, develop better skills and methods of measure and value innovation, reduce emphasis on price, thinking long term about their procurement decisions).

**IMPACT OF CONVENTIONAL PROJECT MANAGEMENT PRACTICES ON INNOVATION**

Construction projects can be described as having multiple layers of management originating from both the client and suppliers, whereas the client project manager has the operative responsibility to realize the use of measures supposedly supporting supplier-led innovation (e.g. procurement methods, performance-based specifications). At a first glance projects do appear as the ideal environment for leading, testing out and implementing innovation; they are unique, flat and flexible. However, due to its novelty innovation is inherently a source of uncertainty, and the inter-organizational environment
adds further complexity in construction projects. Whereas innovation requires flexibility to cope with unforeseen changes (Gann and Salter 2000), project management tend to manage uncertainty by favouring control and planning (Keegan and Turner 2002) which has been understood as hampering innovation (cf. Keegan and Turner 2002; Toole et al., 2013). The conventional project-management rationale is described by Pollack (2007) as a ‘hard’ paradigm that emphasizes reductionist techniques, objectivity and control. Innovation, or ‘doing new’, implies uncertainty which project management deals with by falling back on planning and control (Keegan and Turner 2002).

Goal clarity is seen as fundamental for success in project management (Pollack 2007). But the traditional measures set in time, cost and scope, commonly entitled ‘the iron triangle’, have been criticized for not providing enough support to manage innovation (Keegan and Turner 2002). Ozorhon (2012) suggests that innovation performance should be measured based on innovation objectives in order to support innovation at the project level; but as previous research has suggested, clients lack the tools to value innovation (e.g. Loosemore and Richard 2015). Yet a more nuanced view of project success beyond ‘the iron triangle’ is hard to find in the project management literature. A reason for this is suggested by Keegan and Turner (2002), who claim that it is because of the institutionalization of project-management knowledge. And Toole et al., (2013) conclude that the very strengths of client and contractors’ project-management practices are what make them inept at being innovative. Nam and Tatum (1997) studied ten construction projects and suggested that clients’ technical competence and active participation in the project lower the barriers to innovation acceptance, thus facilitating innovation. They also suggest that the innovative projects studied were dependent on key individuals, ‘champions’, for innovation to be realized; ‘champions’ who preferably have a combination of experience, technical knowledge and power to allocate resources.

**METHOD**

The research was conducted at a large public construction client, investing ~4€ billion euros annually on infrastructure. The empirical material in this ongoing research was collected from explorative semi-structured interviews with three experienced project managers. The project managers have the responsibility to manage the construct of the tender documents, to supervise the progress of suppliers’ work according to the contract and to deliver the internally ordered project within set measures of time, cost and scope. The interviewees came from three different functional areas, and thus provided perspectives from managing different types of infrastructure projects (see Table 1).

The respondents were asked questions about their views on exploration in construction, project management, challenges faced when interacting with contractors and exploring new solutions, and their role in construction innovation. Archival data was also extracted from the organization’s internal networks where guidelines, regulations and documents were used as both a complement and contrast to the interviews. Interviews were recorded and the recordings were later reviewed while taking notes. A summarized transcript of each interview was sent back to the respondents for their review of interpretations made from the interview data. Each respondent then sent back their review of the transcript that was later used to report the data collected.

**STRATEGIC EFFORTS TOWARDS STIMULATING SUPPLIER-LED INNOVATION**

The studied organization has worked with and internally communicated ‘development-friendly’ projects for four years in order to stimulate supplier-led innovation and
productivity in the construction industry. This is a response to the directives the organization has received from the government to stimulate productivity and innovation in the Swedish construction industry. The organization introduced a set of ‘development-friendly’ guidelines in 2016, which consist of 16 actions project managers can take when conducting projects that are supposed to stimulate supplier-led innovation.

Table 1: Interviewees

<table>
<thead>
<tr>
<th>Respondent</th>
<th>Interview length</th>
<th>Experience</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Manager A</td>
<td>90 mins</td>
<td>19 years in construction</td>
<td>Road facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 years PM at the organization</td>
<td></td>
</tr>
<tr>
<td>Project Manager B</td>
<td>70 mins</td>
<td>26 years PM at the organization</td>
<td>Railways</td>
</tr>
<tr>
<td>Project Manager C</td>
<td>120 mins</td>
<td>28 years in construction</td>
<td>Bridges</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 years PM at the organization</td>
<td></td>
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</tbody>
</table>

The organization has also implemented internal measures towards supporting innovation in the industry. Reviewing the guidelines, it should be noted that all actions suggested are to be done before the contract is signed, although some of the actions, such as an innovation bonus, have implications for after the project is finalized. The interviewees expressed their views on exploration as an ongoing process, a continuous search for new solutions and better methods to conduct construction projects. One interviewee stated:

I have always acted in a manner so as to stimulate exploration in projects, the [development of] technology moves forward and we need to adapt and make use of the creativity that can be found both internally and externally in the market. (Project Manager B)

ENABLING FOR SUPPLIERS TO PROPOSE INNOVATIONS

In relation to innovation and exploration (i.e. doing ‘new’), all of the interviewees elaborated on the significance and impacts of contract-related aspects, including issues relating to DBB vs DB. During recent years contracting procedures have changed radically accordingly to one project manager, from mostly DBB contracts to an equal use of DBB and DB contracts:

Today there is no prestige in using either DBB or DB contracts; we use whatever we feel is most suitable for the situation. (Project Manager A)

Whereas DB contracts were commonly understood by interviewees to ‘open up’ opportunities for innovation (i.e. provide better support for exploring new solutions and creativity) some challenges were also highlighted. One challenge was to find where they could make use of performance-based specifications, rather than detailed design specifications, when planning the project. The rationale is to make use of a contractor’s creativity by leaving the design phase open; however, one project manager suggested that some DB contracts can be so restricted by regulations that the possibilities for contractors to come up with new solutions are basically non-existent. One concern expressed with regard to the use of DB contracts was that contractors might come up with ineffective solutions. One interviewee, for example, shared an experience where all bids were considerably higher than expected since all bidders presented more expensive solutions.

The project managers generally described their role in construction innovation as that of providing the possibilities for contractors to come up with new solutions by setting out performance-based specifications, rather than design specifications. Subsequently, the project managers perceived their power to ‘open up’ and thus stimulate innovation as
being most prominent during the planning phase, i.e. where decisions are made to construct performance-based specifications or to use design specifications according to current practices; but to some extent this restricts a contractor's flexibility by defining and controlling the process and the work to be performed by specific and detailed technical specifications:

If the goal isn’t 100% defined, this opens up [the chance] for the contractors to be innovative… but at the same time, as a project manager, you could choose a safer route, to specify everything and do as we’ve always done. (Project Manager B)

Elaborating on project planning and how to ‘open up projects’ in order to facilitate supplier-led innovation, regulations were also highlighted as a challenge by the interviewees. Some of the organization's operations, especially railways, are heavily regulated by standards which were perceived to potentially restrain innovation significantly. At the same time, standards were also suggested to ‘provide security’, i.e. reduce risk/uncertainty by promoting, even prescribing, well-established materials or methods:

Standards do exist for a reason; it provides us with the security of getting what we want. (Project Manager B)

In collaboration with the purchaser, project managers do decide the specifications of a project, what contract form is to be used and what criteria are to be evaluated when procuring. But, in the end – one interviewee concludes – the lowest bid is what wins the contracts when tenders are compared. The interviewee refers this fact to directives from the management as well as difficulties of conducting other evaluation criteria in the tender documents. Moreover, if an innovative idea is procured it is not assessed until after the contract is signed during the first client–contractor start-up meeting. The project process is followed regardless of the type of project, and project managers expressed that after completing a project with the intention to ‘open up’ opportunities for innovation, no specific evaluation is made whether or not any innovative or ‘new’ actually was developed:

We do not evaluate a ‘development-friendly’ project any differently than other projects; if we try a new technological solution we make a note in the project file. (Project Manager A)

CHALLENGES IN THE PROJECT SETTING

Whereas the project managers do get internal organizational directives on what each project is supposed to deliver, it is generally within their power to decide on how to execute the project, while still acknowledging applicable regulations and specific project goals. Thus, respondents highlighted the impact of individual project managers on the extent of ‘innovation friendliness’ in projects. One interviewee stated that the experience of project managers, e.g. knowing the project process well and being confident in what results to expect, might have an impact on their actions in response to the uncertainty related to exploring new solutions. Junior project managers, the interviewee suggested, might tend to stick more frequently to conventional solutions and emphasize stricter control of project process than more experienced project managers:

With more experience you are more confident with regard to the project process and dare to open up for contractors to come up with their own solutions; there is always a certain uncertainty related to handing over responsibility to the contractors. (Project Manager B)

According to the interviewees, projects being procured as ‘development-friendly’, and/or where the contracted supplier introduces new-to-the-client construction methods or technical solutions, are not generally managed any differently during the production phase than other projects:
We try to manage all of our projects in a similar way; the project-management process is the same. (Project Manager C)

One of the interviewees highlighted that project meetings during the production phase are typically time pressured with many things to tick off according to the control documents. Subsequently, the interviewee concluded that time is seldom available to discuss such things as innovation:

There is barely enough time to get through the topics of the scheduled meeting; time for discussing exploration or development activities does not exist. (Project Manager C)

Time-related challenges were also attributed to the length of the project. In fact, one of the interviewees identified this as the single most important factor in enabling any exploration activities to take place in projects (or not):

I think the most important factor that opens up exploration to happen in a project is the length of it. (Project Manager B)

In addition to the importance of the length of the project, interviewees suggested that time scheduling is more critical in some projects than in others. The more the project impacts on the current infrastructure functions the more critical it is in enabling the reliable planning of the production phase and keeping to the planned schedule during execution. Time slots for undertaking work impacting on regular train traffic are, for example, typically schedule-dependent with narrow and specific time frames. In projects such as these, the interviewees stated that well-proven and previously tried-and-tested methods and technical solutions are preferred over the new and innovative:

In a time-pressured situation, where the risk of time-overruns impacts society, it is easier and more comfortable to rely on well-proven methods that we know work. (Project Manager A)

The interviewees expressed the view that to some extent there is always the possibility to be creative, find areas of improvement and even provide entirely new solutions in every project. It was furthermore suggested that in order to stimulate exploration the project manager needs to be responsive and intellectually curious about new solutions. At the same time, one interviewee stressed, this needs to be balanced with some caution. Testing out new solutions is inherently associated with uncertainty, interviewees concluded, which might drive defensive behaviour by them as clients.

**DISCUSSION – INNOVATION REALIZED?**

The review of archival data from the organization's internal networks including guidelines, regulations and documents suggests that strategic efforts has been made towards stimulating supplier-led innovation. Specifically, a guideline of activities to be performed in projects to stimulate innovation has been put together. The guideline contains actions in accordance to suggestions made by previous research, supporting e.g. DB-contracts (Nyström et al., 2016), performance-based specifications in the tender documents (Blayse and Manley 2004) and early contractor involvement (Kulatunga et al., 2011). The organization has also created targeted goals in accordance with the guidelines. However, from the interviews it seems that the three project managers did not view their project-management practices when working with innovation to be different to any other project; they also expressed challenges faced when trying to realize measures taken to stimulate supplier-led innovation.

The use of DB-contracts by public construction clients as a potential enabler for supplier-led innovation has been recognized in previous literature (Nyström et al., 2016), although it has been criticized that procuring DB-contracts based on competitive tendering might
not equal to value and innovation (Loosemore and Richard 2015). While DB-contracts might allow contractors to come up with innovative solutions as suggested by Nyström et al., (2016), the interviewees expressed a concern regarding regulations and standards that do exist and limit the degree of freedom they can give a contractor. In the current use of DB-contracts the interviewees told that solutions are not assessed until after the contract is signed; they also used price as the final criterion for evaluation (after assuring that the time plan and the scope is fulfilled). Innovative and potentially long-term beneficial solutions might subsequently be overlooked, unless the innovative solution lower the price presented by the contractor in the tendering document.

The use of performance-based specifications in the tender documents has been suggested as a means to facilitate innovation (Blayse and Manley 2004; Loosemore and Richard 2015). Performance-based specifications allow contractors to make use of their own methods and materials, thus opening up for potential innovative solutions. However Rose and Manley (2012) suggest that clients’ lack of ability to clearly define adequate measures might lead to inflexible product specifications that do not work as intended. The interviewees viewed their role in supporting supplier-led innovation as being to ‘open up’ the possibility of contractors exploring and proposing innovative solutions, mainly by applying performance-based specifications. However, the project managers seemed to find it challenging to come up with performance-based specifications that are flexible enough for contractors to explore new solutions.

Furthermore, previous research has suggested that clients lack the ability to value innovation (e.g. Gambatese and Hallowell 2011; Loosemore and Richard 2015), supposedly hampering innovation since contractors are dependent on clients creating a market for innovation (Loosemore and Richard 2015). The interviews highlighted some difficulties that client project managers might experience in deviating from an evaluation criterion based solely on price. The client project managers stated that they do not evaluate innovations (per se) proposed by contractors during tendering or evaluate innovations during implementation (or after). Thus, it seems that the interviewees find it challenging to value innovation beyond the traditional project success measures of cost, time and the scope set in the planning phase. Time and scope was by the project managers viewed as a ‘go/no-go criteria’, limiting the potential benefits of innovation to only cost-saving innovations. Interestingly Rose and Manley (2012) found that clients tend to be cynical about contractors intentions when proposing cost-saving ideas, assuming that contractors’ new ideas might jeopardize the quality of the project.

The project-management rationale has been understood to hamper innovation due to its strong emphasis on planning and control (Keegan and Turner 2002). Innovation tend to be viewed as a risky endeavour, which Toole et al., (2013) suggest that project managers avoid due to perceiving the risk of failure outweighing the rewards; implementing traditional methods to ensure that project goals are reached. The interviewees highlighted challenges experienced from pressured time-frames that limit their efforts to try exploring or developing something ‘new’ and innovative. The results from the interviews also indicate that when trying to stimulate innovation, the interviewed project managers find it challenging to deviate from their routines and make any change in the project process. However, the interviewees said that experienced project managers may be more comfortable in the project process and thus have an easier time making decisions that entail greater uncertainty during both the planning and production phases. It was thus argued by the interviewees that experienced project managers are more prone to conduct exploration activities and stimulate innovation; this indicates that the individual importance of the client project managers might have a crucial role to de-emphasize
planning and control that have been understood to hamper innovation. In a similar vein, Nam and Tatum (1997) suggests that individuals supporting innovation, so called ‘champions’, should have a combination of experience, technical competence and power to allocate resources. Nam and Tatum (1997) also suggest that clients technical competence create a better understanding of technical matters, thus clients can make more timely approval of innovative ideas in a project setting. Together then, this raises broad questions of how both institutional and individual competence and experience facilitate and support supplier-led innovation, and particularly how the project management process can be developed to lower the perceived barriers of competence and experience among client project managers.

CONCLUSIONS

The purpose of this research is to explore how client organizations manage construction projects in the pursuit of stimulating supplier led-innovation; more specifically, the challenges of achieving this are addressed from the perspective of a client project manager. The empirical data indicate that in accordance with the findings of previous research the client organization has made efforts on a strategic level to support construction innovation. Despite these efforts, however, our data – representing, of course, the perspectives of only three project managers from a single client organization – show that challenges persist to realizing measures taken to stimulate supplier-led innovation. Although the data from this study are limited, the perspectives of our interviewees have thrown into sharp relief the difficulties they face, difficulties that have up to now been paid limited attention in the construction innovation literature. Clients have been suggested as an important player for innovation adoption in construction, yet the precise role of their project managers is still imperfectly understood. Our paper is a start in rectifying this gap in the literature: for future studies it would be of interest to increase our knowledge of how organizational measures to stimulate innovation of client organizations can be successfully implemented at the project level. In the next step of this study, the views and understandings of client project managers will be further addressed, and the views of suppliers will also be considered.

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COLLABORATION
Managing multiple intra-organisational inputs for the delivery of highways maintenance is a complex endeavour, especially given the multifaceted nature of the provision required. While collaboration in construction projects has formed a major research focus in recent years, attention orientates toward an application of a collaborative approach and in doing so conceptualises collaboration as an exceptional event. Construction management research faces criticism for its failure to consider institutional theory, a perspective dominant in business management research. This working paper sets out a reconceptualization of collaboration as an ongoing accomplishment which requires both an understanding of the micro-practices to reveal its on-going nature, and to reveal the institutional logics that shape collaborative practice. Focus groups identified activities undertaken during project delivery according to the collaborative behaviour exhibited. Findings uncovered tensions between the regulatory and cognitive institutions governing project delivery. This research encourages practitioners to consider the underlying institutional forces during the reconstitution of working relationships. This paper has synergy with ‘organisational becoming’ and contributes to our understanding of collaboration within construction management literature.

Keywords: collaboration, institutional theory, highway maintenance, organisational change

INTRODUCTION

Despite the quantity of research attending to collaborative working practices (Fellows and Liu 2012; Mignone et al., 2016; Suprapto et al., 2015; Donato et al., 2015), we still do not know enough about emergent micro-practices (M-P) of collaborative behaviour and the implications for the delivery of complex infrastructure programmes. In delivering through-life services such as the management, maintenance and renewal of the UK’s highway infrastructure assets, supplier organisations must coordinate their multifaceted service provision. Such suppliers typically possess the resources in-house to provide expertise in a range of engineering disciplines including pavement, structural, environmental, geotechnical and hydrological services. In addition, such organisations have capability in support services such as project management, finance, commercial and legal. Previous research attention has predominantly been orientated towards formalised and established methodologies of collaborative working (Ballard and Tommelein 2012), often applied and facilitated by external consultants (Boyce et al., 2012). These normative accounts fail to provide a rich picture of how and why collaboration evolves. To address this we attempt to uncover the M-P of collaboration and understand it as an ongoing accomplishment (Marshall 2014). Furthermore this exploration will help to reveal the
institutions that shape the M-P and in doing so identify tensions between collaborative working rhetoric and collaborative practice.

**LITERATURE REVIEW**

Construction management research (CMR) is home to a wealth of research extolling the benefits of a collaborative approach to project delivery, particularly in projects characterised by complexity (Ballard and Tommelein 2012). Past research provides us with helpful accounts of the prerequisites necessary (Zou et al., 2014; Dewulf and Kadeffors 2012; Rahman and Kumaraswamy 2005) and the tools and techniques mobilised to facilitate such an approach (Bolstad and Endsley 2003; Hawkins and Little 2011). The research described here is fixated on formalised and implementable styles of collaborative working and consequently, fails to include the collaborations arising from everyday routines and mundane interactions. Previous work by the authors has shown collaborative behaviour that emerges in an informal and pervasive manner can carry with it serious implications for project performance (Grove et al., 2017). Institutional theory, an infrequently utilised perspective in CMR (Bresnen 2017) provides a useful lens through which to explore the M-P of collaboration as an ongoing accomplishment and to inform an appreciation of the influencing forces at play.

**The Institutional Landscape**

Scott (2008) sets out three institutional pillars that can be used to rationalise human behaviour: regulatory, cognitive and normative. Regulatory institutions are formally governed and enforced via commercial and financial incentives/sanctions. Cognitive and normative institutions are concerned with the socially shared and accepted behaviours that, when violated, are sanctioned with ridicule, isolation and ostracism (Henisz et al., 2012). Without explicit links to institutional theory, CMR has attended to the regulatory institutions that govern collaborative working arrangements, in particular through the examination of relational contracting strategies (Gil 2009; Rahman and Kumaraswamy 2005; Zou et al., 2014). Whilst important, these are only part of the story. Financial incentives and sanctions can enhance regulatory governance but they can never fully subsume the sociological perspectives (Henisz et al., 2012). A reconceptualization of collaboration as an ongoing accomplishment would encourage greater consideration of the underlying institutional landscape, or "rules of the games" (Jia et al., 2017). Recognition of the importance of institutions and institutionalisation in CMR is not new (Kadeffors 1995), but prompted by Bresnen's (2017) criticism of the failure to consider institutional theory, we explore here how institutionalism can be used to explore the behaviours associated with collaboration. Theory tells us that institutions are created when people formally and informally organise their time and space into regular patterns that impact their activities (Jia et al., 2017). Furthermore, individuals and organisations are said to automatically reproduce the institutions they inhabit. Theoretically, this deterministic assertion presents a tricky dilemma; how are routines altered and new ones created if the institutional force is so great individuals automatically conform to it?

Seo and Creed (2002) suggest that this question is partially answered by incorporating theory of agency, but doing so contradicts the central assertion of institutional theory which is that actors themselves are institutionally constructed (Seo and Creed 2002). This paradox is interesting in the context of collaboration when we consider the propensity for informal and emergent collaborative action, governed by cognitive and normative institutions, to subversively alter organisational routines that the regulatory institutions govern. As we transplant institutional theory into the context of collaborative working, the question arises: how can actors change the collaborative environment if their
collaborative actions are conditioned by the very institution they wish to change? This suggests multiple and conflicting institutional logics, something not considered in the extant literature regarding collaborative working within construction. Who decides which institutional forces should be altered? Is this even possible given the exaggerated ability afforded to actors to create and transform institutions (Lounsbury and Crumley 2007).

Seo and Creed (2002) discuss how human praxis, triggered by tension, transforms socially embedded, unresponsive actors into conscious change agents, aware that their interests are unmet. Wanting and needing to do a good job but constrained by ineffective contractual arrangements (regulatory institutions) creates significant tensions for project teams and can lead to staff developing their own isolated solutions which can be disastrous (Balthazard et al., 2006). Such internal fragmentation may allow competing institutional logics to exist within the same institutional field (Lounsbury 2007). When tensions develop, deepen and permeate actors' social experience continually and collectively, change agents are said to be mobilised (Seo and Creed 2002). The problem for management is when change occurs unofficially and results in non-compliant action that defies the regulatory institution. A reconceptualization of collaboration as ongoing which encourages sympathetic consideration of the underlying institutions and their effect on behaviour would help our understanding of the M-P of collaboration as emerging and pervasive.

Collaboration Is Not Exceptional

The discourse dominant in CMR treats collaborative working as an applicable methodology that can be transplanted into any situation and yield positive results (Choo et al., 2004), reducing what is a complex set of interconnected relational issues to a set of tools and techniques (Hawkins and Little 2011). Whilst such accounts provide practitioners with insightful accounts of how collaboration can be applied and the positive and negative effects of the implemented initiative, attention is diverted away from the detailed actions and interactions of peoples' activities. Attention to the normative and cognitive dimensions of institutions is the major feature of neo-institutionalism and to take a sociological perspective toward the understanding of governance is reported to have the strongest purchase in micro-level studies (Henisz et al., 2012). For example, Tello-Rozas et al., (2015) takes a M-P approach to describe the social movement phenomenon in South America and trace how actors organise and collaborate to address important issues that political authorities seem unable or disinclined to address. In their study attention is toward the detailed actions and interactions as they open the “black box” to reveal that where numerous collaborations coexist, informal authority usually prevails over formal and that such informal authority emerges dynamically from different meetings and events. Whilst dominant in organisational and management theory, institutional theory continues to be largely absent in CMR. Researchers forego opportunities to cross fertilise ideas from business management research (Bresnen 2017) where recent work emphasises the endogenous pressures that create change in organisations and the belief systems and associated practices that condition how organisations respond to endogenously created change (Tsoukas and Chia 2002). In the same way Tsoukas and Chia call for a reversal of ontological priority accorded to organisational change, we call for collaboration within CMR to be understood as a phenomena created from within and not as episodically enacted events.

A Renegotiation of the Terms

The dominant conceptualisation of collaboration as something that can be applied prioritises stability and assumes that whilst collaborative working is applied, all other
factors remain constant. Considering again the theory of organisational becoming (Tsoukas and Chia 2002) whereby attempts to manage change create additional change we begin to appreciate the dynamic nature of collaborative working arrangements. Interpreting collaboration as ongoing permits an appreciation that the way people collaborate is a result of the immediate tensions experienced as well as previous experiences, interactions, collaborations and disputes, all of which were influenced by the institutions that governed. Just as an application of technology cannot increase or decrease productivity or performance (Orlikowski 2000), collaboration will not simply occur through the colocation of people. A view of collaboration as ongoing encourages a focus on the M-P of action. We have discussed the idea that tensions have the power to create change agents. Tensions may arise when a need to collaborate to "get the job done" is not supported by the governing regulatory institutions that reinforce a senior management approach prioritising financial and commercial factors. Institutional theory can help us to understand the belief systems underpinning the activated institutions as a whole (Jia et al., 2017). The concept of institutional logic helps our understanding of how these incompatible domains (be collaborative and don’t be collaborative) act together to shape behaviour and why some rules are obeyed and others avoided (Jia et al., 2017). In the context of this research this approach could aid our understanding of why collaborative behaviour is enacted in some situations but not in others or during certain periods but not forever. In an attempt to understand why initiatives do not result in the desired behaviours, Jia et al., (2017) suggest the weak link is rooted in various systemic contexts such as incentives constraints, values and beliefs which affect individuals' decision making.

METHODOLOGY
To understand the M-P of collaboration and the influence of underlying institutional forces, data was gathered via interactive focus groups, supplemented by participant observation and one to one interviews. Follow up focus groups were held to further investigate the themes that emerged where a root cause analysis approach was adopted to unearth the underlying issues. Focus groups are an infrequently mentioned data collection technique but have been found to be an effective tool particularly to those studying work environments and associated behaviours (Frey and Fontana 1991). A structured schedule was employed to administer the first round of focus group sessions, participants were asked to list the key activities pertaining to their job role on a sheet of paper. The list of activities then became the bars on a chart. Throughout the session, this base chart was layered with information regarding the identified activity's success, criticality, experienced feelings, levels of collaboration, and the significance of financial and commercial issues. Following the focus group sessions, the 196 separate activities were identified and analysed. Participants were asked to list the activities they complete as a part of their job in chorological order thereby producing an indicative timeline. After normalising the timescale, it was possible to represent the level of collaboration experienced for each activity relative to its position in a timeline and identify a trend. Fourteen participants in groups of between two and six took part in the first round of focus groups. Thirty two participants took part in five follow up sessions. Participants across all groups consisted of office and site-based operatives, engineers, project managers and commercial managers. The groups comprised individuals known to one another and they shared a common frame of reference (i.e. they worked for the same organisation). The sessions were held at the participants' workplace in private meeting rooms. The primary motivation for employing a focus group technique was to gather data from multiple participants in one sitting. The data was captured via the paper-based
materials completed by each participant. Secondary insights were provided by group discussions and observations, giving additional depth to the experiences captured on paper. Here, benefit was drawn from the stimulation and opinion elaboration that the group dynamics permitted (Frey and Fontana, 1991). Listening to what people say in addition to what they write was important; how people talk has profound implications for how they think and act (Orlikowski 2000). Focus groups bring analytical challenges and can attract methodological and epistemological objection. Any confusion of group conformity with individual opinion (Sim 1998) was mitigated as participants provided data specific to them on their individual charts. Accordingly, the data associated with each activity was of an individual matter. All sessions were facilitated by the same researcher which allowed for internal consistency and equivalence (Kidd and Parshall 2000).

FINDINGS AND DISCUSSION

Following analysis of the data from the focus groups, interviews and observations, connections between M-P of collaboration and institutional forces were evident in three ways. Firstly, M-P of collaboration revealed multiple institutions competing within the same operational space. Secondly, collaborative practice not processualised as "collaborative" is not recognised as having value. Thirdly, as a knock on effect of findings one and two, the M-P observed suggest that informal collaborations are allowed to evolve, causing severe problems for service delivery.

Competing Logics of Collaboration

For the case study organisation, the adoption of a collaborative approach to service delivery is a core business value and features prominently on the organisation's website, marketing literature and visual displays in the workplace revealing an institutional logic that recognises a benefit to working collaboratively. Focus group data suggested people start out with a desire and ability to take a collaborative approach, but levels of collaboration are perceived to diminish over the life of project. Discussions during follow up interviews suggested that intentions at the outset of a project to adopt a collaborative approach are felt to be easy to achieve when all other factors (e.g. programme, commercial and financial issues) are positive. But when financial disagreements occur, tensions were reported to arise and the motivation to be open and collaborative was felt to be relegated in favour of efforts to maximise profit. One participant said "collaboration may work very well at local level but it is seen as a 'nice to have' until commercial issues come in and overrule". This suggests an alternative institutional logic to that of collaboration that prioritises profit maximisation and encourages an adversarial approach.

It quickly became evident that the strategic level rhetoric to be collaborative is not supported by the regulatory institutions of lump sum transactional contracts, enforceable by financial penalties. Many participants expressed the view that the contract was to blame and prevented a joined up, collaborative approach to service delivery. The contract is described as "too complicated", as having "unrealistic targets" and "unachievable obligations". But as Henisz et al., (2012) states, contracts are only one part of the story. From the outside looking in it is easier to view the contract as the inanimate object it is. What our investigation aimed to uncover was the specifics of the regulatory institution that were able to grasp hold of people and allow what is essentially only pieces of paper to drive un-collaborative behaviours.

Prioritising cost over collaboration (Grove et al., 2016) driven by regulatory institutions delivers conflicting signals to staff. Findings from the focus groups tell us people want,
need and enjoy collaborating. When asked to assign emotions to their daily activities, those activities relating to meetings and communications were consistently associated with positive feelings such as enthusiasm suggesting people enjoy the opportunity to interact with others. This chimes with the organisational strategic priority to be collaborative. Operationally, however, its importance became less prominent leading to competing logics within the same institutional field (Lounsbury 2007) a situation increasingly recognised in management research (Besharov and Smith 2014). What therefore are the consequences when logics that both value and devalue collaboration are in existence? Other studies suggest that competing logics do not automatically lead to organisational demise and for organisational change to occur, one dominant organisational logic need not be replaced with another (Reay and Hinings 2009).

While an organisation might attempt to fix a definition (e.g. we are collaborative) it does not have total definitional control because the definition is being supplemented, eroded, modified and interpreted by individuals in unpredictable ways (Tsoukas and Chia 2002). A close relationship, such as that observed between project staff, motivates people to develop ways of enacting multiple (otherwise conflicting) logics (Besharov and Smith 2014) as they deviate from the formal logic to their "home" logic. Findings here suggest that if we are to become collaborative in an ongoing manner (rather than simply carryout collaboration) we must be conscious of the likelihood that multiple logics can exist and appreciating how their dominance can alter is important. Whilst popular discussions of collaboration elsewhere in the CMR tend to agree that greater management support and leadership is required for more successful change initiatives, they do so from the perspective that certain critical ingredients are missing from the mix and could potentially be added. We make an alternative assertion that for a collaborative approach to be successfully ongoing, those in a position of influence must learn to appreciate the institutional landscape in which they reside and modify their support accordingly.

Objectification of Collaboration

Findings of the focus groups revealed that as projects progressed, the levels of collaboration associated with the participants daily activities was felt to decrease over time. When asked during follow up interviews why the levels of collaboration were felt to wane during project delivery, responses suggested that during the early stages of contract delivery collaboration required conscious effort whereas in the later stages, working collaboratively had become normalised. For example: "after a while [collaboration] becomes business as usual… so therefore doesn’t feel quite as collaborative because its normal" and "the quality of collaboration that takes place improves, but it perhaps becomes less frequently required as you perform a task… or becomes more natural and streamlined". What people consider collaboration to be is important here. Whilst true collaboration is inextricably linked with behavioural drivers (Lloyd-walker et al., 2014), our findings suggest that collaboration has been institutionalised as a process rather than a behaviour and people have been conditioned to recognise collaborative working only when it is presented to them in its formal state. Until prompted, the participants tended not to appreciate collaborative behaviour it in its unauthorised form. Legitimising only formally organised collaborative interventions once again demonstrates how attention paid to the M-P of collaboration can help us to reveal and begin to understand the dominance of regulatory institutional forces over the cognitive.

Whilst the findings of the focus groups show what people recognise as collaborative working decreases overtime, observations show informal collaboration is ever present.
The failure on the part of individuals to recognise collaboration in its informal state forces it to operate unofficially. The very fact that people best recognise collaboration objectively suggests inherently un-collaborative behaviour. The industry's drive towards a commodification of working together to overcome the challenges of what is a complicated service provision has served to undermine the innate ability we have as humans to interact positively. Continual efforts to quantify and formulise what is essentially a relational outcome is eroding our ability to recognise or value any interactions that do not form part of a process. Despite a lack of recognition, informal collaboration has been observed to be the method by which project staff manage the multiplicity of logics at play (Reay and Hinings 2009). As an unrecognised and unacknowledged activity, the cognitively governed institution of informal collaboration goes on unseen (and crucially) unchecked by management. Although they do not label it as such, the M-P of the participants of this observational study engaged in collaboration to find solutions to problems they encountered and in doing so they continually alter organisational routines. Practically, the findings indicate that informal collaboration is enacted as people navigate the conflicting regulatory and cognitive institutions. Our findings show that cognitively governed institutions that support informal collaborative practice do co-exist dynamically alongside more dominant logics of profit maximisation as behaviour fluctuates between perceived, desired and achievable levels of collaboration. Furthermore, our findings reveal how this creates problems for service delivery.

Local Optimisation

If we revisit our working definition of collaboration, it is the process through which parties who see different aspects of a problem can constructively explore their differences and search for solutions that go beyond their own limited vision of what is possible (Gray 1989). The M-P observed tell us that the dominance of regulatory institutions act as a barrier preventing sub teams from exploring solutions beyond their limited vision. A reoccurring manifestation was observed in the planning of highway maintenance works which are carried out by sub teams segregated by discipline. For instance, street lighting, drainage, inspections and lifecycle, plan their own sub-optimal work programs driven by its own contractual obligations. Not only was this M-P of silo working observed to be a lost opportunity to capitalise on available resources (for example the sharing of traffic management), it was felt to often hinder the objectives of other teams. Negative impacts included issues such as abortive works and conflicting communications to the public. The silo approach to delivery was felt by focus groups to stem from the failure of decision makers at contract mobilisation stage to appreciate the operational significance of the contractual documentation. A rushed mobilisation phase does not allow for learning cycles or recognition of new risks that may impact on a project’s outcomes (Watton 2017). Regulatory institutions prioritising corporate growth and profit maximisation at group level were identified to be the driving force behind decisions made at contract level that reward achievements based on annual performance and therefore encouraged short termism. A full understanding of long term contract obligations and how these would be met operationally was overlooked resulting in sub-optimal at best and frequently absent collaborative practice. Local optimisation of collaborative practice was seen to have a negative impact on project performance but also carries implications for theory. Earlier discussion highlighted theory that says change agents are created and organisational change initiated following internal fragmentation (Seo and Creed 2002). Our findings tell us is that fragmentation alone was not enough and isolated pockets of contradictory collaboration (as experienced by different disciplines within the same contract) failed to change the prevailing

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regulatory institution that has its roots in profit maximisation. Other literature states a wider recognition of the irregularities is first needed. If irregularities are not problematized, extant theory will not be changed and ”rogue activities will wane or persist in a marginalised fashion” (Lounsbury and Crumley 2007: 1005). Where a problem like the silo approach to collaboration is not collectively recognised as an anomaly and therefore not negotiated on or incorporated into extant practice (Lounsbury and Crumley 2007) the sub-optimal solutions occur in isolation, are not collectively recognised and have little chance of spreading up the managerial chain to affect meaningful change or alter the balance of dominance in terms of institutions.

CONCLUSIONS
Management of the UK’s complex highway infrastructure requires project staff to respond to often contradictory institutions governing collaboration. Through a lens of institutionalisation we have seen how regulatory institutions that implicitly and explicitly encourage profit maximisation tend to dominate over the cognitive institutional forces that support people’s desire to enact collaborative working. In line with other studies, we have seen that multiple institutions can and do co-exist and are managed by informal collaborative relationships (Reay and Hinings 2009). Practically, understanding how multiple institutions operate with an organisation are critical for understanding the possible outcomes (Besharov and Smith 2014). A reconceptualization of collaboration as an ongoing and dynamic accomplishment highlights a need to adapt the support afforded to collaborative working whilst accounting for potential conflicting institutional logics. The aim of management need not be to replace the dominant institutions at play. Concentrating on the institutional dynamics that affect the M-P of collaboration, this study has highlighted the importance of recognising how co-existing institutions can be balanced and addresses the criticism levelled at institutional analysis for neglecting internal organisational processes (Lounsbury and Crumley 2007).

Theoretically, a reconceptualization of collaboration as ongoing would prompt research to turn away from the practical, such as formalised collaboration initiatives, toward reflection (Tsoukas and Chia 2002) whilst seeking a renewed understanding of the dynamic institutional processes (Bresnen 2017). Reconceptualising collaboration as ongoing, whilst attempting to understand the institutions at play would encourage researchers to recognise potential sources of tension, and identify where future research attention should be directed. The interesting finding to consider is not that multiple logics surrounding collaboration co-exist but the way in which the multiple logics either blend or contradict and the impact this has on the performance of an organisation. The intention here was not to develop additional techniques for the application of collaborative working, but to provide guidance to management who wish to reconstitute their support of working relationships by encouraging them to see the value in appreciating the institutional context within which project delivery operates and in doing so this paper contributes to the institutional theory debate in CMR.

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COLLABORATION IN EARLY DESIGN: AN ACTION RESEARCH APPROACH TO COLLECTIVE THINKING

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The urgency for increased sustainability in the built environment address the need for improved collaboration and communication among design team members in the early design phase. By the use of collaborative methods, different perspectives and ideas can be expressed, shared and developed in design meetings. Findings are based on an action research-project at a large architecture firm in Scandinavia aiming at developing methods to facilitate collaboration and communication and support problem identification and problem solving in teams in early design. The findings show how collaborative methods can support collaboration between disciplines and create open communication within design teams and enhance collective thinking. Findings have implications for the development of collaborative methods for more sustainable and innovate solutions, and also for enhancing learning and trust within design teams. Findings contribute to the growing stream of research on the development of architectural practice.

Keywords: collaboration, design teams, sustainable development, collective thinking

INTRODUCTION

There is an urgent need for more innovate and sustainable solutions in the built environment and sustainability needs to be integrated into built environment operations and processes (Hannon and Callaghan 2011, Opoku and Ahmed 2013). By sustainability is meant economic, social and environmental factors (Velazquez et al., 2011) that it will ensure long-term economic viability and maintain an environmental balance and commitment to socially desirable practices (Miller 2010). The early design is important when striving for long-term sustainability and creativity in the built environment (Ding 2006). Hence, collaboration and communication in early design teams is essential for integrating sustainability in problem identification and problem solving (Shelbourn et al., 2007) and new and more collaborative practices have to be developed (Walker and Jacobsson 2014). While much research has focused on collaboration and communication in construction projects and construction project teams (for example Dainty et al., 2006), less focus has been on methods for collaboration and communication in early design teams.

New practices are currently emerging within architectural practice that supports team performance, problem solving and how to work creative and innovative in a collaborative environment. These new practices often consist of complex sets of “collaborative constellations” (Nilsson 2013:146) that create and share knowledge and methods through cooperation among disciplines. In these constellations, issues of communication and inter-subjectivity are of importance and crucial for further development (Nilsson 2013).

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Design thinking is commonly seen as an approach within architectural practice to be creative and innovate. Brown (2009) challenged the design community to think beyond the omnipotent designer and the production of products by suggesting that design thinking should be used for social innovation. This way design may be seen as a collaborative effort where the design process is performed by participating actors and competences. Brown (2009) suggests that ideas have to be envisioned, or “prototyped”, and explored hands-on early in the design process in ways characterized by human-centeredness, empathy and optimism.

The aim here is to contribute to the development of methods to facilitate collaboration and communication in early design by an action research approach. In focus here is collaboration and communication within design teams at a large Scandinavian architecture firm. Based on an example from contemporary architectural practice and the ideas of Mercer (2013) on “collective thinking” and of Dunbar (1998) on “the social brain”, findings show how collaborative methods can support collaboration between disciplines in early design, and how open communication within design teams can enhance collective thinking. Findings have implications for architectural practice in the development towards more a more sustainable and innovate built environment and contribute to research on the development of architectural practice.

COLLABORATION AND COLLECTIVE THINKING IN THE BUILT ENVIRONMENT

Research on collaboration in the built environment is extensive and has been performed from a variety of perspectives, for example construction project procurement and partnering (e.g. Nyström 2005, Eriksson 2010). This research shows that collaboration is challenging due to, for example, lack of trust in contractual relationships. There is also research on interdisciplinary communication and the development and use of design concepts (e.g. Emmitt and Gorse 2007, Dainty et al., 2006) that show communication challenges within design teams, for example the different perspectives and the interplay between informal and formal communication. Information technology research with the purpose to enhancing collaboration by integrated visual models and tools has also been extensive (Negendahl 2015, Wang et al., 2013) and there is a stream of research that acknowledges inter- and intra-organizational challenges of implementing new information technology in the built environment (Bosch-Sijtsema et al., 2017, Linderoth 2010). This research explores challenges of adopting new technology for collaboration (e.g. Vass and Karrbom Gustavsson 2017). Combining competences and professionals also includes challenges of interdisciplinary and inter-professional engagement and communication (Keys et al., 2016) and the development of team roles (Senaratne and Gunawardane 2013) and findings show that design team members tend to consider their functional roles rather than their team roles.

Collective Thinking

How people in groups think is studied in the fields of social psychology, evolutionary science and social cognitive neuroscience. The concept “the social brain” (Dunbar 1998) was originally developed in evolutionary science and it describes human ability to think and solve problems in groups. The concept has been used, for example, in psychology and education to explain what social factors affect intelligence and language and how human thoughts are shaped. Studies show that equal participation and diverse perspectives and knowledge backgrounds will have effect on group performance (Woolley et al., 2015). Other studies (e.g. Isaacs 2008) claim that the complexity of today’s problems requires problem solving beyond the individual. Hence, complex
situations require a multitude of perspectives and knowledge backgrounds that can work together. However, working together and understanding each other is not easy. There are multiple dilemmas to be avoided, for example “group-think” (Janis, 1971). Methods to meet those challenges has been studied with the use of “Group Support Systems” (GSS) (Briggs and de Vreede 1997), where digital technique offers methods to anonymous contribution of thoughts that are then visualized in the group in an equal way. The concept “collective thinking” has also been used in education and pedagogic research (Mercer 2013) to address the ability to learn and understand other’s perspectives and to create shared frameworks (Pennington 2008). However, collective thinking requires facilitators that are capable of orchestrating both environments and interactions (Pennington 2008).

**METHOD**

The approach is action research (AR) combined with the architect’s exploratory approach and of being a “reflective practitioner” (Schön 1984). In action research, theory should be grounded in local problems and knowledge should be created from problem solving in real life situations (Lewin 1946). This is supported by Schön (1984), who see architectural practice as education for reflection-in-practice. The epistemological stance for an AR approach is that knowledge does not derive from a single person but is created together in interaction between actors in a setting. Feedback given by colleagues and participants in an intervention contributes to the co-production of knowledge (Lewin 1946). Here, the interventions are real life situations of early design meetings at a large Scandinavian architecture firm. The exploratory and reflective work includes interventions with teams in early design meetings where the researcher takes part in the role as facilitator. These interventions are combined with observations of the actions of the group members during meetings, reflections on responses from design team participants and feedback from colleagues at the architectural firm. The understanding have then been challenged and supported by concepts from literature.

The empirical setting covers a period of 1.5 years. During this time, the researcher was working half time at the architectural firm facilitating 14 interventions with the purpose to improve collaboration and communication aiming at long-term sustainability. Reflections-in-action were ongoing “in the form of a repertoire, making use of past experiences, without reducing the new situation to features that conform to a set of familiar rules” (Schön 1984:5). An inductive process together with piers, during the act of planning, acting and evaluating the interaction supported meta-learning by reflecting on implementations of the action research cycles (Coghlan and Brannick 2014).

To include other’s perspectives, the researcher held one seminar with a critic session and one presentation together with colleagues at the architectural firm. Both the seminar and the presentation were based on the researcher’s reflections from facilitating early design team meetings. Inspired by literature on GSS the researcher used a digital tool that the colleagues could access through their smart phones. The colleagues were asked to individually answer questions on their smart phone such as: What shortcomings and problems have you experienced in meetings with different actors and competences? When do you think this type of method should be applied to achieve sustainability in the built environment? Results were immediately displayed on a large screen through a projector and the researcher followed up with at short reflection and participants were invited to make comments. This way, approximately 40 practitioners at the architectural firm gave feedback on the relevance of the research into the AR cycle observe-reflect-plan-act. After those sessions, the use of the digital tool became more commonly used in
Collaboration in Early Design

meetings, forums, conferences and dialogue situations at the architectural firm. After four months, more than 40 practitioners had already subscribed.

The Intervention in Focus

The intervention in focus here is called “Hållbarhetsanalysen Skellefteå Culture House”. It is an example of an intervention where an expanded collaborative method for a mandatory project-routine document where used. This expanded collaborative method challenged traditional norms and behaviours, which had previously hampered collaboration and communication in the design team. The researcher was facilitating, reflecting-in-action and receiving feedback in dialogue with the design team participants. The facilitator also conducted four interviews with participants of the design team eight months after the intervention. The respondents were the projecting architect, the ordering client and two sustainability co-ordinators. The interviews were based on questions on project roles, project progress and on experiences and effects from the workshop. The interviews were semi-structured and aimed at creating a dialog between the researcher and the respondent. The researcher finally performed a reflective analysis, which included comparing interview notes with notes and documents from the workshop before summing it up in a paper.

FINDINGS

Hållbarhetsanalysen Skellefteå Culture House

Establishing a collaborative culture

The design team began the workshop sitting in a half-moon shape performing a check-in exercise that included a spontaneous half-minute reflection from each team participant on his or her expectations. The seating and democratic way of taking turns talking was initiated by the facilitator and aimed to cultivate inclusion, trust and a feeling of participating in the group on equal terms. The facilitator continued the workshop with addressing the urgency of sustainability in the built environment and then continued to address the complexity of sustainability by showing a video of children’s view on climate change. The video served to create reactions and reflections relating to life cycle assessments (LCA) and responsibility on global and local scale. Then followed an exercise where participants were asked to take position according to what they were most afraid of by standing on an imagined diagonal in the room. This aimed to visualize ethical dilemmas imbedded in sustainability projects. The video and the exercise served to create a common point of departure for the team in sense of responsibility for the next generation due to climate change. The participants were also encouraged to raise different perspectives on climate change in a non-judgmental format. By activating emotions through exercises, and display the differences of personal perspectives/stories without judgment, the members of the team were able to open up for spontaneous communication.

Collaboration in practice

The large design team was later divided into smaller groups. Each group were asked to do a fast pace competition association exercises to support creativity. This aimed to generate a multitude of ideas in a short timeframe. Individual ideas were written on Post-it’s and clustered. The ideas were later re-formulated and a process of prototyping a suggestion followed. The exercise aimed at activating creativity and sharing of ideas, peer-to-peer collaboration and a free flowing dialogue. During the exercise, team participants were intensely talking to each other, they were moving post-its back and forth and they were writing down their suggestions. When summarizing what each group had
developed in terms of solutions participants took turns in presenting ideas for sustainability and pinning them onto a chart on the wall. The chart had two axes spanning from difficult-easy and low-large value. Finally, there was twenty minutes of team reflection on the outcome of the chart facilitated by the researcher in which all participants of the design team took active part. After the reflection the participants returned to the half-moon seating and they were asked to do a checkout exercise. Going around the half-moon circle, everyone was asked to express her or his opinion on the workshop format (best and worst) and what should be the next step in the process. The final exercises served to enhance team spirit, learning and the collective contribution to the knowledge framework in an organized and time optimized manner.

**Feedback**

The design team participant’s feedback was concerning structure and content of the workshop, as well as expected potential effects and perceived effects (i.e. perceived effects eight months later). While some participants were general in their feedback, providing feedback such as: “Interesting and inspiring” or “I was impressed by the commitment, it was really engaging and amazing”, others commented on the high tempo and time-pressure, which were seen as stressful and hectic, and at the same time felt necessary in order to respond spontaneously.

There were also participants commenting on the collaborative exercises and how the collaborative methods supported the creation of trust and commitment. One participant commented that “the format raised many thoughts and created commitment” and it was also said in retrospect that “our relation with HVAC was not great at that time, something which changed during the workshop. My relationship with them is now based on trust, I feel they are doing what they can, they have the same challenge as the rest of us with time pressure etc. and we are now going in the same direction”.

Feedback also showed that the inclusion of different perspectives was perceived as positive since “other people’s interest came out, emerged...” To interact with people with different backgrounds and perspectives was highly appreciated, in particular to meet and interact with the member from the municipality. “Most beneficial was the member from the municipality... and for me to see her contribution...and the other architects how they could contribute”. The interaction between perspectives and disciplines supported a more collaborate and learning climate in the design team and the perception was that “...we learn from each other and we also developed a better relationship since it was weak before the workshop”. The collaborative climate was also perceived as contributing to engagement from all participants, “I thought that everyone was engaged and ‘burned for the task’...” and also made all participants feel included at the workshop and in the project, “I remember that everyone’s perspective was voiced and it has characterized the time I worked on the project anyway...” and that “the work has been characterized by a great openness to learning...”

There were also participants commenting on expected and potential outcomes from the workshop and on future collaboration possibilities. One participant said that it was “fun to get others perspectives and it feels hopeful for good collaborations in the future” and also that “it makes a difference when we invest in the social... we can more easily contact each other...and in the space between private and professional we can engage in other conversations.”

However, there was also perceptions that the design team was not collaborating as much as needed to integrate all dimensions of sustainability, “maybe internally I think the collaboration is not 100 % integrating the sustainability issues...we can improve and
create a more integrated approach”. It was however perceived that the workshop had a positive effect on the integration of sustainability in the project and one respondent said that “it is important to listen to different perspectives from different experts”.

Overall, concerning the issue of integrating sustainability in problem identification and problem solving, participants said that there was no common goal within the team before the workshop, and that the participants had different ideas and thoughts from the beginning. A respondent said that while someone thought material was the most important factor, another thought energy was most important. The major difference before and after the workshop was, according to the respondent, finding common goals.

Before the workshop I was a bit stressed that we would do this a whole day. I thought to myself ‘we have already decided on Green Building Silver’, but it was great to be enlightened.” The respondent continued: “I had thought we would fuzz and fight…I remember we walked around and stood in different places in the room. We did not know each other then but now it’s easier to talk to each other. You get help getting started when you work this way.

Learning was also mentioned as a positive outcome of the workshop. A respondent said that collaborative workshops make participants “learn enormously from each other”. The respondent continues by saying that “we should have this kind of workshop more often, it is necessary in many areas to take time and discuss thoroughly, because you get to know each other and you get a better understanding”.

DISCUSSION

Collaboration in early design is found to be vital for the integration of sustainability in problem initiation and problem solving (Shelbourn et al., 2007). However, collaboration in early design is not easily accomplished and requires development of new collaborative methods and practices (Walker and Jacobsson 2014). Based in the concept of the social brain (Dunbar 1998), this study explores how collective thinking (Mercer 2013) can be supported by collaborative methods. To enhance collective thinking, i.e. the ability to learn and understand other’s perspectives and create shared frameworks (Pennington 2008), findings indicate that there are many aspects to consider when developing collaborative methods for collaborative thinking. For example, there is a need to work with structure and content as well as expectations and effects.

One of the aspects indicated in the findings is the creation of trust. Trust is often lacking in projects in the built environment (compare with Nyström 2005, Eriksson 2010), which was the situation also within the design team in the Hållbarhetsanalysen Skellefteå Culture House. There was an initial lack of trust between participants from different disciplines, which the interactive exercises and open communication that took place during the workshop changed. Findings indicate that it was the building of relationships during the workshop that supported this change. When participants got to know each other better, and when understanding each other’s perspectives better, trust could be developed. This insight, that a social and relational collaborative culture is important for collaboration has also been acknowledged by research on partnering (e.g. Nyström 2005).

Another aspect indicated in the findings is the potential in learning. Collaborative methods support more interaction, which creates opportunities to learn from each other. When seeing new perspectives in action, such as the contribution by the representative from the municipality, challenged the traditional thinking and created shared a frame of reference (Pennington 2008). When participants get to know each other better, they can take each other’s perspective into account and learn from each other.
The main purpose of using an extended collaborative method was to support innovation and the integration of sustainability. While the collaborative methods used in the workshop were generally perceived as positive and contributing to improving the collaboration and collective thinking, there was still a concern about the integration of sustainability. Findings indicate that the integration still needs development. The collaborative method supported the development of a shared goal but it is in need of further development to support the integration of sustainability, or as the respondent says: “…we can improve and create a more integrated approach”.

This study also has its limitations. The study only focuses on one intervention and more interventions are needed in order to be able to generalise the findings. Still, this study contributes with tentative analytical concepts and generalisations that can support future studies of early design teams and of the development of architectural practice.

CONCLUSIONS

The need for increased sustainability and innovation in the built environment can be addressed with an action research approach based in architectural practice, more specifically at interventions in early design work when different actors, disciplines and perspectives come together to identify and solve problems. Findings based on an intervention at a major Scandinavian architectural firm indicate that it is possible to facilitate early design meetings by extended collaborative methods order to support the integration of sustainability by enhancing collective thinking. Findings also indicate that extended collaborative methods support the creation of trust and learning in early design teams. Still, more research needed in order to develop methods that fully integrate sustainability in early design.

Findings have implications on early design team methods and practices in the development towards increased sustainability and innovation in the built environment and they contribute to the growing stream of research on architectural practice and its development (Nilsson, 2013).

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Grosse and Karrbom Gustavsson


Building on previous work addressing Action Research (AR) in the construction management field, this paper examines the application of AR methods and techniques on a project pioneering a new form of project insurance: IPI (Integrated Project Insurance). The practicalities of mobilizing a sustained AR programme on a live construction project are explored as the relationship between innovations (IPI), professional practice and academic research enquiry are juxtaposed. The methodological challenges and perceived values of AR are re-evaluated in the light of practitioner opinion and industry desire to learn and improve practices across the sector. The empirical insights facilitate a reassessment of AR in a construction project context in 4 distinct ways: the nature of the AR learning loop is clarified for a construction project context; the role of project participants in the AR process are examined; the workings of AR “interventions” are explored and the rationale and philosophical assumptions underlying an AR programme in a construction management domain are re-assessed. The informative insights will assist researchers considering an AR programme whilst the supportive recognition of professionals highlights how AR is a potentially valuable approach for industry and academia to work together to create knowledge and refine practice co-operatively.

Keywords: Action Research, collaboration, innovation, research methods

INTRODUCTION

As a research method, Action Research (AR) acknowledges the role of the researcher as an active participant in the project or process being examined; its focus being on doing research with and for the “project actors” to produce practical, useful knowledge (Reason and Bradbury, 2007). AR is as an alternative to “disinterested social science models” (Reason, 2003) where the researcher is a detached observer and examiner of the subject under study; AR is often proposed as a research method that improves practices, generates knowledge and brings about change in specific contexts (Eden and Huxham, 1996; Parkin, 2009). Whilst AR studies have previously been conducted in the construction project domain (c.f. Connaughton and Weller, 2013), such work has often failed to inform or assist other researchers considering an AR approach for their own projects. Moreover, the unique ways in which AR influences the dynamics of a live construction project have often been overlooked, and discussion of the theoretical and philosophical basis of AR as a research methodology has been muted. This paper begins to address such issues by exploring the application of AR on a construction project pioneering the use of Integrated Project Insurance (IPI) to facilitate greater collaborative working amongst construction project partners. The paper provides a continuation of the work reported by Connaughton and Weller (2013), and examines the application of AR techniques on a construction project called ‘Advance II’ for Dudley College in the UK.
The paper aims to enhance scholarly understanding of the application of AR in the construction management domain. It explores some of the methodological issues of mobilizing AR in a live construction project setting, and examines and critiques the role of participants and the nature of AR “interventions” over the project lifecycle. In particular, it examines the implications of adopting the AR ‘learning stage loop’ (Baskerville, 1999) in a construction context. Further, the implications for AR researchers of working in the commercial environment of construction are also examined.

The paper begins with an overview of AR as a research method and explains the rationale for its adoption on the Advance II project. The Advance II project and its novel features relating to the adoption of Integrated Project Insurance are then described. The specific methods of mobilizing AR are then detailed, and issues and problems experienced by the researcher embedded in the construction project are described. The discussion explores the methodological basis of AR, the role of participants and the nature of the AR “interventions” on the project, ending with a re-appraisal of the AR ‘learning stage loop’. The theoretical and philosophical assumptions underlying an AR study are then reconsidered for a construction project context where commercial and academic worlds meet and intertwine.

**ACTION RESEARCH**

Action research (AR) with its strong pedigree of social justice and community action (Reason, 2003) is fundamentally different to other research methods as it actively and intentionally endeavours to effect a change in a (social) system (Lewin, 1946). It typically aims to bring about change in specific contexts (Parkin, 2009) and requires “the active participation of the researcher in the process under study, in order to identify, promote and evaluate problems and potential solutions.” (Fellows and Liu, 2003: 21). AR has a dual goal of improvement and of generating knowledge (Eden and Huxham, 1996) but is also heavily context dependent, being neither standardised nor permanent. Therefore, AR is reliant on the project context and the knowledge, perceptions and subjectivities of persons involved (including the researcher, who should be actively contributing to the project itself). The origins and development of AR as a research method are outlined by Connaughton and Weller (2013) in a paper that also reviewed the history of AR in the construction management domain. Fundamental to AR is “action” rather than theoretical positioning, and these “actions” need to function effectively if the AR method is to work at all; such actions being planned in advance as part of a distinct research process cycle. The emphasis upon “action” has resulted in “models” of how “to do” AR. For example, Al-Balushi et al., (2004) and Azhar et al., (2010) argued that AR could be understood as a 5-step process, as in figure 1 below.

![Figure 1: the 5 step Action Research process (based on Al-Balushi et al., 2004 and Azhar et al., 2010)](diagram.png)

The study reported in this paper follows such a 5-step process, and also follows the recommendation of Baskerville (1999), Argyris and Schon (1978) and Greenwood and Levin (2007) in using specific “learning stage loops” to reflect collectively on the project workings. The AR learning stage loop cycle is depicted in figure 2 and explained further under ‘Planning an AR Programme’ below.
The AR learning stage loop is essentially an enhancement of the 5 step AR process: each of the 5 steps being present in the AR learning stage loop minus the Re-diagnosis stage and the re-iterative cycle indication. This paper adds more detail regarding how the AR learning stage loop model works in actuality when mobilized in a live construction project setting as the role of participants and the nature of AR interventions are also examined.

![Action Research learning stage loop](based on Baskerville, 1999)

**The Advance II project**

Dudley College, a further education institute in the UK West Midlands was actively seeking to procure a new facility (Advance II) to deliver their vocational training programmes. Integrated Project Insurance (IPI), a new approach to construction project insurance developed by Integrated Project Initiatives Ltd, a consultancy, was considered by the College for its potential to support improved collaborative working among design and construction team members and thereby enhance project outcomes. Conventional insurance arrangements require each construction designer and constructor to insure for their individual liabilities, and are believed to promote risk avoidance by team members and inhibit effective collaboration between them (Cabinet Office, 2012). IPI insures all the major project participants collectively, as a single entity (a ‘virtual company’), and is intended to promote improved collaborative working in the design and construction team leading to the development of cost-effective, shared solutions to design challenges (Integrated Project Initiatives Ltd, 2014).

Dudley College, supported by Integrated Project Initiatives Ltd, appointed a design and construction team early in 2015 to trial these new IPI arrangements on its Advance II facility. The project was included in the UK Cabinet Office ‘Trial Projects’ programme for monitoring new models of construction procurement (Cabinet Office, 2012) and the University of Reading (UoR) was appointed as academic partner on an Innovate UK (IUK)-supported research project to examine the performance of IPI on Advance II. A researcher was appointed, being embedded into project activities as much as possible (i.e. attending project meetings; receiving project correspondence; accessing the project Common Data Environment (CDE)).

This trial project represents the first formal adoption of IPI in UK construction. As such, the project parties required an opportunity to learn and improve through a managed cycle of research activities as the project progressed through key stages. An AR programme was therefore considered an appropriate and potentially helpful methodology, with the project researcher actively engaging, contributing and reflecting on the workings of the project with the actors themselves. In doing so, the researcher would integrate with the team as much as possible (whilst endeavouring not to impede or disrupt their work), creating a field for discussion and interpretation of processes and events (Fellows and Liu, 2003) involving researcher and participants.
Planning an AR Programme

A participant/practical approach was adopted for the Advance II project so that diagnosing and action planning would be executed in collaboration with the project players (Chein et al., 1948), such actions involving the active participation and cooperation of practitioners (Zuber-Skerritt, 1996). This approach is in line with the 'Northern tradition' of AR (Brown 1993), concerned mainly with group problem solving for a practical outcome within a commercially-oriented organisational context. More specifically, it is intended to maximize learning and give the project team further assistance with their work although any learning activities need to be carefully managed so as to not interfere with project work. On Advance II, the AR programme was conducted concurrently by 2 parties:

- The UoR researcher reported to IUK whilst assisting the team.
- The IPI Independent Facilitators guided the team (as mentors), continually reflecting on how IPI was working on the trial project.

The academic researcher was primarily responsible for observing and recording project practices, events and performance to help understand the operation of the IPI approach, whilst the Facilitators were focused upon assisting and guiding the project team with their tasks. Therefore, although AR rejects a “self-imposed distance from the world of action” (Dash, 1999: 479), the researcher on this project did periodically need to distance himself from activities in order to reflectively review progress and performance. An important element of the approach to AR on this project therefore was the learning stage loop (figure 2) with its strong focus on a cycle of learning and improvement activities helped by both the academic researcher and Independent Facilitators, albeit in different ways and for different purposes. This approach was adopted as a formal element of the research design on this project, in contrast to some of the more implicit approaches to AR adopted in less specific ways (e.g. Miller and Doree, 2008; Chan and Moehler, 2007). The effectiveness and practicalities of the AR learning stage loop are reviewed later in the paper.

MOBILIZING AR ON ADVANCE II

Introduction and obtaining consent

An essential starting point for the study was to introduce the AR research programme and obtain practitioner consent. This is a necessary activity for all research studies (not just AR), but was particularly delicate on Advance II as the project was the first live trial of IPI in the UK, and a UK Cabinet Office 'trial project', likely to generate significant outside interest. Although the usual obstacles and problems of negotiating access to a project (Laryea and Hughes, 2011) were not encountered (the UoR being part of an IUK-supported research consortium that included Integrated Project Initiatives Ltd, who were also the Advance II project facilitators), obtaining the active co-operation of the Alliance partners was an important issue meriting targeted activity. A formal approach was made to the Dudley College client and the Alliance Board (responsible for project delivery). The project partners recognized the academic merit of the study and were comfortable with the research approach to be adopted. The researcher was then invited to join the project provided that any commercially sensitive data would be safeguarded and data anonymized and protected.

Diagnosis and action planning

With the formation of the Alliance (essentially the governance body for the integrated design and construction team) and signing of an Alliance Contract for Advance II, a
multitude of issues quickly demanded attention and action (e.g. design development; cost planning; procurement strategy; opportunity/risk management; people resource costs). Following the AR learning stage loop (figure 2), diagnosis and action planning were initially executed separately by the researcher and Independent Facilitators. The researcher attended both Alliance Board and more detailed team meetings on design development from the beginning of the project, sitting alongside other team members directly at the 'board table' itself (i.e. not being inconspicuous, at the rear of the room), commenting and contributing to discussions when appropriate. These verbal contributions were managed very carefully and sensitively by the researcher for several reasons. Firstly, too many verbal interventions could be seen as disrupting the practitioners' work; secondly, time was a valuable resource for all members of the project team; and thirdly, the researcher had limited knowledge of some technical issues discussed (an ill-informed comment or question may have been viewed as 'slowing down' the work of Alliance partners by requiring them to explain matters). The researcher continually observed and reflected upon the work of the Alliance through meeting attendance and becoming more known to team members as time progressed. For their part, the Facilitators were integral participants at Board meetings, contributing more vocally at meetings than the researcher and advising and guiding the team on best practices when working in an IPI way. As project work progressed, certain issues became more problematic for the Alliance than others, such as agreeing an overall procurement strategy, establishing a collective understanding of risk and opportunity management and re-stating behavioural expectations for project participants. These provided the main focus of the facilitated interventions (the 'action taking' of the AR learning stage loop, figure 2).

**Action Taking: Facilitated Interventions**

Integral to action taking were the facilitated interventions undertaken by the Independent Facilitators and, to a different degree, the researcher. These interventions were designed to assist project partners with their work and generate data to help understand the operation of the IPI approach. The Independent Facilitators made many interventions during the course of the project, designed explicitly to improve the operation and effectiveness of the IPI model. In addition to their verbal and written contributions (at meetings; via email; telephone/skype calls), there were numerous Facilitator-led interventions, including the following:

- Plan in a Day & Build in a Day workshops facilitated focused Alliance discussion around an evolving 3D building model
- IPI training sessions: targeted assistance with workings of the IPI "gain/pain share"; Alliance Contract terms and ideal procurement strategy
- Refresher coaching: covering the principles underlying the IPI approach and the behaviours expected of project participants.

Whilst undertaking these interventions, both Facilitators and researcher observed and reflected upon their use with the Alliance. This led to a sharing of ideas of how they could be done differently for subsequent interventions (i.e. the re-diagnosis in the AR learning loop). As a result, several were done differently for the next iteration. For example, the format and attendance list for the 'Build in a Day' workshops were revised 2nd and 3rd time around to maximize supplier input; collaborative working principles were more forcibly communicated at refresher coaching sessions in later phases of the project. These are examples of “double-loop” learnings (Greenwood and Levin, 2007):
those that explicitly acknowledge the context of use within which interventions are mobilized in order to improve their effectiveness.

It is also appropriate, in the context of AR, to consider some actions undertaken by the researcher as interventions. These were aimed at assisting project partners to identify learning that could support the adoption of IPI. Such interventions included:

- Board presentations: to provide an independent view of project performance
- Lessons Learned discussions: enabling team members to reflect collectively on working practices and overall performance
- Reflective Opportunities: individual interviews; small group interviews and questionnaire dissemination provided the researcher with data whilst also enabling project players to reflect and re-consider issues themselves, leading to potential changes on the project
- Specific suggestions: the researcher contributed verbally at meetings with ideas (e.g. suggesting explanation of calculations of the Commercial Alignment should be included in the Alliance Contract Annex; encouraging partners to apply for Corporation Tax Relief as part of an R&D project)

These interventions were managed carefully. For example, interviews with Alliance members were scheduled at convenient times; transcripts were anonymized and returned to interviewees for review (and potential retraction). Obtaining and retaining the trust and confidence of project partners throughout this AR programme was essential, so these interventions were reviewed by the researcher prior to further use.

**Re-diagnosis**

The AR learning stage loop (figure 2) is predicated on the assumption that an action can be repeated (following re-diagnosis and modification) for a better outcome. On Advance II, there were several examples of this occurring:

- Work Package development: following Facilitator advice, responsibility for project work packages was transferred to "Trinities" (small 3-person groups representing commercial, programming and design interests) to facilitate better management
- Procurement: initial informal approaches transformed into more formal engagements with accompanying letters of intent/modified contract terms.
- Cost management: Facilitator intervention resulted in external reviews of costs by the wider project team, enhancing collective confidence.
- Workshop formats: Plan in a Day/Build in a Day workshops formats were refined iteratively, improving outcomes for all participants.
- Coaching: group training in IPI philosophy transformed into individual coaching to help some team members to work in a collaborative project environment.
- Look Ahead review meetings: format changed following Facilitator advice to include key site supervisors, site requirements and latest information.

These examples illustrate the value of the learning stage loop in action: re-diagnosis of an issue resulting in refinement and better execution. However, it is not always possible or desirable to repeat an action for a better outcome in a construction project context. For example, the bidding and selection process cannot be repeated and numerous site activities (e.g. pipework installation; steel frame erection) should ideally only be executed once.
DISCUSSION

The mobilization of an AR programme on Advance II enables 4 different aspects of AR to be re-evaluated: the nature of the AR learning loop; the role of project participants; the working of AR interventions and the theoretical assumptions underlying an AR programme.

The AR Learning Loop

The nature of the AR learning loop has been clarified for a construction project context. AR action planning should include careful consideration of how the researcher will become methodologically engaged in project work (e.g. some site activities will be difficult to examine). Subsequent action taking should be appropriate and considered carefully (e.g. the number of facilitated discussions held could be counter-productive). In this paper, we consider researcher verbal intercessions as interventions and a form of "re-diagnosis" or "action planning" (see Figure 2) with the potential to affect further action taking by the project participants. Such contributions distinguish an Action Researcher from a passive observer.

On Advance II, the use of AR "learning loops" proved positive; the researcher being directly engaged with project participants to gather their thoughts and opinions, with the work of the researcher and Facilitators being distinct but complementary. In this way, the AR approach resulted in a combined "co-production" of knowledge, action and outcomes (Harty and Leiringer, 2007) between researcher and Facilitators.

Role of Project Participants

Some scholars, such as Azhar et al., (2010), make compelling cases for the value of AR to improve construction industry practices, but do not discuss the social issues that inevitably arise when an “outside party” enters a project and suggests changes. Evidence from Advance II suggests this is not an insignificant issue. Firstly, there is a distinction between obtaining consent to participate in research and obtaining the agreement of the participants to the more active participation in their endeavour of the researcher. On Advance II, for example, researcher requests for information or assistance were sometimes overlooked as the team maintained a focus on their activities.

Moreover, the opinions/knowledge of the researcher were rarely sought out by the Alliance partners who believed themselves to be competent in relevant technical matters. Ideally an AR researcher should be acknowledged as an active participant in the process being studied. While on Advance II, the project partners recognized the R&D (research and development) potential of the project and did co-operate with the researcher, they did not always seek the researcher’s views to the same extent as those of the IPI Facilitators.

On construction projects, an AR researcher must expect to introduce themselves repeatedly to new people on the project, who enter at different phases of activity. Whilst there may be initial suspicion about the researcher’s presence and intentions, this can be allayed via pre-prepared information sheets and through continual meetings. In a fast moving project context, new faces will frequently appear at meetings and the researcher must keep track of personnel changes and introduce themselves at appropriate times.

Further clarifications may be needed of what the researcher is trying to achieve. Seymour et al., (1997) explored the notion of objectivity in research and how researchers were often faced with a dilemma of whether or not to be seen as organisational "outsiders". On Advance II, the distinction between the interventions of the Facilitators and those of the researcher help clarify their respective roles and positions; the Facilitator interventions being oriented towards the practical, project issues and the researcher
interventions providing Alliance personnel with opportunities to reflect upon and change practice. However, the distinction highlights a dilemma a researcher faces in being both an outside observer and an active project participant at the same time. On Advance II, differences in participant outlook towards the interventions of the researcher and Facilitators suggests that this dilemma was not entirely resolved, with the researcher being seen as essentially a project "outsider".

Working of AR Interventions

The researcher’s experience of AR on Advance II aligns with arguments of Henry (2000) that 3 primary requirements must exist for AR to work in practical terms: a trust-based relationship between parties; negotiated access to information and interpretation of data; an open-ended research project plan. On Advance II, the Facilitator’s role was focused upon coaching and guiding participants on conducting the construction project work in an IPI way: they were the “problem-solvers” that people often looked to when difficult issues arose. The researcher, by contrast, was more of a “background figure”, observing project progress whilst contributing periodically via comments, presentations and providing opportunities for reflection.

Theoretical assumptions of AR

Azhar et al., (2010) state that AR is not a specific method of research, but rather an approach to doing research. It can be understood as an interpretivist method for understanding human behaviour, having a distinct emphasis on reaching an empathetic comprehension of human action, and aiming to understand human behaviour rather than explaining it (Bryman and Bell, 2003). There are also assumptions about an AR programme that need to be highlighted. Whilst an AR researcher may be welcomed into the project fold, it is impossible for the researcher to be privy to all conversations and interactions occurring, particularly in a dynamic and fast-moving project and it may be inadvisable to repeatedly contact individuals for information and assistance. Additionally, keeping track of project activities may be difficult due to the intensity of work occurring, especially once a site is fully operational, though the insights reported here relate mainly to design phase work, where activity was off-site (i.e. in meetings and discussion groups).

The underlying rationale of AR posits that knowledge may be increased and performance enhanced by working closely with participants so that a “co-production” of knowledge can take place (Harty and Leiringer, 2007). However, mechanisms need to be in place to facilitate this interaction. Moreover, an AR approach is likely to produce a potentially more rich and nuanced understanding of the social realities of construction work than either a purely quantitative or qualitative analysis of the same interactions; an additional strength of AR being its’ in-built reflexivity (embodied in the learning loop cycle) that encourages a critical reflection of methods used in the domain under study. On Advance II, the reflections led to improvements to multiple issues, including procurement work and work package management.

SUMMARY

The paper has provided a detailed account of AR work undertaken on the Advance II project. The use of "learning stage loops" (Baskerville, 1999), has extended the application of AR techniques in the construction management domain, whilst the account of activities and researcher experiences adds to scholarly understanding of mobilizing AR in a live construction project setting. Additionally, by detailing the methodological practicalities of employing an AR approach and the role of participants and AR "interventions” over time, a more sophisticated account of AR has been provided that
builds upon simpler definitions (e.g. Fellows and Liu, 2003). The paper findings indicate the AR learning loop is a potentially effective approach for improving practices and generating knowledge, although the issues surrounding its’ mobilization are significant, including obtaining the active assistance of practitioners, careful consideration of executing interventions in a live project setting and providing time for reflection and re-diagnosis. These insights indicate the value of the AR method for construction project management research as well as its’ practical challenges.

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Collinge and Connaughton


Public engagement has become an integral feature of urban development projects in many parts of the world in recent years. This paper focuses on what takes place within the formal administrative engagement platform for urban development projects in Hong Kong. An ethnographic approach is employed to explore public engagement as a social and cultural phenomenon. In so doing, elements from the Latour-Callon ‘translation model’ of power are borrowed to examine how the actions of managers of public engagement constitute ‘moments of translation’ within a wider power system. In particular, an ethnographic interview with a project manager is closely examined, to explore the different techniques that are used in attempts by the manager to align the diverse and conflicting interests of multiple stakeholders with those of the project. By recasting the interactions between stakeholders as a continual process of enrolment into the project, we set out to challenge the way public engagement is commonly conceptualised in construction management as a risk management strategy or corporate social responsibility requirement. Instead, it is argued that each entity that enters the public engagement process aims to define the project to their advantage, and that various moral or normative rationales may be used by actors to justify their position.

Keywords: public engagement, project briefing, power, ethnographic interviewing

INTRODUCTION

In recent times, increased societal pressure has been placed on governing bodies to embrace the notion of ‘inclusive governance’ (cf. Lane 2005) and allow for the public to be involved in some of their decision-making processes. Urban development projects, which tend to have a long-lasting effect on large groups of people, have been a prime target within this movement (cf. Legacy 2012). In response, many such projects in Hong Kong are now incorporating some form of official public engagement (PE) process as part of their planning and feasibility studies.

The premise of PE is for the government to meet with stakeholders of the project in a systematic way. Through these meetings, project information is communicated to the public, their feedback is sought in turn, and that feedback is then incorporated into the ongoing design. In general, there are three main aspects that define PE mechanisms: ‘public communication’, ‘public consultation’, and ‘public participation’ (Rowe and Frewer 2005). ‘Public communication’ is the process of information dissemination by the project sponsor; ‘public consultation’ is the process of gathering feedback from the
public; and ‘public participation’ is the two-way dialogue, facilitated through ‘public communication’ and ‘public consultation’, whereby feedback from the public may be incorporated into the ongoing project. Effective ‘public participation’ requires continual assessment by the project manager to incorporate new goals formed as a result of partaking in dialogue with the public.

The PE process provides opportunities for participants to exert their influence on the project, and participants act to put themselves in the most advantageous position for negotiating project goals. By democratising the decision-making process, the project sponsors, and numerous interest groups and professional bodies must also vie for power alongside public stakeholders. In the following section, we give an overview of how Latour and Callon conceptualise power relations by explaining their ‘sociology of translation’ (cf. Latour 1986, Callon 1986a, 1986b), and specifically, the four ‘moments of translation’ coined by Callon: ‘problematisation’, ‘interessement’, ‘enrolment’, and ‘mobilisation’ (Callon 1986b). A brief summary of PE within the Hong Kong context is then given, with particular attention to the specific socio-political conditions under which PE operates. Thereafter, an ethnographic interview with a manager detailing her experiences of managing PE processes in Hong Kong is presented to illustrate how the actions of the manager and those around her may constitute examples of ‘moments of translation’. The aim of the exercise is to explore the role of the manager within a wider power network. The paper concludes with suggestions on what new insights may be gained by conceptualising the role of the manager in this manner.

A SOCIOLOGY OF TRANSLATION

Rather than categorising whether certain entities possess power, Latour argues that power is lived out and played out in social situations, and exists in the abstract space where relationships are developed. When entities interact with a task, they exercise their power by ‘translating’ the task to align with their own interests. He calls this the ‘translation model’ of power (Latour 1986). Callon (1986b) elaborates on the ‘translation model’ by exploring how entities are defined, associated and simultaneously obliged to remain faithful to their alliances. A series of translations are identified to have taken place when entities from the social and natural world form associations and alliances with each other. During this process, certain entities control others, and form the foundations of power relationships.

Within this interpretation of power and power relationships, alliances are formed in series of events which Callon coins ‘interessement’ events. Roughly translating to ‘inter-positioned’ from French, ‘interessement’ describes a group of actions by which one group of entities (for example, ‘A’) use their influence to impose or stabilise the identity of other entities (B, C, D, E) in order to conform to the way a situation has been framed in their minds. In the process of A forming a connection or alliance to B, A must act to sever or weaken any active or potential connections that B might have formed with other entities C, D, or E (see figure 1).

Callon’s study identified four ‘moments’ of translation: ‘problematisation’, ‘interessement’, ‘enrolment’, and ‘mobilisation’. ‘Problematisation’ describes the way one entity seeks to become indispensable to another entity by giving definitions to the problems, and then suggesting that these problems could be resolved if they were to follow certain actions. ‘Interessement’ describes a progression of events where the first entity seeks to secure each of the other entities in the previously prescribed framework. However, merely setting up a series of ‘interessement’ events may not necessarily lead to the other entities taking any action.
To do so, the enrolment of other entities is necessary. Therefore, ‘enrolment’ denotes the set of strategies that an entity uses that leads to other entities accepting their designated roles. Finally, ‘mobilisation’ describes the actions taken by the first entity to make sure that their spokespersons are representative of the cause they claim to represent. It is only through observing a ‘translation’ in the process of taking place that the strategies, intrigues and power plays could be made visible. If the ‘translations’ were successful, then all that would be left to be observed would be tangible results (Callon 1986b), such as the documents, regulators, a project timeline, and a development proposal.

Public Engagement in Hong Kong

The processes for PE in Hong Kong remain contentious, with the government in the past being criticised for the heavy-handed way in which they have managed engagement efforts (Cheung, 2011). In an ‘executive-led’ government, the civil servants still have the capacity and the resources for setting the agenda for development, including the pace and scale of development (Ng, 2006, 2008). It has even been argued that PE exercises are used as a ‘tool of hegemony’ by the Hong Kong Government to control aspects of planning policy (cf. Tang, Lee, and Ng, 2012). Although statutory PE processes do exist in Hong Kong, the type of PE as described by Rowe and Frewer (2005) fall under the umbrella of non-statutory PE. These are increasingly being applied to urban development projects, typically in the early conceptual design stages, before the plans are formally gazetted to the Town Planning Board for government funding. From the above, it may be inferred that the manager operates within a tense political climate where they are at once given the freedom to interpret the way public feedback can inform project goals; and under enormous public scrutiny in the way they conduct PE.

Despite the lack of regulations governing non-statutory PE, a review of recent PE processes show a protocol set around 2 or 3 general stages. At the launch of each stage, a ‘project digest’ along with other project information, is published online; and hardcopies are made available for distribution at meetings with stakeholders. The formal events for each stage may include a ‘roving exhibition’, followed by focus groups, workshops, and/or public forums. These events aim to garner feedback from the participants towards the project, and provide an opportunity for the project team to answer participants’ questions or concerns. Participants may use these events to lobby for changes to, or stymie aspects of, the project brief as proposed by the project team.

Data Collection

Acknowledging the importance of observing a ‘translation’ in progress, this research utilised ethnographic methods that placed the researcher within close proximity to the subjects of research. Data was collected by the primary author, and included participant observations, ethnographic interviews, and document analyses. Spanning a period of 34
months, the author participated in seventeen formal engagement events for a range of urban development projects, each lasting 2 to 3.5 hours in duration. These participant observations provided an understanding of the rules of engagement of PE in Hong Kong. From the insights gained, one project team from a consultancy firm who had been heavily involved with PE of urban development projects was selected for in-depth study, and seven ethnographic interviews were conducted with three core members of the team over fourteen months. Each of these in-depth interviews was audio-recorded and transcribed verbatim, and ranged from 42 to 90 minutes in duration. The premise of ethnographic interviewing is to incorporate the ideological underpinnings of an ethnographic approach to conduct interviews. It values the quality of the relationship with respondents, and on the meaning of actions and events to respondents (Jupp 2006: 99). The researcher is there to learn from the interviewee, rather than to impose an external frame of reference (Spradley 1979).

The examples presented for illustration in this paper are drawn from the PE processes of ‘NewTown Extension Project’, a planning and engineering feasibility study for a town of around 200ha located in the New Territories of Hong Kong which, together with the masterplan for its neighbouring suburbs, aims to provide more than 600,000 new residences to the area. The quotes are extracted from an ethnographic interview with ‘Stacey Lee’, one of the core team members on the project, who is a planner by profession (all project identifiers are pseudonyms). The experience, and specifically the researcher’s experience, is central to ethnographic studies, both empirically and theoretically (Willis and Trondman 2002). In staying true to the ethnographic tradition, the following section reporting on the interview is written from the first-person perspective of the primary author.

The Interview

I first met Stacey in mid-2013, during the participant observation of a community workshop for the NewTown Extension Project where Stacey was one of the facilitators. A social relationship was initiated at this event, and a formal interview was conducted in mid-2015. By that point, Stage 3 of the public engagement for NewTown Extension Project had been completed and Stacey was working on finalising the plans to be gazetted at the Town Planning Board. The interview was conducted in one of the meeting rooms at Stacey’s workplace: a glass tank that overlooked an internal atrium. We talked about her experiences on the project with particular focus on exploring how she dealt with specific situations that arose. Because I had attended the community workshop for Stage 2, and the public forums for Stages 2 and 3, we naturally gravitated towards discussing various scenes from those engagement events. At the beginning of the interview, she self-identified as a ‘project coordinator’ for the NewTown Extension Project. She was forthcoming with answering my questions and keen to highlight her involvement in the project, and she was especially proud of her professional growth within that project. This was apparent when she reflected on how pleased she was that she had joined the project as a junior staff member, but by Stage 3, she was chairing most of the meetings and leading most of the discussions during PE events.

Educating the Public

To Stacey, the main goal of PE is to educate the public. The planner needs to educate the public about many things. They need to explain planning related terms and concepts to laypersons before the layperson can understand the plans presented and they need to translate pragmatic problems voiced by participants into design solutions. When interacting with individual stakeholders, the planner needs to convey not just how the
design will affect the individual they are talking with (which is usually the individual’s sole concern), but also how it affects others.

S: I think one of the merits of the public engagement, apart from really making a plan to happen that is suitable for the locals, [is that] it’s also a learning process. Because they know. They now know what is ‘zoning’, what is ‘plot ratio’. I think a lot of people don’t know; even my mum doesn’t know. Like, for some villagers, from Stage 1, they know nothing. And to be frank, each stage, they may be (…) challenging [as more]. Because they know nothing, and you know the villagers, they worry the village will be destroyed and their vast interests be affected. But in Stage 3, they will tell [us] – “ah, I like Plot Ratio 1 next to me”. So it is good. Yeah.

This discussion concerning a layperson’s perspective reminded me of the Stage 2 community workshop I attended. The discussion tended to drift off to issues concerning their everyday plight, such as the cost of public transportation, but which did not necessarily relate to design or planning issues. Stacey responded:

S: Yeah… Sometimes they don’t understand. They thought a planner can do everything: we can adjust the bus route; we can adjust the bus price (…) so I think what is important in the workshop is that the facilitator has to know very well what is the scope of the study; we have to confine the – of course, their comments on these are also written down and recorded, but, it’s not something that we can change on the plan. But we have to tell them, “this is outside our scope, but we will reflect for you, but [what you just said] might affect this, this, this, and that,” and focus the discussion on solutions.

The local resident’s goal may be ‘overall quality of life’ but the planner needs to define the problem for the workshop and (by extension) the project, and make sure the participants focus on aspects of the project that has the possibility of being addressed within their professional capacity.

**Conflict of Goals between Stakeholders Groups**

Within the area earmarked for redevelopment are different stakeholder groups, including local residents, local business owners, an assortment of special interest groups such as environmental and political lobbying groups, and other users of the site. Of this last category of users, a group of Buddhist nuns who have a temple complex in the area were amongst the most vocal. I recalled the difference in atmosphere between Stages 2 and 3 of the public forum. During the Stage 2 public forum, when the nuns stood up to speak, the room grew respectfully quiet. In the Stage 3 public forum, however, villagers would grow impatient and interrupt a nun when she was talking, and towards the end, would even direct hostile verbal abuse at them. The nuns responded with composure throughout, and the drama of the moment was captured by the media’s cameras, which were stationed in the back corner of the forum. Stacey filled in the gaps for me:

S: It was kind of… a political issue, I guess, about the interests of the landholders. Because during Stage 2, I think the nuns group were pretty good at the media stuff. And then, the voice is really great, but actually, from my experience with them, there [are] stakeholders or residents of villages, and the village representatives in the valley area, [who] haven’t heard of this [temple], and [the temple] is quite new to the area. And afterwards, they got a lot of media coverage… I think the villagers and the temple got a… a worsened relationship in that year. (…) The villagers somehow talked to us and saying that we are giving benefits to the temple. And saying that (…) actually [the nuns] are outsiders coming in, and they ask for more and more, and then they actually occupied a private land without a licence, but as they have already built something there, and now it is legalised. Something like that. So, there are quite… it’s a little bit political, and about the land interest.
Then a few minutes later in the interview, to focus attention back to how she dealt with this situation, she explained:

S: To be frank, it’s an existing structure, and we need to respect it… But of course, about the relationship, I think it’s better not to put any emotional attachments to these arguments, because we just, as a professional planner, we see that this location is a temple (…) And for the area surrounding it, with [the] butterfly habitat, it’s a green belt. It’s pretty straightforward.

When deciding how to deal with a situation, Stacey believed it was important to be a planner first and foremost, and not be side-tracked by ‘emotional attachments’.

Switching abruptly to a planner’s lexicon, Stacey converted their conflict, which she identified as ‘political’ issues, into design issues.

**The Use of Visual Materials**

Throughout the interview, Stacey had hardcopies of the project digests on hand, and she liked to refer to them as she talked. The digests were coloured booklets of around 30 pages each, detailing project information and consisting mainly of high-resolution images paired with short textual descriptions or explanations. The plans presented in Stage 2 were bubble diagrams; whereas the plans in Stage 3 contained more detailed zoning maps, photo montages, and computer-rendered visualisations of proposed designs.

Pointing to a bubble diagram in the Stage 2 digest, Stacey explained that deliberately using ‘cartoonistic’ diagrams in Stage 2 enabled them to focus discussions on the general concept behind the design proposal, whether it be to highlight the provision of housing, or the balance between housing and new job opportunities. Conversely, the Stage 3 digest contained more detailed plans and computer-rendered images, where each image was chosen for a specific reason. Stacey pointed to each image as she explained to me:

S: Say this one, this was chosen because we wanted to show the visual corridors. Because, yeah, um, you can see the visual corridors and ventilation corridors. (…) And this one, it’s [a] photo montage, because um, these are the proposed areas, so you can see these are along the hillside. And (…) these are the existing villages; this is our proposed development. You can see the density is not that high. So they can have the concept of “3-D plan”.

The diagrams were overlaid with oversized, brightly coloured arrows that highlighted design features such as ‘visual corridors’ and ‘ventilation corridors’. The photo montage was a helicopter-view that showed a photo of the existing development and the adjacent hillside, with a computer rendered image of the purposed development superimposed. It represented what the finished design will look like, against the existing landscape. An image may also prompt design changes in other ways. Referring to a computer-rendered architectural street-view of the town centre in the Stage 3 digest, Stacey explained:

S: Our idea for promoting street shops was originally from Stage 1 and Stage 2 PE. They wanted [pedestrian] streets, and they wanted more economic opportunities, and they wanted more shops, but they had some concerns as well, after seeing this picture. “Ah, maybe there will be a noise problem”. Like, “ah, we always like alfresco dining, but that may cause a lot of noise issues”. So, [these are] new ideas. And then “ah, maybe we can set back the residential a little bit”. And this helps us to refine our design as well.

In these examples, imagery has been used in three distinct ways. Firstly, they served as a tool for explaining abstract design concepts such as ‘visual corridor’ and ‘ventilation corridor’. Secondly, they lend clarity and authority to more contentious issues such as building density, thus aiding Stacey to sell certain design solutions. Finally, by conveying the design concepts in a visually accessible manner, they opened up avenues for discussion which led to further changes in design.
Engagement as Enrolment

Each of the entities identified in the previous section were actively engaged in the translation process, in that they both translated others’ goals, and their goals were translated by others. The entities include Stacey the project coordinator, the villagers, the group of nuns, the media, and even the visual images in the project digest. Their translation process encompassed each of the four stages as outlined by Callon (1986b): ‘problematisation’, ‘interessement’, ‘enrolment’, and ‘mobilisation’. Examples for each of the stages are explored below:

Problematisation

As the project coordinator, Stacey needed to guide the participants to discuss issues that could lead to design solutions. Although she did not inhibit participants from raising their concerns, and may go so far as to note their comments down, any comments that were not translated from personal or political issues into design or planning issues would simply not be acted upon, and would not be incorporated into the final design. Likewise, each of the entities had the opportunity to present what they saw as the problem, and each of the other entities had the discretion of accepting or rejecting their problematisation of the issue. As a case in point, the media accepted the nuns group’s problematisation, whereas the villagers did not.

Interessement

Empirically, it is difficult to resolutely claim that interessement has taken place, since it includes the hypothetical condition of severing or weakening potential alliances that may have been formed in place of what was observed to have been formed. In such cases, it can only be inferred from actions surrounding the observed event. The nuns group had successfully formed an alliance with the media and was able to use the media to amplify their voice. Because Stacey’s domain is planning and design, she was relatively immune to their attempts at ‘interessement’, but she did accept the temple into her plan because of its status as an ‘existing structure’. In a way, the physicality of this structure was the prime characteristic that successfully interested and enrolled Stacey to secure its place in the final design. This example shows that, firstly, successful interessement does not always lead to successful enrolment of a cause; and that secondly, successful enrolment requires at least a perfunctory alignment of goals between entities.

Enrolment

After a participant had agreed on the project coordinator’s characterisation of the problem, and their path had been cleared of competition by way of interessement, Stacey needed to take actions to then enrol the participants and ensure they adhered to their designated roles. Stacey has expert knowledge of how to use the images as a tool for persuasion, and was attuned to how a bubble diagram and a realistic photo montage may be used in different ways to focus or divert discussion. Once the images were created, printed on paper, and distributed as part of the project digest, they also played an active role to enrol entities. The design digest booklet in its concrete and tangible form held authority in its own right, which other entities then used to their advantage. Besides the drawings, Stacey also identified the importance of educating the public. Specifically, she understood how educating the villagers to planning concepts, such as ‘zoning’ and ‘plot ratio’, was key to enlisting their support. After the villagers had formed some sort of alliance with the project coordinators, evidenced by their attendance and participation at the event when they could well have been somewhere else, Stacey took certain actions, within the format and expectations of the PE event, to enrol those who were in
One way was by making the planning concept visually accessible to laypersons; another was by educating laypersons to the meanings of urban planning jargon terms.

**Mobilisation**

While how Stacey used the images within a community workshop setting is an example of enrolment, the production of the project digest itself, and especially the selection of images, can be used to illustrate the process of mobilisation. As the project coordinator, Stacey and her team had been charged with the task of incorporating the feedback of multiple stakeholders together into a product that can be presented as the overall design solution. Graphical representations of the design were developed alongside the conceptual design, cumulating in the production of the design digest booklet. Hence, the mobilisation of the design solution was partly actualised through the compilation of the project digest. As Stacey indicated, bubble diagrams were deliberately selected to represent ‘conceptual’ designs, whereas photorealistic images were used to convince the viewer of specific design attributes such as density, visual aesthetics, and ventilation. Collectively, the compilation of images enabled Stacey and her team to present a narrative that speaks for their design.

**CONCLUDING REMARKS**

This paper explored the public engagement processes of an urban development project, to illustrate how Latour-Callon’s ‘translation model’ of power could be applied to study interactions between stakeholders in a situation where the goals are highly contested. Power was exercised by entities by enlisting other entities to confirm to their own way of viewing the problem, and enrolling them to take certain actions towards addressing this problem. Interactions between entities enabled project details to be challenged, discussed, and renegotiated. By avoiding a project-centric view of PE, this study shows that the ‘public participation’ aspect of PE is based around an open dialogue between parties and characterises an underlying system of power where each entity attempts to align the project goals to their own interests. The ‘participation’ aspect of PE is highly dependent on whether participants agree to the problematisation of the events, how they are able to interest the process, what actions they take to enrol others, and finally, whether they can find the right format of representation to give voice to their views.

Stacey’s accounts point to an awareness that public engagement is an ongoing process extending beyond the official ‘public engagement period’, and further, that it is interwoven into the overall plan-making process. The analysis of the accounts show that managing public engagement processes requires the manager to take on a range of roles, for example, as a communicator, coordinator, negotiator, educator, or advocate. These roles are managerial as well as social in nature, and they are borne out of circumstance. In other words, managers employ tactics that they judge to be pertinent for a specific time and towards specific people. Hence, instead of classifying public engagement as a stakeholder management exercise (e.g. Rowlinson and Cheung 2008; Turner and Zolin 2012), a risk management exercise (e.g. Close and Loosemore 2014; Cuppen et al., 2016; Loosemore et al., 2006; Yu and Leung 2015), a conflict management exercise (e.g. Tam et al., 2009), or a trust-building exercise (e.g. Tsang et al., 2009); the accounts illustrate how the process may be all of these things at different times, depending on the circumstance and the role the manager decides to take on. Stacey’s account supports the premise that the public engagement process is emergent, dynamic, and in the midst of co-production (cf. Chilvers and Kearnes 2016). Rather than characterising public engagement as a means to an end, and attempting to abstract the ways in which the
outcomes of public engagement may affect the outcomes of a project, the approach taken by this study places the emphasis on exploring how public engagement acts as a conduit for divergent, and at times conflicting, interests to travel through. By conceptualising the exercise of ‘power’ as ‘moments of translation’ and exploring a manager’s attempts at affecting social behaviour to achieve goal alignment, the study provides insight into the ways in which a manager navigates an evolving and complex power network.

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Chow and Leiringer


DESIGN
REDEFINING DESIGN IN CONSTRUCTION

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Several theoretical framings have been proposed regarding the nature and process of designing but these mainly see design as a creative activity. However, designing in construction is a collective undertaking that involves not only ‘creating’ discipline-specific parts of the design but also ‘organising’ them to ensure consistency and coherence. Nevertheless, organising design in construction is under-theorised, and there are no clear explanations of what constitutes design collaboration and how it is different from designing. These gaps imply not only a shortcoming for managing design in construction, but also a difficulty for developing technology that effectively supports it. Therefore, this paper adopts a practice-focused approach to explore the interdisciplinary design interactions in a project from an organisational point of view. This develops further insight into the natures and processes of designing and design collaboration in construction, thus informing the management of design. When seen from a practice-based perspective, multidisciplinary design development becomes an ongoing process of re-establishing 'a shared sense of purposefulness' that enables both autonomy of, and consistency between, different design disciplines. This provides an explanation of the interdependency between specialist knowledge and interdisciplinary interactions. Thus, the paper develops definitions of design and design collaboration in construction that are centred on 'organisation' rather than 'creativity'. Implications for technology development and management are outlined.

Keywords: design management, organisational analysis, research methods

INTRODUCTION

Design in construction requires collective working of multiple professionals from different disciplines. However, different professionals see design differently based on their discipline-specific perspective to make sense of and develop their part of the design. Hence, defining and managing the practice of design in construction is problematic as both autonomous (i.e. discipline-specific) and collective (i.e. interdisciplinary) aspects of it need to be considered in an interrelated way. This implies that the nature and process of interdisciplinary design interactions need to be better understood to establish a definition that explains both the autonomy and collectivity inherent in the practice of construction design. Such an understanding of design in construction is critically needed to develop practically-relevant support technologies and management approaches.

Wider literature on design provides theorisations of design that are centred upon the creative designer (e.g. Alexander 1964), performance of the designed artefact (e.g. Simon 1999/1969) or creative development process (e.g. Le Dantec 2010). Although these present a range of theoretical lenses to establish design as a peculiar artistic or professional activity, they hardly inform the management of or technology development

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for multidisciplinary design in construction (Kvan 1999; Koskela et al., 2002). Thus, until recently, construction design management has largely been studied either as architectural management (Emmitt 2016) or as technical project management which relies on discipline-based breakdown of design tasks (Zerjav 2012). Besides, the concept of 'design collaboration' has been under-theorised and used as a generic term to mean different things in different studies (Kvan 2000).

This paper adopts a practice-based approach (Feldman and Orlikowski 2011), and builds theory upon everyday interdisciplinary design interactions in a construction project to redefine design in construction from an organisational point of view. It builds on the view that interdisciplinary design interactions are not the means for integrating isolated parts of the design 'created' by different design practitioners. Rather, the 'practice of design' suggests that design develops through ‘overwhelmingly-intertwining’ interdisciplinary interactions which present a continuous path of unfolding decisions and activities (Zerjav 2012). Consequently, the paper aims to set ‘design’ (in construction) as an organisational phenomenon to balance the current theorisations focusing on creativity, and enable insights into its day-to-day management and support by technology. It uses empirical data from an educational building project in the UK at its detailed design stage. The analysis provides insights into how a sense of ‘what to do’ and ‘what ought to be done’ was established and maintained in the project. The paper reveals that multidisciplinary design development is an ongoing process of re-establishing ‘a shared sense of purposefulness’ that enables both the autonomy of, and consistency between, different design disciplines. Based on this, it is argued that more critical practical management of interdisciplinary interactions is crucial for effective design management, and that the focus of the collaborative technologies must shift away from data-integration.

THEORISING DESIGN

According to Minneman (1991), design research appeared as an individual topic of research in the 1950s due to the doubts about whether increasingly complex engineering projects could be rationalised to be managed. Therefore, at the early times of design research, the dominant debate was around the roles of rationality and intuition in design. For example, Alexander (1964) focused on conceptualising ‘the designer’ and claimed that he/she needs to employ a mixture of intuition and rationalism to develop the correct form. On the other hand, Simon’s (1999/1969) unit of analysis was ‘the designed artefact’, and he developed a conception of design based on the designer's limits of rationality in considering the possible future conditions to which the artefact would be exposed.

However, the centrality of rationalism in this debate attracted criticism. One of the best-known critiques came from Rittel and Webber (1973) who argued for a conception of design centred on the ‘design problem’ rather than the rationally designed artefact or privileged designer. The authors claimed that design problems must be differentiated as ‘tame’ and ‘wicked’ when conceiving design. Tame problems are the ones that are suitable to be understood and resolved rationally in certain pre-agreed terms. However, the resolution of ‘wicked’ problems do not have definitive formulation and relies on intuition because “the information needed to understand the problem depends upon one’s idea for solving it” (Rittel and Weber 1973: 161).

The criticisms around the rationalistic views of design gave birth to a ‘second generation’ of analytical methods that focused on what designers do and how they think (Coyne 2005; Kimbell 2011). This shifted the ground to an empirical consideration of how professional rationality is established, giving a profession a unique character and a texture that can be
recognized externally in rejection of a rationality based on an abstract logic (Coyne 2005). The work of Schön (1983) is well-recognised among this so-called ‘second generation’ of analytical methods. Schön (1983) argues that problems are not given in professional practices, and therefore, professionals ‘frame’ problems based on their judgements. According to Schön (1983), these judgements, which he calls ‘professional artistry’, enable professionals to tackle unique problems in practice. Thus, he claims that design is a ‘reflective conversation with the situation’ which involves reflectively acting on the situation to ‘frame’ the problem, and so advancing its perception (Schön 1983).

Since 1990s, several theoretical viewpoints conceived design based on the social and material conditions that underpin either the ‘rationality’ or ‘professional artistry’ of design practitioners. For example, Bucciarelli (1994) conducts an ethnography and reveals that the engineering design is not an instrumental process but a historically situated social process that is full of uncertainty and ambiguity. Julier (2006) argues for studying design as a culture that is open to the effects of the immediate context of designing, but also shaped by pervasive norms, technologies, organisational patterns, and morality which enable universal applicability of design to a variety of unique issues. Similarly, Le Dantec (2010) conceives design as a social creation relying on 'cultural cognition' to account for the shared understandings in design situations as well as the moral and practical purpose that are ascribed to the shared activity.

The practice-based view of design, which is adopted in this paper, is another theoretical approach that considers the socio-cultural, historical, and material embeddedness of design to explain the enactment of 'rationality' or 'professional artistry' that is argued to underpin design. Nevertheless, uniquely, its unit of analysis is 'practice' and so it emphasises the observable interactions of practitioners (with social and material entities) (Kimbell 2009; 2011). However, so far, practice-based studies of design have been preoccupied with investigating design situations to unpack ‘creativity’ inherent in design (e.g. Luck 2012) rather than conceiving design as an organisational phenomenon.

RESEARCH ON ORGANISING DESIGN IN CONSTRUCTION

The previous section has shown that theoretical approaches to design are fragmented and divergent both philosophically and methodologically, and they are dominated by ideas of design as a creative activity. Also, there are surprisingly few studies that aim to build theory about the nature of design in the construction industry. Some contributions (e.g. Koskela et al., 2002; Baudains et al., 2014) give a critique but do not converge into wider theories. Additionally, as suggested by Emmitt (2016) individual studies on organising and managing design in construction are non-accumulative and confused in terms of their concepts and theoretical directions. Therefore, it is difficult to establish theoretical and conceptual ground(s) when studying construction design as a collective and multidisciplinary undertaking.

A reason for this difficulty has been identified by Bygballe and Jahre (2009) who suggest that, in the construction industry, there are different value creation logics applied by different professions, which can be in tension with each other. In line with this, Emmitt (2016) argues that construction design management has only recently started to be seen as more than discipline-based management of parts of the design. Zerjav (2012) joins Emmitt (2016) to criticise the view that engineering and architectural designs are fundamentally different in their nature, arguing that this assumption does not hold in practice. Consequently, both Zerjav (2012) and Emmitt (2016) suggest that design management in construction must be different from technical project management which relies on analytical reductionism (i.e. task-specification, -breakdown/isolation, and -
Redefining Design in Construction

integration), implying a need for exploring how design practices are contingent on their organisation and management. In this context, ‘design collaboration’ has also become a disputed concept as pointed out by Kvan (2000) and Wang and Oygur (2010), who criticised the use of the concept with its simplistic taken-for-granted meaning, being unsupported by evidence and theory. This has negative implications on the development of information technologies, as it drives the development of technology that is inappropriate (Kvan 1999).

Consequently, there is a need to develop an organisational definition of design in construction that is grounded in everyday practices but that is also able to capture both the autonomy and the collectivity that are observable in project-level organisation. Zerjav (2012) argues that practice-based studies of design and design collaboration in construction have mainly provided descriptive accounts of everyday undertaking of design work. Hence, they do not converge into project-level theory that can guide effective practical management and support of multidisciplinary construction design. Therefore, this paper will explore the practice of interdisciplinary design interactions to take a first step to develop an organisational definition of design in construction.

METHODOLOGY

A practice-based research approach (Feldman and Orlikowski 2011) is adopted to develop organisational theory on multidisciplinary design in construction based on exploration of everyday interdisciplinary interactions. Design-as-practice (Kimbell 2009) is a theoretical perspective that avoids decontextualized (e.g. centred on designer, designed artefact, and so on) as well as abstract (i.e. centred on cognition, culture, and so on) explanations of design. The relational epistemology (Emirbayer 1997) employed in practice-based theorisation suggests that design, designed artefact, or designer are not fixed or universal categories of entities; and so they must not be defined as such through decontextualised and abstract explanations of practices. Rather, design, like any other practical undertaking, consists of a set of empirically observable, unfolding (i.e. path-dependent) interactions in practice which continuously re-configure designers’ understandings about design situations, and thus providing their sense of ‘what to do’ and ‘what ought to be done' (Nicolini 2012).

This implies that construction design can be seen as an organisational phenomenon in which the creation of the discipline-specific parts of the design and interdisciplinary interactions drive each other. Thus, such a practice-based approach also implies that design management must not be considered as a separate function performed by distinct 'design managers' that regulate the creative activities. Rather, it is an integral part of designing because, in practice, the activities of managing and developing design are interacting parts of the same organisational whole. So, they are socially and materially interrelated, and thus unfolding on and shaping each other. Consequently, a practice-based approach can be employed to develop empirically observable theory on organising design that would yield new definitions of construction design as an organisational phenomenon. Ultimately this can provide concrete explanations about the role and means of design management in the successful delivery of construction design projects, thus producing managerial knowledge that has practical application.

According to this approach, organisational structures and routines don’t have an existence of their own as they are merely patterns of interactions resulting from certain courses of actions being repeated, and thus unfolding in certain ways in practice (Feldman and Orlikowski 2011). Therefore, structures of organisational life, including those in autonomous organisation of discipline-specific work and collective organisation of
project-wide design, are rooted in and continuously (re)-produced through everyday
interactions in practices. This assumption implies an empirical orientation towards the
exploration of interdisciplinary interactions in practice with an agenda of investigating
how the sense of ‘what to do’ and ‘what ought to be done’ is established and maintained
in construction design projects. According to the adopted practice-based approach, the
answer to this question must be explored through an analysis that establishes
interrelations between project-level patterns (i.e. routines) of interactions and practice-
level instances of interactions. This is because, in practice, they are interconnected and
drive each other (Nicolini 2012).

The paper uses findings from an educational building project in the UK at its detailed
design stage. As part of a larger research project, the first author observed the project for
10 months and attended 23 interdisciplinary design meetings. The findings from the
project will be presented in two sections. First the organisational environment of the
project will be described with a focus on the patterning of the coordination activities to
provide a basis for arguing about which activities were significant for the organisation to
coordinate and how these were framed. Second, two events from practice will be
presented to explore how the sense of ‘what to do’ and ‘what ought to be done’ were
enacted and maintained in and through design situations. Associations will be made
between the practice- and project-level findings. This will enable an organisational (re)-
definition of multidisciplinary construction design that is based on everyday
interdisciplinary practices, but that also explains the connection between the discipline-
specific autonomous and the project-wide collective organisation of design. This new
definition will yield a practice-based understanding of design collaboration as well as
insights into design management and technology development.

INTERDISCIPLINARY DESIGN IN PRACTICE

A range of interdisciplinary design interactions at project-level

In the observed project, there were a variety of interdisciplinary interactions for design
development. These interactions can be grouped under two main categories: face-to-face
interactions, and remote interactions. Face-to-face interactions included scheduled
meetings, spontaneous meetings, site visits, and informal conversations. Remote
interactions included e-mail correspondences, telephone conversations, and those that
involved the use of design artefacts such as checking, reviewing, and signing-off design
documents and information models produced by other practitioners. These various modes
of interaction were not well-defined instruments for problem-solving that were used to
resolve specific and well-defined design issues. On the contrary, interdisciplinary
interactions were almost always in flux and resolution of interdisciplinary design issues
actually included iterative series of realisations, explorations, expressions, and planning
through a number of emergent interdisciplinary interactions. In this regard,
interdisciplinary interactions for design development almost always pointed to future
interdisciplinary interactions and so framed them. A sketch sent as an e-mail attachment,
a phone conversation about design criteria of a building system, a contested space in
building (which surfaced in a previous meeting) could trigger planning for further
interactions to resolve the unfolding issues and develop the design gradually.

Connected and unfolding nature of various kinds of interactions for design development
implied that practitioners skilfully employed a range of face-to-face and remote modes of
interactions. In practice, this meant they had to be aware of, and exploiting, different
strengths and weaknesses of each available mode of interaction in a complementary way.
For example, most episodes of discussion in regular design-coordination meetings
(DCMs) were concluded by agreeing on some action points involving further remote interactions, such as commenting on, or marking-up some design documents related to the topic of discussion. In such cases, face-to-face discussion of an issue (e.g. ventilation of a ground floor) complemented remote interaction about more-detailed aspects of that issue (e.g. reviewing the schedule of outlets on the ground floor) and vice-versa (i.e. remote interactions that resulted in discovering new issues created needs for face-to-face discussions).

**Evolving range and nature of interdisciplinary interactions at project-level**

The longitudinal study of the project revealed that the need for interdisciplinary interactions evolved during the observed detailed design stage of the project in both expected and unexpected ways. Practitioners responded to this by employing various modes of interactions in varying combinations based upon their perceptions of both the issue, and the strengths and weaknesses of each mode of interaction. Therefore, the skilful use of various modes of interactions depended on the appreciation of the changing needs of various designers along the design process. For example, the design team chose to increase the number of site visits during the observation period, which increased the number of references made to site visits during the discussions in DCMs. Moreover, the topics of the discussions that referred to site visits changed over the observation period revealing the changing nature of the circumstances that were considered relevant and important during site visits. There was a gradual change in the topics from design of specific building systems to the tests of the installed systems.

Importantly, most of the time practitioners knew that they would be dealing with changing types of issues, and also they knew the kinds of issues that they would have to deal with. Thus, these were expected issues. However, in DCMs, most of the time was spent for discussing and action-planning the unexpected and differently expected issues. Even the agenda structure of DCMs, which was consisted of two sections (i.e. ‘previous minutes’ and ‘updates’ sections), reflected this aspect. The ‘previous minutes’ section mainly dealt with making sense of, and planning for, the resolution of the unexpected or differently expected issues that were previously discovered. Whereas, the ‘updates’ section mainly included expected issues such as information and meeting requests between disciplines, updates about work-in-progress for each discipline, and so on. As a result, interdisciplinary interactions evolved in the face of a mixture of mutually expected, differently expected, and unexpected, needs for interacting. The available modes of interaction were skilfully used to respond to changing needs, which resulted in different ranges and natures of interdisciplinary interactions. Ultimately, this was an indication of the interdependence between discipline-specific work and interdisciplinary interactions because maintaining a progressive sense of 'what to do' and 'what ought to be done' in discipline-specific work depended on these evolving interdisciplinary interactions.

**The nature and process of interdisciplinary interactions at practice-level**

*Event 1:*

Apart from the atrium area, all the areas in the building were serviced through suspended ceilings. This was a very conventional system for such buildings, therefore the architect, the M&E consultant, and the M&E sub-contractor were experienced in their design and installation, and there were agreed design strategies in the project for working with them. However, for the board room, the client briefing stated that “the ceiling in board room will be different” and the architect specified a decorative wooden ceiling. This had serious implications on several other systems, thus, this single irregular ceiling type required much following coordination. For example, the chilled beams that were
specified for the board room arose as an issue. The complexity of the decision involved: the fixing details of both wooden ceiling and chilled beams, the efficiency of chilled beams when placed above the wooden ceiling, the laying direction of the individual wooden pieces and chilled beams, the colour of wooden ceiling and chilled beams (because the chilled beams would be visible from the gaps between wooden pieces). These issues all needed to be discussed at different occasions in DCMs between the architect who were responsible for the ceiling, the M&E consultant who specified chilled beams for that space, and the M&E sub-contractor who were supposed to deliver detailed design and do the installation. When this issue was first raised by a representative of the M&E sub-contractor, his first strategy was to establish the premises of this decision: whether the wooden ceiling was particularly specified by the client or the client only specified a different type of ceiling for which the architect had decided to have wooden ceilings. Once it was established that it was the client that led the architect to specify wooden ceiling, all the issues mentioned above needed to be coordinated due to the irregular character of wooden ceilings in the project.

**Event 2:**
At the beginning of the detailed design stage, the design changed significantly with the purpose of increasing the total net internal area of the building because of the request of the client. Although the previous service and architectural strategies were reviewed before the confirmation of the design change, some areas of the design needed to be coordinated in detail as they fell out of these general strategies. One example of this was about the servicing problems of the rooms in the corners on the floors above the ground level. The main servicing strategy for these floors was to pass the main services along the corridors on each floor, and distribute them into the rooms that open to the corridor. However, the rooms that were in the corners of each floor required additional coordination because they were in remote positions (i.e. largely isolated from the corridors) and their servicing needed to be specifically coordinated due to the number of the services that would have to pass through a very limited space. This issue stayed as an outstanding issue for long time as detailed drawings by the architect and the M&E sub-contractor were needed before the coordination could be done at the desired level of detail. The strategy followed in this situation was to coordinate one of the corner rooms in a very detailed way, and then to apply the agreed design principles to the other similar rooms. It had been thought that doing detailed coordination of all isolated rooms individually would take too much time.

**DISCUSSION**
Design in construction, as a collective undertaking of practitioners from various disciplines, is under-theorised, and for this reason practitioners lack the concepts and understanding for its practical management and support. A practice-based research approach suggests that design in construction is accomplished based on the sense of ‘what to do’ and ‘what ought to be done’ that is enacted in and through interdisciplinary interactions and professional contextual issues. The discussion will show that design is a developmental process contingent on the professional environment and what mattered most in interdisciplinary interactions is to maintain a ‘shared sense of purposefulness’, as implied by the consistency and coherence between different autonomous discipline-specific designs. The notion of ‘shared sense of purposefulness’ will be unpacked through an examination of how the unexpected or differently-expected issues and unknowns required significantly more interdisciplinary efforts to be resolved in comparison to the expected issues and unknowns. It will also reveal that because design was unfolding, the line between the expected and unexpected issues was relative and continuously shifting.
thus making the need for interdisciplinary interactions path-dependent and continuous. Ultimately, these results will enable a (re)-definition of construction design that is centred upon its organisation. Managerial and technological implications of this new definition will be outlined.

**Redefining design and design collaboration in construction**

The project-level findings revealed the continuous and path-dependent nature of interdisciplinary interactions in construction design with an emphasis on the practical concern of judging, establishing, or re-confirming the degree of familiarity of the design situations that were faced. The events provided additional insight by revealing how the familiarity of a design situation was judged in relation to interfaces between design practitioners. Event 1 revealed that numerous rooms with chilled beams did not require much interdisciplinary effort as a general coordination strategy was sufficient. This ‘general coordination strategy’ was formed through noticing the interfaces that needed to be considered by the parties that have a stake in that part of the design, and the negotiations about how these could be sorted. As soon as these were agreed, parties could proceed with their discipline-specific design without engaging in further effortful interdisciplinary interactions. However, when exceptions to the general coordination strategy arose (e.g. later in Event 1) much interdisciplinary effort was required to jointly re-establish the interfaces. Event 2 also provides an example of this path-dependent negotiation process by showing (i) how the rooms in the corner were irregular and their coordination required additional interdisciplinary effort; and (ii) how the coordination of multiple corner rooms was achieved through the detailed coordination of only one of them.

These findings suggest that design in construction is organised at interdisciplinary interfaces so that discipline-specific designs can be developed autonomously but also consistently and coherently. In the observed project, various design stakeholders were not interested in knowing everything about what others did neither were they interested in seeing the design from others’ eyes. Also, they did not develop a ‘shared understanding’ as suggested by Valkenburg (1998). Rather they were interested in developing an awareness and familiarity of the interfaces between their parts of the design and others’ parts of the design so that they could develop purposes which would enable them to further develop their discipline-specific design. This awareness and familiarity relied on two major resources in the observed events. The first was the previous individual experience, and the professional and institutional standards of practice. These provided an initial repertoire and guideline for where to look and how to operate at interdisciplinary interfaces. The second resource, which was equally important, was the jointly constructed shared past of interdisciplinary interactions in the project; this gave a joint appreciation of what led to the present. This significantly reduced the negotiations about potential ways forward that would be acceptable to the parties involved, thus creating a remarkable efficiency both for discipline-specific decision making and interdisciplinary interactions. Consequently, it is argued that, from a practice-based point of view, practitioners established and maintained a sense of ‘what to do’, and ‘what ought to be done’ by continuously re-establishing ‘a shared sense of purposefulness’. Based on this explanation of design, design collaboration can also be reframed as the ‘purposeful organisation of meanings attached to design’. This definition suggests that face-to-face and remote interdisciplinary interactions may or may not be collaboration depending on whether they play a part in establishing a shared sense of purposefulness.
Finally, the proposed practice-based views of design and design collaboration enable insights for the practical management and support of design in construction. This suggests that design management in construction should focus on supporting adequately everyday interdisciplinary interactions. Managerial efforts must acknowledge that these interactions are for establishing a shared sense of purposefulness required at design interfaces, and therefore do not necessarily need close-coupling of design practitioners. Although design standards, templates, and guidelines provide an important foundation for design to be accomplished, design management in construction must recognise that creating the adequate environment for design practitioners to jointly construct a shared past is of utmost importance for successful design. In this context, collaborative design technologies in construction, such as building information modelling software, must support practitioners in establishing and confirming a shared sense of purposefulness. This implies that the focus of collaborative technology development must shift away from integrating every possible piece of design data, to developing digital environments that can support people in their interactions by helping create a shared sense of purposefulness. Also, this paper suggests that the current trend of promoting the replacement of face-to-face interactions with remote interactions through digital means must be re-evaluated. Supporting design collaboration cannot be thought separate from supporting establishment of a shared past through continuous interdisciplinary interactions. Therefore, exchanging digital models between design practitioners without a conscious planning for other kinds of interactions would not help collaboration and could even be harmful to collaboration.

**CONCLUSIONS**

Theory on the nature of design is diffuse in its philosophical and methodological approaches and does not provide enough insight for the practical management of the collective activity of multidisciplinary design. Besides, theory on organising construction design mostly focuses either on discipline-specific management of design or relies on traditional project management which is based on analytic reductionism criticised by previous work. Thus, the practitioners cannot gain an understanding for the effective support and management of design in construction. This paper demonstrated how practice-based approach can be used to develop organisation theory on construction design that jointly considers the autonomous discipline-specific work and the collective project-wide design. The emerging definitions of design and design collaboration emphasise the necessity of maintaining a ‘shared sense of purposefulness’. Hence, they provide valuable insights into the understanding of multidisciplinary design in construction as well as its effective management and support. Therefore, the paper advances the previous work on construction design management as well as the practice-focused studies of design which mainly focus on developing thick descriptions of design situations rather than building organisational or management theory. Future research will further employ this approach to develop a critical agenda to change current design management and technological support strategies. Key to doing this is the acknowledgement that construction design relies on continuous re-establishment of a shared sense of purposefulness.

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Redefining Design in Construction


EDUCATION AND KNOWLEDGE
KNOWLEDGE, AUTHORITY AND THE DEVELOPMENT OF EXPERTISE IN CONSTRUCTION

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This paper examines the development of expertise in construction from the perspective of knowledge. Using interviews with construction professionals, the paper develops a knowledge-based model of expertise development. Qualifications gained initially by construction professionals form a base for expertise, based in authoritative knowledge designated as essential through accreditation processes. Subsequent knowledge is acquired and expertise then develops from practice through exposure to construction problems, new ideas, new knowledge, innovations, and the expertise of others. Some of this knowledge accumulates through what is argued to be authoritative knowledge. Other knowledge develops through individual learning and practice, exposure to innovation and through reflection on practice. Both forms of knowledge extend the expertise of construction professionals offering further extension of potential theorizing about expertise in construction.

Keywords: expertise, practice, knowledge, discourse, construction

INTRODUCTION

Recent attention has focused on better understanding the development and theorizing of expertise in construction (Addis et al., 2016, Sage 2016, Chan 2016, Mogendorff 2016, Author 2016). This paper extends that research proposing a knowledge-based framework to both better understand the development of expertise in construction and extend the potential of theorisation of expertise from the perspective of knowledge types affected by, and affecting, expertise in construction. Bernstein’s theory of knowledge (1999) and Nonaka’s (2003) classification of knowledge are also used to frame a discussion of an analysis of interviews with construction professionals from various countries to both describe and extend our understanding of expertise.

Expertise and Construction

Kanjanabootra and Corbitt (2016) argue that expertise emerges from understanding the existential - who am I and what kind of person do I want to be as a practitioner; the relational - how do I as a practitioner relate to others and to the world around me?; and praxis - understanding the self-conscious questioning expertise development as both past actions and future possibilities. However, such an approach is at best simplistic. Addis et al., (2016) argue that expertise is difficult to theorize as it spans reason and intuition, knowledge and learning, and thinking and action as well as being both an individual and collective attribute. Within construction management, work on expertise tends to be pragmatically oriented towards the improvement of practice with an emphasis upon seeking and implementing solutions to practical difficulties.

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Sage (2016), however, suggests that technologies such as BIM, paperwork, and materials, shape, develop and constrain human construction expertise through politicization. Chan (2016) revisits the human element in the development of expertise and argues for the need not to take expertise as a done deal, but also to consider ‘expertise as effortful accomplishments in constant flux’. Mogendorff (2016) further notes that in construction projects there is a need to show that a technology or process such as BIM is relevant to the actual project before it may be deployed in construction work. Kokkonen and Alin (2016) investigated a case where BIM implementation caused changes in the traditional project practices.

To implement new technology or new processes, management often provides guidelines and structures. However, the practitioners often need to learn how the guidelines and structures can be followed in their daily practices within the context of a specific project. Kanjanabootra and Corbitt (2016) show that learning and ‘expertise development in construction professionals emerges incrementally’ and contextually from their peers and within cultural/social practices. Expertise is also bounded, they argue, by regulations of professional associations and the law, and restricted by both the financial constraints of project budgets, and the varying project demands of owners. In a similar way, Newton (2016) argues that both declarative knowledge and deliberate practice are integral to expertise bringing together both explicit and implicit forms of knowledge. This raises the relevance then of shared knowledge (Nonaka and Takeuchi 1995) and its role in expertise development and raises a question about what constitutes knowledge.

**Knowledge**

Learning in both formal and informal contexts is often framed by modalities of elaborate codes generating social context and the construction of discourse (Bernstein 1986). Bernstein (1999) used this discourse to define two types of knowledge. A vertical discourse, which he argues refers to a type of knowledge which is systematically structured, hierarchically organised, coherent and explicit. The features of this discourse are formed in a specialised language, with specialised criteria of texts production and circulation. Distribution of this knowledge requires strong rules, with regulating access, transmission and evaluation. This is achieved through specific requirements of time, space and actors or agents (Bernstein 1999). This distribution of knowledge is a complex process, but deliberately designed to ensure that it meets social relevance and needs. Professional or domain expertise knowledge development often starts in some form of training. This training can be either formal in a vocational institution or university, or as informal training such as an apprenticeship. This can be labelled authoritative knowledge, i.e. knowledge designated in curriculum structures and approved by accreditation and professional associations.

Bernstein also argues for a horizontal discourse which refers to a type of knowledge that is typified as ‘common-sense’ knowledge. This knowledge is context dependent and specific. It is local, multi-layered, tacit, and segmentally organised. However, the realisation of this knowledge depends on its cultural segmentation, specialised activities and practice (Bernstein 1999). Because the horizontal discourse is not systematically formed and is socially dependent it shares characteristics with what Nonaka (1995) terms tacit knowledge and refers to non-authoritative knowledge that accumulates, is not necessarily spoken, and is learned through observation or in practice, within the domain context (Bernstein 1999; Nonaka and Von Krogh, 2009).

Bourdieu (1977) notes how knowledge reproduces, sometimes coercively, sometimes accidently, and sometimes by social change, irrespective of its form or prevailing
Practical Knowledge, Authoritative Discourse and Expertise

discourse. This paper therefore argues that knowledge reproduction, both as authoritative and non-authoritative knowledge, offers an additional perspective on expertise development in Construction. Firstly, there is an authoritative knowledge focused on what has to be known, and what has been taught at university/training institution, to enable a professional to begin practice. Secondly, there is another form of authoritative knowledge (what is allowed to be known, and what accreditation and professionalisation through practice requires practitioners to know). This becomes a socially informed set of knowledge where authoritative determinations frame designated sets of knowledge within which new/different/innovative expertise can be supported or suppressed. Authoritative knowledge represents the reproduction of systems of expertise and forms of authority that they articulate.

Kothari (2005) argues that authoritative knowledge has a focus on the creation of professionals and subsequently frames the exclusive forms of knowledge that both surround and inform practice. This can be argued to represent the physical act of engineering or constructing or designing. Knowledge is then, it can be argued, the emotional expression and/or performance of that practice. It is then within that context this research is seeking to answer the following question: how does the interrelationship between so-called authoritative knowledge based on the prescriptions of professional qualifications/discourse and ongoing knowledge accumulation through experience account for the development of expertise in construction?

METHODOLOGY

The type of research in this project on expertise in construction is still exploratory (Fellows and Liu 2015). The intent is to seek insights about expertise in construction, looking to better understand how expertise develops and better understand the forms of knowledge within that expertise. This research then uses ethnography as a tool to collect and analyse stories from construction professionals (Geertz 1973) to gain those insights. Ethnographic research reports narratives, most often as vignettes (Stake 2013). However, a lack of research objectivity is often questioned in qualitative research (Denzin and Lincoln 1994). Wall (2008) and Ellis and Bochner (2000) argue that whilst objectivity might be questioned, ethnographies seek the inherent truths and validity in respondents own stories. It is essentially the reality of those participating. It is their objectivity.

Each conversation between participant and researcher was recorded based on the existential, relational and praxis elements of professional practice in construction, described above. The conversation sought to expose the types and forms of knowledge that informed the practice and subsequent development of expertise of the respondents working in construction, seeking to add to what Addis et al., (2016), Chan (2016), Sage (2016), Kokkonen and Alin (2016), Mogendorff (2016), Newton (2016) and Kanjanabootra and Corbitt (2016) have already proposed about expertise development in construction.

The 29 research participants interviewed so far in this project comprise the following two senior British engineers, six senior Thai mechanical engineers, three senior Australian engineers, two Thai architects, one Australian architect, two directors of Thai building companies, four directors of Australian building companies, one British business construction developer, four Thai executive managers of property development companies and four Australian quantity surveyors. They were selected either through convenience of ‘knowing’ by the researcher, and then by reference to others referred onto the researcher as a snowballing process (Biernacki and Waldorf 1981). All interviewees are experienced professionals in the construction industry, some in Australia, some in
Thailand and some in the UK. For consistency, the definitions of ‘professional’ by Engineers Australia and the Australian Institute of Architects are used: ‘a professional holds a 4 year university degree or equivalent, and minimum of three years acceptable work experience at the level of Professional Engineer (Australian Institute of Architect, 2017; Engineering Australia, 2017). The interviews were transcribed and then analysed using an iterative analysis trying to determine themes. Use of NVivo and then thematic coding assisted in identification of themes in the interview data as they related both to knowledge and learning, and to expertise (Fereday and Muir-Cochrane 2006).

EXPERTISE AND KNOWLEDGE

A number of themes have consistently emerged from the interviews and offer a preliminary framework for discussion of the interrelationships of expertise development and knowledge. These include the role of formal training and qualifications in knowledge acquisition; the less formal, but prescribed, role of professional development training; and the informal role of knowledge sharing and knowledge transfer with and between professional colleagues.

Qualifications and Authoritative Knowledge

Respondents consistently noted that formal training such as TAFE/University provides the authoritative knowledge, prescribed by professional associations and accreditation institutions. However, they note that this only constitutes 10-15% of the knowledge used and needed in their professional careers in construction. Their remaining knowledge, they claim, was developed through practice. It is commonly understood that we cannot compact all life-long learning into 3-4 years of university training period. As a result university’s programs, curriculum and courses often have been designed to cover only superficial levels of essential knowledge that are adequate for graduates to start their profession.

The claim from the respondents is that the additional knowledge needed comes in two forms, either as knowledge prescribed to be gained in ongoing professional career development offered by the professional associations, or informal learning on the job. The former can be determined as authoritative knowledge. It is socially constructed through formal professionally prescribed ‘communities of practice’. The latter is informal, non-authoritative knowledge developed through professional relationships and observation in the workplace, again in ‘communities of practice’ but with no formal requirements determined socially. Both are integral to expertise development of the construction professionals. This mixture of both the formal and informal types of knowledge, whilst both authoritative, exemplifies Chan’s (2016) claim that expertise is not a ‘done deal’, rather it is better seen as ‘effortful accomplishments in constant flux’.

Prescribed Professional Development Training

The respondents highlighted the role of professional associations and accrediting bodies in determining the initial authoritative knowledge essential as grounding for professional acceptance. In Australia, these include the Architects Accreditation Council of Australia, The National Standard of Competency for Architects, Engineers Australia, Chartered Institute of Building (CIOB), Australian Institute of Quantity Surveyors (AIQS) and the Royal Institution of Chartered Surveyors (RICS).

With the construction industry comprising various stakeholders, architects, engineers, construction managers, quantity surveyors, building certifiers, owners, suppliers and facility managers/operators, the accreditation process and determination of initial
authoritative knowledge is complex. This authoritative knowledge, the respondents all agreed, must frame the accepted minimum qualifications in all constituencies for professional employment. Other professionals interviewed noted that similarly, following graduation, the new professional still has to acquire another set of knowledge, determined by various members in their professions. This too is a typical incidence of formal authoritative knowledge acquired by construction professionals.

The respondents also gave examples of what, it can be argued, are instances of informal authoritative knowledge, still essential, for professional development, knowledge acquisition and expertise development in construction professionals. In Australia, professional bodies define competencies differently. For example the Master Builders Association determines that to become a member you have to hold an initial adequate education qualification (initial authoritative knowledge), actively practice in construction industry, and have certain level of experience (Master Builder Association, 2017). In addition to maintain membership, professionals have to engage in gaining professional Continuing Professional Development (CPDs) which adds knowledge and determines professional advancement. Most of the CPD courses provided by accreditation bodies require members to pay an extra fee on top of their annual membership. They can constitute either formal or informal authoritative knowledge acquisition.

Interviewees gave instances where CPD points were simply awarded for attendance with no associated evaluation. Others required some form of evaluation as well as attendance. Undertaking accumulation of CPDs is essentially voluntary but without undertaking them, and paying for that training, professional accreditation cannot be continuous. Expertise development in the construction industry, the respondents noted, is informed by the requirements of the professions and their politicisation of who controls standards and training which Sage (2016) argued is used to shape, develop and constrain human construction expertise. This politicisation is then executed as expertise through job processes and through career professional development. Again this represents authoritative knowledge in the systematically structured, hierarchically organised and coherent and explicit form argued by Bernstein (1999). However, this authoritative knowledge is imbued with the politics of determinations of professional association to maintain control of standards.

**Informal Knowledge Sharing and Transfer**

Outside the scope of knowledge graduates acquire formally and in the structured context of a degree, the graduates have to rely on both knowledge sharing via informal teaching from more senior practitioners, from peer interactions and from exposure to new products and processes from the commercial sector. Professional relationships with a more senior supervisor will determine what they can learn, and how much they can learn through job or tasks allocation. The research respondents highlighted instances where knowledge was withheld, either deliberately or through allocation of mundane, repetitive tasks, seemingly disengaged from acquiring new knowledge, hence expertise development can happen in a very slow manner. Graduates can learn new knowledge through the tasks that they are allocated to do and work under close supervision of more senior staff.

For example, on respondent noted, in a typical Quantity Surveyor practice in Australia, new graduates have to start work under the close supervision of a registered Quantity Surveyor for two years before they can be registered as a professional QS. During this period, graduates have to apply basic knowledge (learned in what Bernstein would argue is his vertical discourse) that they have been trained in. The interviewees also consistently noted that expertise develops as well from informal, unstructured practice.
This learning process for construction professionals over time is determined, according to the construction professionals, by the types and amount of tasks that are allocated in construction projects. This is a complex situation because if the difficulty of the allocated tasks does not match their knowledge level, they might take longer time to execute those tasks. In the case of the QS professional at the end of this two year learning period, graduates also have to be nominated by a specific grade of AIQS member who has the responsibility to evaluate whether they have adequate competencies to be registered as a Quantity Surveyor or not (AIQS, 2017). This, it can be argued, represents a continuity of authoritative knowledge through a professional discourse, but relies on the unstructured, almost serendipitous acquisition of less formal knowledge through knowledge transfer and knowledge sharing in the workplace. Newton (2016) argues that knowledge through ‘declarative and deliberate practice and knowledge’ are integral to expertise development in construction. The construction professionals interviewed in this research exemplify that knowledge transfer and knowledge sharing in the workplace are at times either or both declarative and/or deliberate, both being essential to the development of expertise of the construction professional.

The respondents’ data also highlighted individual instances where new professional knowledge can develop through process modification with the introduction of innovations. However, the QS interviewees consistently noted that the Quantity Surveyor role does not really enable innovation to take place as their role is defined in a very explicit way. While in the engineering profession new knowledge derives mostly from either new products or a modification of existing processes, by trial and error to improve designs or processes. This modification of existing processes often comes in a form of new constraints that are project specific. This resulting new knowledge, the engineering respondents noted, develops through the process of finding on-site solutions to address new project constraints.

The respondents highlighted what, it can be argued, exemplifies the effect of a discourse of benign knowledge sharing within what Bernstein calls his horizontal discourse. This benign knowledge sharing can happen through the introduction of technologies such as BIM in the construction workplace. There is substantial evidence for viewing the constraints of this type of supervision, and the demands for professional development career points (CPDS) discussed above, to represent parameters to learning, constraining the development of repertoires of skills/knowledge into formal structure perspectives. That discourse determines what has to be known to maintain professional practice as a career develops. In essence, it can be argued, these may form constraints on the development of an individual’s expertise as an example supporting the argument of Sage (2016) that knowledge acquired through technologies can shape, develop and constrain human construction expertise. This process of knowledge sharing and transfer is also indicative of Author’s (2016) argument that expertise development is not only constrained by the politics of control, but also by the incremental acquisition of knowledge.

The respondents consistently raised another issue related to the incompleteness of skills sets in the initial set of knowledge accrued in their vocational and degree learning. There was an often cited expectation that the initial knowledge given needed more attention to understanding the importance of lifelong learning and the ability to reflect on ‘your own performance’. These findings reflect another professional argument by Nash et al., (2016) that student pharmacists must have their competency standards, lifelong learning and self-assessment skills embedded into their university curriculum to ensure a strong foundation for practice. This, it can be argued, recognises the importance of
understanding not only the value of authoritative knowledge, Bernstein’s hierarchical structured knowledge, and the corresponding importance of developing that knowledge through informal learning, professional development and through peer practice. This latter process represents a view that expertise emerges as both Bernstein’s ‘common-sense’ knowledge and supports Chan’s (2016) argument about the dynamic nature of expertise being in a state of constant flux, influenced, it can be argued by the constraints of attempts at control through professional politics (Sage 2016), and by demonstration of relevance to construction work (Mogendorff 2016).

**DISCUSSION**

The findings can only be considered as preliminary but, as with all qualitative research (Francis et al., 2010), once data saturation occurs, preliminary positions can be argued. This paper has used a series of interviews with construction professionals and interpreted the data collected within both the theoretical context of knowledge proposed by Bernstein (1999), and the theorizations about expertise in construction by Addis et al., (2016), Sage (2016), Chan (2016), Kokkonen and Alin (2016), Mogendorff (2016), Newton (2016) and Author 2016 to develop a framework to better understand the role of knowledge in expertise development of individual professionals in construction (Fig 1).

![Figure 1: A knowledge-based framework for expertise development in construction](image)

Bernstein’s vertical and horizontal discourses can be seen as framing two separate sets of knowledge. The vertical represents knowledge that is structured, hierarchically formed and situated within formal learning systems. Lifelong learning can also occur in that formal, hierarchical, structured form of knowledge through programs like CPD. However, the interviews with construction professionals in this research have also talked about practice after graduation. This process is described by them as less structured, transmissive from a supervisor, or people who know more, or peer practitioners. However, with CPD type schemes required for continued professional accreditation in the Australian context, practice and new learning appears, in their opinion, to be imposed or dictated. This paper has suggested that this hierarchical, structured knowledge can also be perceived as authoritative discourse/knowledge and the stories of the respondents show that it is embedded in the vertical discourses where programs or curriculum have to
comply with the accreditation requirement, as well as in required learning through programs such as CPDs. This authoritative knowledge is then embedded in the lifelong learning process as well. However, this interpretation is more conceptual that the more explicit theorizations of expertise by Sage (2016), Chan 2016, Kokkonen and Alin 2016, Addis et al., 2016, Mogendorff 2016 and Author 2016) discussed above. Their interpretations of expertise expose a series of direct processes or factors impacting on the development of expertise in construction: incremental change in practice, the direct impact of relevance on adoption in practice, and two dynamic elements, seeing expertise in a state of constant flux, being continuously affects by politicization of practice. Each of these explicit impacts on expertise development has emerged in this research and noted in the previous section. What has also emerged by adopting a broader model of expertise to include knowledge, is a more expansive mode of theorization, enabling the researcher and the practitioner to see how the acquisition, sharing and transfer of knowledge reflects what constitutes expertise rather than how expertise is being created.

The model (Fig 1) can be interpreted in a way that various professions who practice in the construction industry are people who determine the knowledge and expertise reproduction process. The construction professionals interviewed here suggest a number of scenarios for practice. Compliant professionals are accepted into practice, non-compliance may result in removal or partial acceptance, or even acceptance as an outcast. Some will not be allowed to practice as registrations, membership, or licences might be voided. This might be considered as an ‘inbred’ situation that restricts out of the box thinkers to grow or not encourage innovative thinking to flourish. The research is also confirming both Kothari’s (2005) position that the focus of authoritative knowledge is on the creation of professionals and subsequently frames the exclusive forms of knowledge that both surround and inform their practice, and Newton’s (2016) argument that expertise develops from declarative and deliberative practice grounded in knowledge.

CONCLUSION

Evidence in the construction professional interviews done so far in this research supports a view that expertise development goes beyond the professional understanding of the existential - who am I and what kind of person do I want to be as a practitioner; the relational - how do I as a practitioner relate to others and to the world around me?; and praxis - understanding the self-conscious questioning expertise development as both past actions and future possibilities. That existential, relational and praxis in construction is subject to parameters in knowledge acquisition and learning imposed as structured discourse by professional and accreditation associations. Those parameters are often designed to protect as well as control but in either way they can be seen as inhibitors to the development of expertise through knowledge acquisition along an informal and unstructured discourse that encourages learning through observation and innovation.

This research is showing that expertise development emerges from the dynamic state of knowledge accumulation, transfer and sharing. This knowledge process is influenced by constraints imposed deliberately and politically, by constraints of relevance and structure, and by constraints of incrementalism creating a state of expertise that is in constant flux. The research is showing that using knowledge, both authoritative and non-authoritative (formal or less formal) offers potential linkages across the existing theorisations of expertise (Addis et al., 2016).
REFERENCES


ENVIRONMENTAL MANAGEMENT AND SUSTAINABILITY
LOW ENERGY INNOVATIONS IN BUILDING CONSTRUCTION: A REVIEW OF THE CHALLENGES

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With almost half of all UK CO2 emissions attributed to energy use in buildings, there is a major role for construction in meeting the UK climate change targets. Doing so will necessitate major changes in construction industry practice. The sector will need to adopt energy efficient and low-carbon innovations, integrate these within novel building designs and ensure these designs are optimised and implemented successfully. This is likely to require greater levels of integration within the construction supply chain. Over the past three decades, there have been numerous attempts to promote integration within the UK construction industry, but these have only been partially successful. This narrative review synthesises insights from three streams of literature, namely (1) innovation and construction innovation, (2) low-energy buildings, and (3) supply chain integration. In doing so, the review concludes that the combination(s) of integration components enabling low-energy innovations, do not necessarily overlap fully with those enabling project performance and other types of construction innovations. The study concludes by posing a series of research questions for further investigation and by presenting a synthesis of insights on practical and policy implications originating from the analysis.

Keywords: sustainability, climate change, low-energy innovation, supply chain integration

INTRODUCTION

To put the UK on course to meet its Climate Change Act target, there needs to be acceleration in the rate of decarbonisation of buildings, transport, industry and agriculture. In the building sector, this is likely to require all new buildings to be ‘near zero-energy’ (Guertler 2016). This will require a step change in the way buildings are designed, built and operated (CIBSE 2015). Through the adoption of low-energy innovations, the sector offers great opportunities for radical improvements in energy efficiency (Sorrell 2003). Both technology and regulation will play a key role in delivering the change needed. But it is ultimately the ability of construction supply chains to embrace, optimise and deliver those innovations that will allow near zero-energy buildings to become the norm.

There are only a handful of studies exploring low-energy innovations through the lens of construction supply chains at project level. The construction innovation literature is extensive, but tends to focus on either innovation management within firms or the diffusion of innovations within the industry. On the other hand, the literature on construction supply chains mainly discusses the effects of integration on construction projects (e.g. cost, delivery time) rather than building performance and innovation. And where the relationship between integration and innovation is explored, this usually considers innovation as a single construct, thereby ignoring the important differences between different types of innovations. In light of this gap in the literature, the paper first

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identifies the particular characteristics of low-energy innovations, and discusses the challenge of adopting these within individual construction projects. The paper then discusses the link between supply chain integration and construction innovation and elaborates on why previous integration attempts are insufficient for the promotion of near zero-energy buildings. The paper concludes by highlighting some practical implications and providing recommendations for further research.

**PLACING LOW-ENERGY INNOVATIONS WITHIN THE CONTEXT OF CONSTRUCTION INNOVATIONS**

Freeman (1997) defines innovation as “Any improvement in a process, product, or system that is novel to the institution developing the change”. Slaughter (2000) defines construction innovations as the products (materials and components), processes and systems, associated with the design and construction of built facilities. Low-energy innovations may be defined as technologies, processes and products that affect a building’s operational energy performance. They are construction innovations, because they are delivered by construction firms within construction projects and are associated with the design and construction of buildings. This review focuses on low-energy innovations that directly influence a building’s operational performance. Those may include advanced façade materials, natural ventilation systems and low-energy cooling technologies, smart controls and energy monitoring systems, and energy management processes and procedures (LCICG 2016). As argued below, there are three important characteristics of low-energy innovations in building construction: (1) their systemic nature, (2) their building performance improving outcomes and (3) their user-dependency are used in conceptualising how low-energy innovations fit within the 'superset' of construction innovation. The majority of low-energy innovations have at least two of these characteristics. Figure 1 clarifies how low-energy innovations fit within the ‘superset’ of construction innovation, while Table 1 classifies several innovations against this framework.

*Figure 1: Visualising low-energy innovations in construction (Source: Author)*

**Low-Energy Innovations as Systemic Construction Innovations**

The largest energy-saving opportunities arise through considering a building as a system and by optimising how the different elements work together, rather than relying on
individual energy-efficiency technologies (IEA, 2013; Harvey 2009). Since energy-saving opportunities at the system level are substantially greater than at component level, systemic innovations are perceived as key to improving energy performance (Mlecnik 2013). Defined as “a set of complementary innovations which work together to provide new attributes or functions and together can significantly advance the state of knowledge or practice” (Mlecnik 2013), these innovations offer significant opportunities for long-term productivity (Shabanesfahani and Tabrizi 2012), by exploiting synergies between components. However, their diffusion rates are slower than those for other innovation types (Taylor and Levitt 2004).

Table 1: Different types of construction and low-energy innovations (source: author)

<table>
<thead>
<tr>
<th>Low-energy innovations</th>
<th>Construction Innovations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed mode ventilation</td>
<td>H Sustainable Supply Chain Management</td>
</tr>
<tr>
<td>High performance insulation</td>
<td>C Lean construction practices on site</td>
</tr>
<tr>
<td>Biomass boiler</td>
<td>F Off-site prefabricated components/Modern Methods of Construction</td>
</tr>
<tr>
<td>Smart facade</td>
<td>H Use of 3-D CAD design tools</td>
</tr>
<tr>
<td>Green roof</td>
<td>H Relational contracting/Partnering</td>
</tr>
<tr>
<td>Ground source heat pumps</td>
<td>H Optimised cladding system requiring less maintenance and greater lifespan</td>
</tr>
<tr>
<td>Integrated photovoltaics</td>
<td>H Environmental certification of construction project</td>
</tr>
</tbody>
</table>

Systemic innovations may be contrasted with modular innovations. While the latter incorporate a significant degree of change, they require no change in linkages with other components or parts of the building system (Slaughter 2000), systemic innovations necessitate deeper collaboration and coordination between actors within the supply chain. This can present a challenge in the fragmented supply chains that are typical in construction (Slaughter 2000, Sheffer 2011, Lindgren and Emmitt 2017). In addition, unlike incremental and modular innovations that can be introduced at any point in the design and construction process, systemic innovations need to be introduced at the early design stages by technically competent actors that have a coordinating role without a vested interest in retaining existing configurations (Mlecnik 2013). Examples of systemic innovations in general construction contexts include Building Information Modelling (BIM), modularisation and prefabrication of building components, lean construction processes and 3D CAD design and construction tools (Shabanesfahani and Tabrizi 2012).

**Low-Energy Innovations as Building Performance Enhancing Innovations**

At a project level, construction innovation aims to either improve the project process, through reducing costs and construction times, or improve the building product, through improvements in quality and performance (Slaughter 2000, Semlies 1999). Low-energy innovations belong to the latter category. Their primary objective is enhanced building performance, which may be driven by client demand for reduced energy costs or improved sustainability or by public policies at national (e.g. building regulations) or local level (e.g. planning regulations). Low-energy innovations mostly originate within engineering design disciplines and sub-contractor trades (Manley 2005) and their beneficial impact on building performance may or may not be accompanied by improvements in the project process. Innovations of this type may be more difficult to incentivise and orchestrate within projects, as typically there is little value to the building...
industry in making buildings perform better (Lutzenhiser and Biggart 2001.). While clients may have an incentive to minimise whole-life costs, contractors and consultants are rarely accountable for operational performance and hence may seek to maximise profits at the expense of building performance (Sorrell 2003).

**Low-Energy Innovations as User-Dependent Innovations**

There is often a significant gap between the predicted energy performance of a building and its operational energy performance (Robinson and Foxon 2016). A range of factors contribute to this 'performance gap', including lack of accurate information at design stage on occupancy profiles and user behaviours, inconsistent information on material properties, underestimation of heating and cooling loads and lack of allocated time for building commissioning (Sorrel 2003, Robinson and Foxon 2016, Bordass *et al.*, 2001, Tetlow *et al.*, 2012). The possible ‘unintended consequences’ of low-energy innovations and the need to shift the focus of the UK industry from production to ‘in-use’ performance was highlighted in the PROBE series of building post-occupancy evaluation studies undertaken between 1995-2002 (Bordass *et al.*, 2001, Tsitnidis 2016). Since then, many studies and voluntary initiatives have encouraged a shift of focus in the industry towards ‘in-use’ performance. But there is still a long way to go before Post Occupancy Evaluations become the norm in the industry (Tsitnidis 2016).

**BARRIERS AND ENABLERS FOR LOW-ENERGY INNOVATION IN CONSTRUCTION PROJECTS**

Minimising energy consumption and costs will require low-energy innovations that have at least two of these characteristics (Figure 1). In other words, low-energy innovations tend to be systemic, building performance enhancing and/or user dependent. This combination of characteristics influences their adoption within construction projects.

**Client Types and Roles**

Many studies identify the role of the client in fostering innovation (Blayse and Manley 2004, Ozorhon *et al.*, 2014, Ling *et al.*, 2003, Barlow 2000). Blayse and Manley (2004) find that clients are influential in driving construction innovation, due to their capacity to develop detailed project requirements and exert pressure on suppliers to deliver innovative solutions. This works best when clients are both 'demanding' and 'experienced' (Barlow 2000). The client’s role in facilitating innovation is documented in several studies, including those by Ling *et al.*, (2003) and Ozorhon *et al.*, (2014). In the latter two case studies, clients were both demanding and knowledgeable and ensured, through their participation in the projects, that a win-win situation was created for all parties involved. Similar, the literature on systemic innovation stresses the critical importance of an active client to the innovation process (Shabanesfahani and Tabrizi 2012, Lindgren and Emmitt 2017).

Where modular innovations are driven by improving project process efficiency (domain A), client knowledge and involvement becomes less important. These innovations are delivered within single disciplines, with benefits accruing to the innovating firm. As noted by Bordass *et al.*, (2001), new technologies that improve the speed, cost or quality of construction are of interest to both the supply-side and to clients where better, cheaper or faster buildings are made possible. Client involvement becomes more important for systemic innovations (domain B) and to a greater extend for those systemic innovations that are output driven and user-dependent (domains E, G, F and H). These innovations entail greater levels of uncertainty and the benefits and risks are not evenly shared between participants in the innovation process. Systemic building related technologies
need more time, money and effort to orchestrate, nurture and optimise (Bordass et al., 2001) which can make clients reluctant to pursue them. The role of a knowledgeable and committed client in these cases is critical. Such a client would set the innovation agenda early on into the project process and ensure the use of appropriate procurement and contractual arrangements that align objectives between participants, and allocate risks fairly (Bygballe and Ingemansson 2014).

In construction, client types and roles vary significantly. There are a range of client types, including owner occupiers, portfolio owners, speculative developers and managing agents. These have differing degrees of experience in construction procurement and have different organisational profiles (e.g. private, public, international, commercial, domestic etc.). Knowledgeable clients are a minority (Cox and Townsend 1997) and there are few examples of near zero-energy buildings from which to learn, therefore low-energy innovations tend to face greater obstacles than other types of innovation.

Relational Aspects

Long-term relationships, between parties in construction projects and between the industry and external parties, are identified in the literature as another enabler of construction innovation (Sorrell 2003, Ling et al., 2003). These contrast with the prevailing industry cultures, where firms rely on short-term, market-based exchanges, within temporary project coalitions. The role of trust as facilitator of construction innovation is highlighted by Baiden (2006), Kumaraswamy et al., (2004) and Lloyd-Walker (2014) and others. The collaborative environment formed by trust-based relationships creates a no-blame culture that fosters learning and information sharing and allows project actors to share the risks and benefits of innovation. But Fearne and Fowler (2006) argue that the industry has a long way to go and improving construction performance would involve a fundamental change in the management of relationships between clients, contractors and sub-contractors.

Long-term relationships between supply chain actors, clients and users are essential for the realisation of near zero-energy buildings. For user-dependent innovations, the effectiveness of the technological and operational systems in a newly constructed building can only be assessed through systematic post-occupancy evaluation. Furthermore, innovations that are both systemic and user-dependent require optimisation, during which designers, contractors and users fine-tune components at system level for optimum performance. In procurement routes where the role of designers and contractors ends upon building handover, the incentives for learning and knowledge sharing are limited, particularly where short term market-based relationships prevail. Given the discontinuous nature of project-based construction, suppliers and manufacturers are possibly the only loop of the construction supply chain interested and able to pursue feedback between projects. Those actors seek to learn about their products (Blayse and Manley 2004). According to Blayse and Manley (2004), manufacturing firms operate in a relatively more stable market and can maintain in-house R&D programs that accommodate for learning feedback loops that facilitate innovation. Alternative contract solutions, based on the principle of integration for products and services have emerged in response to the need for long-term relationships within the supply chain. These provide clients with whole-lifecycle support from their supply chains, including financing, design and systems integration, implementation and construction, technical support, commissioning, maintenance, operation and de-commissioning (Gann 2000).
Project Structure and Process

Under traditional procurement routes with linear design and construction processes, subcontractors and suppliers are typically brought in late into projects and have little or no links to clients (Nawi et al., 2014, Eriksson et al., 2007). In contrast, evidence suggests that integrated design processes with suppliers and sub-contractors involved from an early stage can play a positive role in delivering systemic innovations. The literature supports the positive role of integrated design processes and involvement of suppliers and subcontractors from early stages into the project process (Mlecnik, 2013).

The literature also identifies the importance of a systems integrator, which has been extensively explored within the Complex Products Systems (CoPS) literature. Two innovation parameters are described as ‘innovation superstructure’, representing the market, the regulators and the professional bodies and ‘innovation infrastructure’ comprising suppliers and specialist builders and trades. These are bridged by the role of the system’s integrator, a role that encompasses detailed knowledge of client requirements, skills to integrate interdependent components and knowledge of the rules and regulations of the industry (Miller, 1995). Winch (1998) argues that innovation in construction suffers because the system integrator role is shared between architect/engineer and main contractor and there is typically a split between design and construction. This has implications for near zero-energy contexts, where complexity is high and systemic low-energy need to be negotiated between parties. Building enhancing innovations are more likely to be driven by client teams on the demand side which in most cases includes professional disciplines, such as architects and engineers, rather than in projects where the contractor has overall project responsibility, such as in Design and Build projects. This implies a conflict. While process efficiencies and better inter-organisational cooperation are expected in projects that are more vertically integrated, such as design and build contracts, traditional procurement routes should a better platform for low-energy innovations, due to the focal role of the client. In summary, all the above factors would need to be present simultaneously to facilitate low-energy innovations.

INSIGHTS AND CONCLUSIONS: INTEGRATING TOWARDS LOW-ENERGY OUTCOMES

The literature review identified enabling factors for low-energy innovations and discussed prevailing conditions in the industry that hinder their adoption in projects. Most of those hindering factors arise from the fiercely competitive and fragmented structure of the industry and can be summed up in three key conditions (Sorrell 2003, Nawi et al., 2014, Wolstenholme, 2009): (1) - the separation of design and construction phases, whereby different disciplines participate and input sequentially. This contributes to lack of ‘systemic vision’ within projects and hinders integrated design and collaboration during the key early stages, (2) - the continuously changing coalitions of supply chain actors on different building projects, leading to lack of trust and misalignment of objectives. Due to the temporary nature of projects, feedback loops between clients, supply chain and users are less likely to exist and (3) - the proliferation of general contracting and sub-contracting of the various building trades, resulting in lack of a coordinating and integrating focal presence in projects, to promote innovation and to bridge between demand and supply in projects. This also leads to an industry geared towards project process performance rather than building product outcomes. This fragmented set-up has been heavily criticized for its potential to create conflict and adversarial relationships at all stages of the building process and for its negative impact on the quality of the finished product (Sir Egan 1998, Sir Latham 1994).
The concept of supply chain integration originated within the manufacturing sector (Flynn et al., 2010), where supply chains have been integrated by focal companies (usually client firms) linking and coordinating suppliers’ processes to their own business processes. The underlying principle is that a supply chain that delivers a product should not comprise disconnected functions (Vrijhoef, 2011). Within a manufacturing context, the normative concept of supply chain integration refers to the adoption of collaborative structures and tools that promote seamless flow of information, materials and goods (Vijayasarathy, 2010). The high level of alignment achieved through supply chain integration has improved productivity and led to the development of mutually beneficial partnerships and long-term coalitions between firms (Flynn et al., 2010). Existing literature makes the case for the multi-faceted nature of integration (Vijayasarathy, 2010; Vrijhoef, 2011), which explains the diverse nature of approaches taken in defining and measuring it within various contexts. The supply chain integration concept, as developed and implemented in construction as part of the ‘Rethinking Construction’ movement (Sir Egan 1998) focuses primarily on improving the construction process (Bordass et al., 2006). In contrast, there are relatively few studies that explore the relationship between supply integration and innovation.

Those that do, either examine construction innovation as a singular concept or tend to analyse innovations located in domains A and B of the conceptual framework. Analysis of some of those studies indicates that in most cases, the construction innovations explored are located within domains A and B. Ozorhon et al., (2014) explores supply chain integration in a case study building project in relation to two innovations, Modern Methods of Construction (MMC) and lean construction, both of which belong to domain B. The study finds that the use of partnering between the client and contractor, which was also extended to the supplier, consultant, and the community; and the effective leadership of the client and the contractor acted as enablers for the innovations. Ling et al., (2003) explores top-down construction (domain B) in a case study mixed-use development in Singapore and finds that client involvement as the developer and project manager contributed to a win-win situation for the project supply chain and contributed to the success of the project. For Holmen et al., (2005) the innovation is timber-frame multi-storey construction (domain B) investigated in two Norwegian projects and finds that tight relationships within construction would allow learning across projects and foster innovations, but would reduce flexibility for individual firms, and for this reason are not valued as much in the industry. Mlecnik (2013) explores the innovation journey of structural timber wall construction (domain B) for Passivehaus housing projects and notes the important role of suppliers and manufacturers in developing systemic innovations and the pre-requisite knowledge transfer between different players in the innovation process.

So, while many of the attributes of integrated supply chains align with the enabling factors for low-energy innovations, the relationship between low-energy innovation and supply chain integration in construction projects has not been adequately explored and needs to be researched further. Possible research questions that arise are: (1) How can construction supply chains integrate to deliver simultaneous construction process efficiencies and low-energy building outcomes? (2) What dimensions of supply chain integration are critical for low-energy outcomes when considering different construction innovation types? (3) What are the implications of the above findings for industry, policy development and firm level management?

The analysis in this study provides some insights into how supply chain integration can be re-directed towards low-energy outcomes. The industry needs to focus on strategic partnering between different supply chain actors to facilitate long-term relationships and
allow for feedback loops to be created between clients, supply chain and users. Bespoke relational contracts that go beyond partnering, could be utilised to facilitate trust and commitment to common outcome-driven objectives. Given the diverse types and roles of construction clients, the role of the systems integrator is critical in bridging demand and supply in projects and enabling co-ordination between actors in the innovation process. More involved and deeper exchange relationships between industry actors, such as clients, designers, contractors and users or user groups with external bodies, such as research institutions, agencies and non-profit organisations and associations, would ensure that knowledge and information flows are communicated and managed. Increased efforts by industry governing bodies to increase awareness and knowledge of clients on procurement methods and whole-life cycle benefits of performance in use. Finally, there needs to be a proliferation of new alternative procurement routes that ensure the industry is geared towards building performance and in-use efficiencies.

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ZERO CARBON CONSTRUCTION SITES: A NEW CALL TO ACTION

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Current evidence from academic, industry and government publications indicates that built environment research and practice have not focussed sufficiently on reducing carbon emissions of construction sites (CEoCS). Particularly, the evidence suggests lack of practical tools that can be readily deployed to reduce CEoCS. This leads to the following research question: how should we approach the challenge of developing and delivering solutions to reduce CEoCS to match/exceed UK capital carbon reduction targets? This research question was addressed using focus groups over a two-day workshop. The focus group was comprised of participants from diverse stakeholder groups and constituted as a ‘Delphi’ group. The two workshop days were separated by an interval of two weeks which enabled participants to consult with colleagues as appropriate to maximise chances of successful implementation of the ‘solution’ to the research question. The solution that emerged from the focus groups is comprised of four parts: developing and disseminating a zero carbon construction sites (ZCCS) initiative, creating a ZCCS research network, creating a ‘ZCCS Challenges and Opportunities Repository’ and developing better understanding and solutions for specific ZCCS challenges. This solution is a new call to action to facilitate reduction of capital carbon in the built environment.

Keywords: capital carbon, construction site, embodied carbon, zero carbon

INTRODUCTION

The construction industry needs to make its fair contribution towards reducing carbon emissions and has been taking appropriate steps but mainly focussing on emissions during the operation phase of construction projects and embodied energy of construction materials. Operation phase emissions are increasingly being reduced close to zero through innovations in energy efficiency and green and/or renewable sources of energy (International Energy Agency, 2013) and reducing the embodied energy of construction materials is becoming increasingly difficult (Gutowski et al., 2013). This means that we have to look at other phases in the construction project lifecycle if we are to reduce carbon emissions significantly further. One such phase that has hitherto received very little attention is the construction phase.

The opportunity to reduce carbon emissions in the construction phase can be appreciated if we look at data from construction contracting organisations. For example, a sustainability and environmental manager of one national civil engineering contracting organisation in UK which runs about 30 construction sites every year with an annual turnover of about £80 million disclosed that the organisation used 244,000 litres of diesel to generate electricity for its site offices and 760,000 litres of diesel for its site plant in a recent financial year. This means that the organisation produced 636tCO2e from site offices and 1,980tCO2e from site plant. By way of comparison, this organisation’s carbon emissions from offices and plant were similar to emissions from 115 and 360

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average dwellings respectively in UK in 2010 (Palmer and Copper, 2014). There are many organisations of this type in UK which can be assumed to be producing similar amounts of carbon emissions. Considering the effort, rightly, put on reducing carbon emissions in individual dwellings and realising that carbon emissions of construction sites (CEoCS) for one contracting organisation easily match carbon emissions from nearly 500 dwellings, the author contends that making construction sites zero carbon work places constitutes a timely area of research and will go a long way in helping the construction industry play its full role in reducing carbon emissions to meet or exceed targets set in Climate Change Act 2008.

**THEORETICAL FRAMEWORK**

One framework that has emerged in literature which provides a very good conceptualisation of carbon emissions from the built environment is the binary categorisation of carbon emissions as either operational or capital carbon. Operational carbon (OC) refers to carbon emissions associated with operating built environment assets whereas capital carbon (CC) refers to carbon emissions associated with constructing built environment assets. This framework has recently been used by the Green Construction Board in the United Kingdom (UKGCB) to articulate a route map for low carbon in the built environment for the period 2010 - 2050 (Green Construction Board, 2013). The framework is widely accepted and expected to persist into the future, hence, it was adopted for the research reported herein. However, OC is beyond the scope of this article and will not be considered any further but CC is explored further in the following sections.

**Capital Carbon - Academic Perspective**

CC has also been referred to as embodied carbon in various academic literature. In this article, the academic perspective on CC has been discerned from refereed journal publications. Recently, Pomponi and Moncaster conducted a systematic analysis of 102 refereed journal articles to identify strategies for reducing embodied carbon in built-environment literature (Pomponi and Moncaster, 2016), which resulted into what the author refers to as the Pomponi and Moncaster typology. The typology comprises of seventeen mitigation strategies as shown in Table 1.

In Table 2, the author illustrates CC from UKGCB’s perspective and provides an indication of how it maps onto the Pomponi and Moncaster typology. Moreover, the author also highlights where the respective mitigation strategies have potential to address CC but do not appear to have been captured in the Pomponi and Moncaster typology. In so doing, the author uncovers two crucial points. Firstly, no specific strategies were reported pertaining to two main areas: 1) transport (materials, people and plant) and 2) construction/demolition (workers welfare and construction plant). Secondly, while opportunities for improvement appear in all sectors and all sources of CC, transport and construction/demolition deserve the highest priority by virtue of receiving minimal attention thus far. However, transport will not be considered any further here as it is beyond the scope of this article. Instead, the author focuses on CC of construction/demolition activities covering processes, welfare of workers and plant.

**Capital Carbon - Industry/Government Perspective**

The industry/government perspective has been discerned from non-academic literature that captures the practice and/or intended practice with respect to reducing CC in the built environment. Such literature is primarily from reports and other materials published on websites of authoritative organisations. From the literature, a few measures pertinent to
reducing CEoCS can be identified and categorised as strategies and actions, measurement and reporting initiatives or rating systems.

Table 1 Typology of Mitigation Strategies for Reducing Embodied Carbon in Built-environment Literature (adapted from Pomponi and Moncaster, 2016)

<table>
<thead>
<tr>
<th>Mitigation Strategy (MS) Code</th>
<th>Author’s Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS1</td>
<td>Use materials with lower embodied energy and embodied carbon</td>
</tr>
<tr>
<td>MS2</td>
<td>Produce better design (design practice that seriously considers options to minimise embodied carbon in the project life cycle)</td>
</tr>
<tr>
<td>MS3</td>
<td>Reduce, re-use and recover construction materials with intensive embodied energy or embodied carbon</td>
</tr>
<tr>
<td>MS4</td>
<td>Use tools, methods, and methodologies for quantifying operational and embodied carbon in a holistic and integrative manner</td>
</tr>
<tr>
<td>MS5</td>
<td>Put in place national/international policies and regulations pertaining to embodied carbon to nudge designers, constructors, developers to adopt low embodied carbon strategies</td>
</tr>
<tr>
<td>MS6</td>
<td>Refurbish existing buildings instead of constructing new ones</td>
</tr>
<tr>
<td>MS7</td>
<td>Decarbonise energy supply</td>
</tr>
<tr>
<td>MS8</td>
<td>Utilise waste, by-products, used materials into new or reconstituted construction materials</td>
</tr>
<tr>
<td>MS9</td>
<td>Increase use of local materials to reduce embodied carbon emanating from transportation</td>
</tr>
<tr>
<td>MS10</td>
<td>Put in place organisational policies and industry standards to promote low embodied carbon practices</td>
</tr>
<tr>
<td>MS11</td>
<td>Manage change to remove barriers to innovative practice among all stakeholders in the built environment</td>
</tr>
<tr>
<td>MS12</td>
<td>Apply more efficient materials, plant, processes, management, etc. in the construction phase</td>
</tr>
<tr>
<td>MS13</td>
<td>Incorporate carbon mitigation offsets, emissions trading, and carbon tax in construction project development</td>
</tr>
<tr>
<td>MS14</td>
<td>Incorporate carbon sequestration as part of scope for construction projects</td>
</tr>
<tr>
<td>MS15</td>
<td>Design and build structures for durability and adaptability</td>
</tr>
<tr>
<td>MS16</td>
<td>Increase use of prefabricated elements/off-site manufacturing in the construction industry</td>
</tr>
<tr>
<td>MS17</td>
<td>Demolish and rebuild after determining that refurbishment is an inferior option</td>
</tr>
</tbody>
</table>

Strategies and actions
The first in this category is 'Construction 2025' (Her Majesty’s Government, 2013) and it indicates the UK construction industry and government’s desire to reduce greenhouse gas emissions in the built environment by 50% versus the 1990 baseline by 2025. This is to be achieved through market and technology based plans for investment in low carbon construction.

The second in this category is the 'Low Carbon Routemap for the Built Environment' (Green Construction Board, 2013). It provides proposals to reduce greenhouse gas emissions from the built environment. To reduce CEoCS, the following are suggested: for the period between 2013 and 2017, encouraging measurement and reporting of on-site carbon emissions, reviewing progress against 2010 targets, revising and strengthening...
targets and promoting research into new solutions; for the period 2017 to 2021, reviewing and updating guidance to ensure best practice is disseminated; for the period 2021 to 2022, revising and strengthening targets; for the period 2022 to early 2027, mandatory reporting of site emissions and league tables; and from early 2027, revising and strengthening targets.

Table 2 Sources of Capital Carbon in the Built Environment

<table>
<thead>
<tr>
<th>Sector (UKGCB, 2013)</th>
<th>Source of carbon (UKGCB, 2013)</th>
<th>Mapping on Pomponi and Moncaster typology</th>
<th>Potential not reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>Production or manufacture</td>
<td>MS1, MS3, MS8, MS9, M12</td>
<td>MS7, MS10, MS13, MS14</td>
</tr>
<tr>
<td>Transport</td>
<td>materials</td>
<td>-</td>
<td>MS5, MS7, MS10, MS11, MS12, MS13, MS14</td>
</tr>
<tr>
<td></td>
<td>people</td>
<td>-</td>
<td>- ditto -</td>
</tr>
<tr>
<td></td>
<td>plant</td>
<td>-</td>
<td>- ditto -</td>
</tr>
<tr>
<td>Design and consultancy</td>
<td>industry design or consultancy activities</td>
<td>MS1, MS2, MS3, MS4, MS5, MS6, MS8, MS9, MS10, MS11, MS12, MS14, MS15, MS16, MS17</td>
<td>-</td>
</tr>
<tr>
<td>Construction or demolition</td>
<td>processes</td>
<td>MS1, MS4, MS5, MS9, MS10, MS11, MS12, MS13, MS14</td>
<td>MS2, MS3, MS7, MS8, MS15, MS16</td>
</tr>
<tr>
<td></td>
<td>welfare of workers</td>
<td>-</td>
<td>MS1, MS2, MS5, MS7, MS10, MS11, MS12, MS13, MS14, MS14</td>
</tr>
<tr>
<td></td>
<td>plant</td>
<td>-</td>
<td>MS2, MS5, MS7, MS10, MS11, MS12, MS13, MS14</td>
</tr>
</tbody>
</table>

The third in this category is 'Carbon Action 2050 Toolkit' (Chartered Institute of Building, No Date). It advocates for best-practice energy management on construction sites, connecting to long-term energy source earlier, encouraging subcontractors and supply chain to reduce their own carbon, using energy-efficient plant and using energy-efficient site accommodation.

The fourth in this category is 'The Well Building Standard' (Delos Living LLC, 2017). It encourages engine exhaust reduction and pollution management around occupied buildings. These issues can extend to construction sites as many sites tend to be near occupied buildings and, also, exhaust fumes and any pollution from the construction sites will eventually affect people in buildings further away from the construction site.

On the whole, strategies and actions do not provide specific tools for reducing CEoCS but, instead, provide generic objectives to pursue.

Measurement and reporting initiatives

Measurement and reporting initiatives include: 'Construction C02e Measurement Protocol' (ENCORD, 2012), 'BS EN ISO 14064 - 1: 2012' (British Standards Institution, 2012a), 'BS EN ISO 14064 - 2: 2012' (British Standards Institution, 2012b), 'BS EN ISO 14064 - 3: 2012' (British Standards Institution, 2012c) and 'BAM SMaRT' (BAM Construct UK, 2010). Measurement and reporting initiatives facilitate standardisation of quantifying CEoCS. Such standardisation is expected to be a precursor for targets setting and, generally, managing reductions in CEoCS at micro and macro levels. However, like strategies and actions, measurement and reporting initiatives do not provide the specific tools for reducing CEoCS.
**Rating systems**

Rating systems focus on measuring organisational performance using a variety of metrics. The main rating systems in UK are BREEAM, CEEQUAL and Considerate Constructors Scheme. BREEAM focuses on performance based on operation carbon and some aspects of capital carbon but not on site emissions. CEEQUAL focuses on energy and carbon impacts of construction plant and machinery but in a qualitative manner. Considerate Constructors Scheme focuses on a qualitative consideration of measurement and reporting of emissions and efforts to reduce CEoCS. The two main rating systems outside UK are Leadership in Energy and Environmental Design (LEED) and Green Star. These two systems focus on operational carbon and, as of 2017, do not cover CEoCS. While the rating systems nudge organisations to seek tools to reduce CEoCS, they do not provide the tools.

**Research question**

The foregoing consideration of CC from academic and industry/government perspectives, leads to two concluding points. Firstly, current efforts to reduce CEoCS are sparse and provide very limited practical tools to reduce CEoCS at rates consistent with the carbon reduction targets set in the Climate Change Act 2008. Secondly, the reaction to the first point has to be to provide (as fast as possible) tried and tested tools to reduce CEoCS for organisations to acquire and deploy. These two points lead us to the central research question which is as follows: how should we approach the challenge of developing and delivering tools to reduce CEoCS to match/exceed UK capital carbon reduction targets?

**METHOD**

Focus group was the method chosen to address the research question. The choice was justified on the basis that focus groups would enable deep and meaningful discussion of the issues at hand and enable a sustainable approach to developing and delivering tools to reduce CEoCS to emerge. Besides, focus group is a well-established and widely-used method in built environment research (e.g. in Baldwin and McCaffer (2000), Christina, et al., (2014) and Loosemore (2014)), and it is particularly appropriate when addressing research questions, such as the one in this article, which require consensus about plans to be implemented. The focus group method was implemented in a two-day workshop entitled ‘Workshop: Introducing Zero-carbon Construction Sites (WIZCS)’ held in March 2017. WIZCS was designed around the central concept of zero carbon construction sites (ZCCS) which was promoted as the ideal to be pursued as a final destination on the journey of reducing CEoCS.

On focus groups, Gomm (2008) stipulates three issues that require careful consideration namely: representativeness and generalisability, focus group as a group interview and the role of facilitator. The issue of representativeness and generalisability was dealt with by seeking to bring together people from diverse backgrounds on the principles of quota sampling in line with recommended good practice (ibid). In recognition of a focus group as a group interview, WIZCS was ran on principles of a Delphi group, thereby, acknowledging that outcomes would be attributed to a consensual group rather than individual members. The facilitator paid attention to focussing group discussion on a set of clearly defined and pre-prepared issues (rather than simply asking questions) as well as moderating the participants’ influence on each other by encouraging/facilitating all to vocalise their views.
Forming the Focus Group

Due to the specialist nature of the issues pertinent to WIZCS, a targeted invitation (as opposed to open invitation) strategy was adopted. After careful consideration of potential participants, over sixty potential participants were invited from five categories. The potential participants were encouraged to distribute and/or forward the invitation to their colleagues for whom they felt the issues were relevant.

In the first category, academic researchers, invitations were sent to four individuals, nineteen members of the Management Committee of the Association of Researchers in Construction Management, three distribution lists (covering researchers in energy, environment and physical technologies) and one international distribution list of the co-operative network of building researchers. In the second category, construction contractors, fifteen individuals from twelve construction contracting organisations based in the Yorkshire and Humber Region were invited. In the third category, local government, fourteen senior officers in the constituent councils of the West Yorkshire Combined Authority (Her Majesty’s Government, 2014) were invited. In the fourth category, central government, invitations were sent to five senior officers from the Department of Transport, Highways England, Department for Business, Energy and Industrial Strategy, Department for Environment, Food and Rural Affairs as well as to the organisations’ helplines. For the fifth category, research and technology organisations, after scrutinising a list of 57 research and technology organisations in UK (Association for Innovation, Research and Technology Organisations, 2017), five (BRE, BSRIA, CIRA, Horiba Mira and WMG HVM Catapult) were found to be the most appropriate and invitations were sent to nine senior officials from the five organisations. For the sixth category, quasi autonomous non-governmental organisations (quangos), after scrutinising a list of 463 quangos in UK (Cabinet Office, 2016), four (Committee on Climate Change, Council for Science and Technology (CST), Environment Agency and Innovate UK) were found to be the most appropriate and invitations were sent to the CST helpline and six senior officials from the other three quangos.

Focus Group - Day 1

Eleven participants attended WIZCS on the first day and constituted day 1 focus group. The eleven included: five academic researchers with research interests in solar energy, wind energy, biofuels, construction management and sustainable construction; two senior managers of two construction contracting organisations - the individuals were responsible for environment and sustainability in their respective organisations; one senior officer from central government’s Department of Business, Energy and Industrial Strategy; one senior manager from a large public sector client organisation responsible for environment and sustainability; one student undertaking a research project in carbon capture technology on construction sites; and one research administrator with knowledge about funding for research in UK. Four hours were spent presenting and discussing the following topics: ZCCS: why and why now; Renewable energy opportunities for ZCCS; Biofuel energy opportunities for ZCCS; Solar energy: challenges and capabilities; Learning from low cost low carbon homes; Construction contractors' perspectives on construction site emissions; and Research and development funding schemes. A further two hours were spent on formulating, using brainstorming and interrogative discussion, draft strategies relating to a ZCCS network, ZCCS scheme, ZCCS science, technology, engineering and mathematics research, ZCCS policy research and ZCCS business modelling research.
Interval

There was a two-week interval between days 1 and 2 of WIZCS. A summary of day 1 deliberations was circulated to day 1 focus group together with questions/issues to consider and/or consult about during the interval. The interval was included to enable participants to reflect deeply on the issues discussed on day 1 and consult with colleagues in their organisations before reconvening for day 2 to confirm commitment to ZCCS and agree plans for post-workshop activities. During the interval, the facilitator kept in touch with the participants and addressed any emerging queries and collated emerging ideas for discussion on the day 2.

Focus Group - Day 2

Seven participants attended WIZCS on the second day and constituted day 2 focus group. The seven included: three academic researchers with research interests in solar energy, wind energy, construction management and sustainable construction; one Director of a construction consulting organisation - with previous work experience with construction contracting organisations in UK and mainland Europe; one senior manager from a large public sector client organisation responsible for environment and sustainability; one student undertaking a research project in carbon capture technology on construction sites; and one research administrator with knowledge about funding for research in UK. Day 2 focus group benefitted from contributions in writing from one senior manager in a construction contracting organisation responsible for environment and sustainability and one academic researcher with research interests in sustainable construction. Day 2 focus group spent six hours formulating plans for the four post-workshop activities that emerged from day 1 and reflections over the interval through brainstorming and interrogative discussion. The objective of day 2 was to identify what was to be done, who was going to do it, when it would be done, what participants and/or organisations would contribute and which other individuals/organisations could be invited to join in the activities.

RESULTS/OUTCOMES

CEoS Today - Acknowledgment of Need for New Action

The discussions of the focus group led to consensual acknowledgment of six points. 1) There is growing interest in reducing CEoS across government, industry and academia but the interest is not widespread. 2) From a construction industry perspective, action to reduce CEoS is often limited by lack of solutions to the barriers faced. 3) Actions to facilitate reduction of CEoS in the short, medium and long term are urgently required. 4) Since different organisations will be interested in different time frames, it is important to avoid a ‘one-size-fits-all’ mentality when seeking solutions to the challenge of reducing CEoS. 5) ZCCS is a timely concept and has potential to accelerate and spread reduction of CEoS.

CEoS Tomorrow - A Solution to the Research Question

A four-part solution to the research question emerged from the focus group. The solution constitutes a plan of action that can lead to practical tools that, over time, can improve theory and practice of managing CEoS and create a better landscape than the one illustrated in Table 2. The solution is presented below.

1. Developing and disseminating ZCCS Initiative (ZCCSI)

ZCCSI should be developed to achieve the following objectives: 1) define ZCCS, 2) document the barriers/challenges to reducing CEoS, 3) develop solutions to the
barriers/challenges to reducing CEoCS, 4) diffuse solutions to the barriers/challenges to reducing CEoCS, 5) develop a measurement framework for ZCCS performance at project level and 6) develop evidence-based protocols to promote reduction of CEoCS.

Moreover, pursuit of the above objectives should take cognisance of and build on the work of organisations such as United Kingdom Green Building Council, Green Construction Board, European Network for Construction Companies for Research & Development, World Green Building Council and CDP Worldwide. Publications such as Her Majesty’s Government (2013), Green Construction Board (2013), ENCORD (2012), Chartered Institute of Building (No Date), Delos Living LLC (2017), British Standards Institution (2012a), British Standards Institution (2012b) and British Standards Institution (2012c) should also inform the development and implementation of ZCCSI. In addition, industry systems such as BREEAM, CEEQUAL, Leadership in Energy and Environmental Design (LEED), Green Star, Considerate Constructors Scheme (CCS) and BAM SMaRT should be taken considered in the development and implementation of ZCCSI. To maximise dissemination, ZCCSI should be taken to main stream literature and bodies of knowledge in trade, professional and academic periodicals such as Construction News, New Civil Engineer, Construction Manager, Building, The Construction Index, Proceedings of Institution of Civil Engineers - Management, Procurement and Law, Proceedings of Institution of Civil Engineers - Energy and Proceedings of Institution of Civil Engineers - Engineering Sustainability.

2. Creating a ZCCS research network
A ZCCS network should be created to be comprised of pioneers of ZCCSI from among WIZCS participants and others already, and to be, identified who were unable to attend WIZCS. Funding for the network for a period of three years should be sought from appropriate research funding bodies with a view becoming self-sustaining after this initial period. The network’s activities should be aimed at 1) providing a forum to incorporate stakeholder opinions in the area of capital carbon emissions reduction in the civil engineering and building sectors 2) increasing public understanding of the importance of construction sites in reducing capital carbon emissions, 3) stimulating knowledge transfer between industry, academia, government and other stakeholders and 4) identifying and promoting future ZCCS research and development requirements based on stakeholder contributions.

3. Creating a ‘ZCCS Challenges and Opportunities Repository’
There is immediate need for research to establish and publish the challenges faced by construction organisations when seeking to reduce CEoCS. Publishing the challenges will be an invitation to everyone to develop solutions. There is also immediate need to identify opportunities available from within and outside the construction industry that can enable construction organisations reduce CEoCS. The research required for these activities will entail, but not be limited to, the following: working with construction and building contractors to create a training programme for ZCCS analysts; deploying ZCCS analysts to document ZCCS challenges and opportunities; creating an online repository of ZCCS challenges; creating an online repository of ZCCS opportunities; identifying external drivers for ZCCS; developing standards for ZCCS; and creating a training programme for construction professionals to become ZCCS analysts.

4. Developing better understanding and solutions for specific ZCCS challenges
A number of immediate challenges relating to CEoCS were identified. These include but are not limited to plant idling, heating and drying on construction sites, plant logistics on construction sites, power generator set technology, delivery logistics on construction sites, alternative technologies for construction plant, impact of battery technology on
ZCCS, impact of offsite manufacturing on ZCCS and impact of ZCCS on air quality. These are some of the challenges that require immediate attention.

**CONCLUSIONS**

From the foregoing sections, it is clear that while there is appreciation of the need to reduce CEoCS in literature and practice, the current effort to reduce CEoCS is not enough and there is need for new initiatives to accelerate achievement of desired reductions, particularly, through development of practical tools for real challenges faced by the construction industry. A solution to the question 'how should we approach the challenge of developing and delivering tools to reduce CEoCS to match/exceed UK capital carbon reduction targets?' is provided in four parts thus: develop and disseminate ZCCSI, create a ZCCS research network, create a ‘ZCCS Challenges and Opportunities Repository’ and develop better understanding and solutions for specific ZCCS challenges. Due to the nature of the solution, its implementation requires and deserves participation from all of us, particularly, scientists, engineers, technologists, construction and building contractors, construction plant manufacturers, construction plant hire organisations and construction clients.

**ACKNOWLEDGMENTS**

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EXPLORING THE INFLUENCE OF AUSTERITY ON THE SUSTAINABILITY PERFORMANCE DELIVERED WITHIN FOUR SPANISH HOSPITAL PROJECTS

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The economic recession in Spain (2008-2012) has resulted in a period of unprecedented austerity as the Government attempted to align with the requirements of EC financial aid. Budgets for new hospital projects were significantly reduced and many on-going projects forced to adjust their initial proposals to fit with the new economics. As the crisis eases this research seeks to explore the impact of the economic crisis on the priority placed on sustainability in new hospital projects during this period asking whether it was 1) perceived as a luxury against other priorities and removed, 2) retained purely as a requirement (i.e. CTE-2006) or 3) embraced as a driver to reduce operational lifecycle costs and if so to what extent did this go beyond energy. Four hospitals projects located in Pamplona (Navarra) reflecting a staggered timeline in their inception (before, during and after the economic crisis) are evaluated through a triangulation of methods (checklists, project documents and interviews) and a common evaluation framework based around BREEAM and CTE. Analysis revealed that sustainable measures which were regulated by legislation and those which have been proven to achieve an economic benefit over the building lifecycle have been retained and implemented despite the budget cuts.

Keywords: hospitals projects, sustainable construction, Spanish economic crisis

INTRODUCTION

Between 2007 and 2009, after years of prosperity, the Spanish economy suffered a GDP decline of -7.5%, the highest in history. As a consequence, the construction industry collapsed due to the lack of Government liquidity and the lack of credit for private investors. Since 2008 public spending has been declining each semester at the request of the Economic European Community as a condition to continued financial aid from its European partners. The trend of continued economic recession reached historical declines in GDP with an unemployment rate of 27% at the end of 2012 (INE, 2017). New construction projects have not been carried through and ongoing projects have experienced cuts of up to 40% of the initial budget. In this context, the potential exists in the few projects taken forward for the inclusion of sustainable measures to be downgraded and even removed due to the perception of cost and additional project risk. On the other hand, sustainable design has the potential for both environmental and economic benefits when considered across the whole life cycle of the building thus reducing both the operational energy costs for public buildings but importantly contributing to the wider Governments CO2 reduction targets. Indeed, despite this period of economic austerity Spain still requires to align with the European Directive

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Influence of Austerity on Sustainability Performance

(202/91/CE) on energy performance of buildings (OJEC, 2003) which has been adapted since 2006 through Spanish legalisation forming the Technical Edification Code (CTE) stipulating the promotion of sustainable design within buildings to improve its energy performance and reduce resource consumption (CTE, 2006). This commitment has promoted awareness of sustainability amongst public and private sectors, and is further emphasised by green building certification schemes such as BREEAM and LEED. The promotion and standardisation of good practice in sustainable design, aligned with the availability of innovative products is increasingly reducing the associated costs. Despite this, the perception is retained amongst many construction professionals that sustainable design and construction represents a luxury not deliverable during times of austerity and social hardship (Rotherham, 2010).

Prior to 2008, financial support was being offered to build and retrofit buildings helping them reach A or B energy ratings, and a requirement set within the Plan for 2008-2012 for energy efficiency through the public procurement of buildings (IDAE, 2007). However, similar to the UK’s Code for Sustainable Homes (which was discontinued in 2015) the pressures caused by the collapse of the Spanish economy resulted in the majority of these grants disappearing. In 2004, Spain’s held the status as having the highest rates of solar energy in EU with the highest rates of subsidies for promoting photovoltaics through RD 436/2004 (BOE, 2004). The financial crisis has led to the repealing of the legalisation as part of RD 1578/2008 reducing grants and penalising those who had already had solar installations, a practice heavily criticised by Spain's National Energy Commission.

At the beginning of the crisis, the Government tried to boost the economy with an injection of funding for public projects (Forcada, 2013), but by 2009 investment had collapsed as government expenditure was adjusted to align EU funding requirements, in addition to stringent tax increases (Hunter and Sim, 2012). Many public building and infrastructure projects were cancelled or halted but ongoing projects were adjusted with their initial proposals and their budgets fitting the new economic and political scenario. Although recent economic data shows an improvement in the Spanish economy; high unemployment and corruption currently clouds the country's economic reality with society demanding transparency and accountability for public expenditure (INE, 2015).

**Austerity, Sustainability and Hospital Projects**

Hospital projects provide the context for this research and have attracted a high level of public scrutiny over expenditure levels with many projects being cancelled, reduced in scale or even suspended. In May 2015, the Government announced the resumption of seventeen hospital projects with an investment of 1,400 million of euros (Sanchez de la Cruz, 2014), with many within the health sector believing that this was only an electoral hook (ISANIDAD, 2014). However, it is true that some stalled projects have recently been continued and completed, and other buildings that were closed due to lack of capital have also been recently re-opened. Despite the recovery, the Spanish Government will continue with austerity policies over the coming years shaping the context within which decisions relating to promoting sustainability are framed.

Hospitals represent a key context when considering the implications of austerity on decisions taken to invest on sustainability measures in public projects. The traditional association of sustainability measures and technologies with high upfront costs, additional risk and uncertain payback periods remains in both the public sector and construction industry and the potential exits for this perception to be heightened during a period of austerity with the safe traditional option preferred. Despite this, there is growing
recognition that investing in sustainability measures has the dual benefits of achieving savings on the operational energy costs and in contributing to the reductions in the aligned CO2 emissions’ targets (Griffiths, 2006). This has significant implications for hospitals due to their continuous use (365 days and 24 hours) and hygienic requirements resulting in buildings having a high demand of energy and water. The introduction of the CTE (2006) has seen sustainability measures being included and becoming mandatory for new buildings and large refurbishment, and this applies to hospital projects. Initially the Spanish Promoters and Builders Association criticized this code because it involved an increment in the price of projects, especially problematic in a crisis scenario. The Spanish Association for the Quality (AEC) also pointed that construction costs increased 10% due to CTE, in addition to the surface increment for service areas and the insulation of new requirements (LARCOVI, 2008). However, the decline in labour prices and standardization of products demanded by CTE, has eliminated these extra costs (Eustat, 2015). Evidence from housing related research suggests that in Spain, CTE has had a positive impact with one block of flats presented as a case study seeing 33.9% of energy savings.

There is to date little empirical evidence from the hospital sector to support a similar positive story demonstrating cost savings in practice during this period of austerity (Legido-Quigley et al., 2013). When investment decisions are placed in such a challenging context it is important to ask whether the whole life value of the investment is recognised by decision makers (Kirkham and Boussabaine, 2005). IPSOM Consultants (2012) confirm than most hospitals could save 50% of their running costs with the appropriate application of sustainable measures. WRAP (2015) in the UK cite that ‘life maintenance and operational costs of buildings can be five times greater than construction costs’, highlighting the importance of efficient services and sustainable materials in new buildings. Hospitals are usually owned by the same organisation across the lifecycle so the potential exists to realise the benefits of the initial investment (Campion et al., 2016). Despite apparent recognition, the question remains over whether the scale of the austerity crisis has translated into decisions supportive of investment in sustainability or whether the traditional perception prevailing in practice of it as a luxury? If sustainability is now a required consideration for hospital projects, a further question exists over whether it is viewed specifically in the context of reducing operational costs through energy savings with carbon savings regarded as a by-product; or does it extent to a more holistic understanding of sustainability in the built environment?

**RESEARCH AIM**

To answer these questions, this research adopts a case study approach with four hospital projects located in Pamplona (province of Navarra), a region of the North of Spain which suffers an extreme seasonal climate. These longitudinal case studies have been chosen to reflect a time line from their inception to represent a mix of projects making key project decisions before, during and in the later stages of the crisis in order to consider the impact of the recession on the priority placed on sustainability within project decisions, to explore cost implications, perception of clients and other stakeholders, influence of legalisation changes, level of innovation or the promotion of specific sustainability measures. This will allow for comparison to assess whether there has been a shift in the way sustainability has been perceived during this timeframe and whether it is viewed during decision making in a positive or negative manner within an austerity focused context.
RESEARCH METHODS

This research is based on the study of four hospital projects in a longitudinal approach reflecting approaches to investing in sustainability before, during and after the Spanish economic crisis. The case studies also were selected to reflect the same city, climate, and a mix of private and public ownership. Pamplona is selected for two reasons; 1) it is one of the few towns in Spain that had several large hospital projects in between 2000-2015 and 2) this is the place where the lead author enjoyed access to project information and stakeholders due to her professional role working with a local construction consultancy managing the bidding and procurement of each project. Table 1 provides a description of the characteristics of each showing a mix of private and public funded projects and start dates. A pragmatic approach is adopted reflecting the researcher’s desire for inductive research which seeks to explore practice and allow questions to emerge to shape the findings. The starting point of the research emerged from professional concerns and intuition as to what was happening in practice.

Empirical evidence was sought through the research favouring an exploratory and explanatory approach which builds on her professional understanding in order to provide context and ask the right questions. The case studies are explored through mixed methods focused on an iterative process combining project observation and a checklist of information requirements (drawing on project documents, drawings, and available data relating to costs, projected operational performance and level of sustainability investment). In depth interviews with key stakeholders relating to each project (architects, engineers, client representatives, estate managers, construction project managers) explored the questions emerging from the analysis using thematic analysis, with a questionnaire used to access individuals who were unable to conduct a face to face interview with a view to obtaining specific information. The methods applied permitted strong use of triangulation. This was permitted through the lead author’s access to the data and wider contextual understanding of the projects.

An evaluation of the aspects of sustainable construction implemented provided a consistent framework across the four projects around which each were investigated against the themes of the technical handbook of BREEAM New Construction for Non Domestic Buildings (SD5073 - 2.0:2011). Despite increased awareness in practice in Spain of this assessment method and a tailored version BREEAM Spain (2013), only two hospitals have implemented the BREEAM certificate with modest results of GOOD or VERY GOOD (BREEAM Spain, 2014). Therefore, this research doesn’t conduct an evaluation of an existing assessment but merely uses the criteria to allow evaluation of each case study against a consistent framework. Using professional judgement and access to relevant data the implications of the sustainable design and wider measures were costed (reflecting initial cost, and implications for operational costs) as well as reflecting on the timeline of the project process and the reasoning for changes which took place in terms of investment for delivering sustainable design. The research started in 2012 and completed in 2015.

SUSTAINABILITY EVALUATION OF HOSPITAL PROJECTS

The four case studies were evaluated considering documentation related to design and procurement, consideration of BREEAM technical handbook, CTE regulations and exploring the context of related decisions through interviews with key stakeholders. An analysis grid was developed using BREEAM categories and sub categories (Energy, Water, Materials, Waste, Management, Health and Wellbeing, Transport, Land use and
Ecology, Pollution) evaluating each project against the credit awards in the technical handbook.

Table 1: Characteristics of the case studies

<table>
<thead>
<tr>
<th>Case study</th>
<th>Cost (sector)</th>
<th>Timeline</th>
<th>Nature of project</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Miguel Hospital</td>
<td>6 M Euro (Private)</td>
<td>2005-07</td>
<td>Building extension and refurb</td>
<td>The initial project was a retirement home attached to the hospital and ended up becoming in hospital rooms by the increase in patients due to the decline of public health.</td>
</tr>
<tr>
<td>Virgen Del Camino Hospital</td>
<td>8 M Euro (Public)</td>
<td>2009-11</td>
<td>New building for paediatric emergencies</td>
<td>The government gave priority to this project, because it was a lower investment and is already running.</td>
</tr>
<tr>
<td>Hospital De Navarra</td>
<td>21 M Euro (Public)</td>
<td>2009-14</td>
<td>New building for emergencies</td>
<td>The building began construction in 2010, but it took four years to complete due to lack of public funds.</td>
</tr>
<tr>
<td>San Juan De Dios Hospital</td>
<td>41 M Euro (Private)</td>
<td>2011-14</td>
<td>Renovation and new building</td>
<td>The project suffered budget cuts from the start of construction due to the lack of public support.</td>
</tr>
</tbody>
</table>

**Energy**

The interviews revealed that stakeholders are increasingly aware of energy consumption as a key consideration during decision making as the potential to achieve operational savings is recognised. Significantly comparison revealed that projects signed after 2006 demonstrated greater consideration of low/zero carbon technologies and promotion of solar panels and co-generation systems. The increased inclusion of low consumption external and internal lighting, transition to LED lighting, motion sensors, and importantly in the two later projects embracing principles of daylighting through measures such as internal gardens. It is clear that the introduction of CTE in 2006 has been a key determinant in the investment and inclusion of these measures, with those signed after 2006 all aligning to a strengthened energy criteria. As well as legislation acting as a driver for this, it was apparent that stakeholders recognised that there was evidence of the benefits due to reducing costs of the technologies and recognition for reducing operational costs which was seen as an increasing priority when it came to making energy related decisions.

**Water**

Awareness of water savings is widespread among developers and the general public in Spain. Consequently, most taps and WCs available in the market have water saving systems. Therefore, these measures can be included in projects without any increment on the budget. Despite this widespread acceptance of its value, in the Navarra hospital with water saving features heavy in the original project proposals, the most expensive devices were discarded in the construction phase. Interviews revealed that unlike with energy, legislation such as CTE does not extend to improving water consumption within a sustainable design so when costs require to be reduced then these features become vulnerable. However, even without legislation driving the change evidence was presented through the interviews that stakeholders are recognising that advances in water saving technology is reducing costs year after year, and that contemporary projects are displaying a higher level of innovative water technology due to the stronger association with operational cost benefits. For this reason, the weakest project in relation to water is
San Miguel hospital and the best one San Juan de Dios. The interviews revealed a growing commitment towards the implementation of behaviour change programmes.

Materials
Despite a noticeable increase across the timeline of sustainable materials, the interviews revealed that this was not related to the ecological awareness of the designers, but rather was related to an appreciation by decision makers of the cost savings over the life cycle of the building achieved by using these materials or was seen as a need to comply with legislation covering their inclusion. The interviews revealed that the dominant consideration relating to materials is to promote robustness, with the associated link to ecological design which is low in terms of its priority. It is noteworthy that only San Juan de Dios Hospital project is designed with recycled materials, which are recognised as being more expensive but were seen as a big part of the design concept. In other projects priority was given to ecological materials which were proven to save money and stakeholders when asked felt that the crisis was indirectly affecting the decision making within the projects. CTE legislation was crucial in encouraging the improving isolation levels observed and a big difference was noted with the pre-2006 San Miguel Hospital.

Waste
The interviews revealed that the key driver for waste management during project decision making related to both general and specific legislation. San Juan de Dios hospital is the only project with separating containers for the recycling of specific site materials. Projects signed post CTE in 2006 showed an increase in the level of waste management consideration in the criteria with San Miguel Hospital emerging as the weakest project as a result.

Management
Most of the clients have taken into account sustainability in project procurement, and the interviews revealed that this was a bigger consideration during the design stage within each project. Comparison revealed that there were not big differences between the projects when considering performance against BREEAM criteria, and that the introduction of CTE legislation had no influence on management processes. However, it is true that San Juan de Dios hospital as the most contemporary project achieved the highest rating and actively considering analysis of the cost and savings of sustainable measures during decision making.

Health and Wellbeing
The interviews revealed that this is an aspect that has been taken into account within all of the hospitals, both private and public. The private hospitals, San Miguel and San Juan de Dios are located in a green area and both have been designed to ensure that the stay of patients in the hospital is more pleasant with attractive views which are aspects that are not part of a legislative framework. Indoor air and water quality, acoustic performance and safety are aspects where the designs are again conditioned by compliance with CTE regulations. San Juan de Dios hospital is the best building in this aspect it was revealed for two reasons; the good location and the owners’ aim to get the best for its patients.

Transport
Hospitals located in the outskirts of the city have the advantage of having a greener and more pleasant environment for patients, but they have the disadvantage of having poor transport connection, amenities, and travel plan. The absence of bike lanes and low frequency of public transport, invite the use of private vehicles to get to both private hospitals which are out of town. The interviews revealed that these are factors where austerity limits the solutions emerging from local authority as they struggle to provide a
more sustainable transport infrastructure and also starving funding to support incentives directly by the hospitals.

*Land use and ecology*
San Juan de Dios Hospital is especially sensitive to this aspect because the expansion of the building is in an area of garden and orchard belonging to the religious community who own the hospital. The interviews revealed that this project placed emphasis on an ecological design and strong connection between land and wellness of patients. The other three projects are located in places of less ecological significance and with the exception of tree protection, with no further action imposed by law. The interviews revealed that unless sustainability measures are addressed within legislation, then decision makers will not consider these.

*Pollution*
Hospitals can be defined as high polluting buildings. They produce tonnes of waste, refrigerants for air conditioning and laboratories and NOx emissions from central heating boilers. The interviews across the projects revealed that whilst they try and comply with legislation minimums, there is not a big commitment to improve these aspects beyond this. The key drivers are again the compliance with regulations (i.e. CTE and other regulations) and the technology advancement which is driving improvements and cost reductions. The latest projects include modern boilers, as well as the most efficient noise isolation and display a big advance compared to the older ones, again the interviews revealed that austerity did not limit their inclusion as there was an obvious operational cost saving.

**FINDINGS AND DISCUSSION**

The economic crisis began in Spain in the year 2008, but it was in 2010 when at the request of the CEE, a strong campaign to constrain public spending began. San Miguel Hospital started its activity at the end of 2007, still representing the boom of the Spanish economy and as a result this project was not affected by the drawback of the economy. However, the two public hospitals were directly affected by the deep cuts in public spending with both projects reducing the useful area of buildings and experiencing delays. In the case of Virgen del Camino Hospital, the construction phase experienced delays due to an inability to adapt to the monthly payments to the Government of Navarra. The Navarra Hospital, suffered 29 months of delay in opening the building, due to the lack of public money for the equipment expenditure. The austerity policy also affected the private hospital San Juan de Dios. This hospital had planned a co-generation system, which was removed from the project when the Government slashed subsidies for renewable energies. The private company that would have managed the co-generation system abandoned the project because it was considered unprofitable without the subsidies. But the project needed to comply with CTE regulations in relation to renewable energy sources and consequently the warm double roof was changed for a gravel roof that allowed the installation of solar panels.

The projects were evaluated depending on the featured sustainable measures against each of the BREEAM categories ranking the hospitals (4-Best, 3-Good, 2-Bad and 1-Worst). The newest hospital (San Juan de Dios) is the best rated hospital with an average of 3.78, with Navarra hospital next with (3.0), followed by Virgen del Camino (2.23) and San Miguel (2.09) hospitals. This highlights the evolution of sustainable design and technologies from 2005 to 2011 and also makes clear the high level of sustainability across all projects with all achieving high scores for certain criteria and an overall rating over 50%. These findings can be aligned to the cost analysis displayed in Table 2.
illustrating the project budget, investment in sustainable elements outlined in the design phase and the real investment achieved for sustainability. This reflects the reduction in investment for San Juan de Dios hospital in cogeneration solutions due to removed subsidies thus reducing the real sustainability investment by nearly half. This project showed that despite an overall increased appreciation of the value of sustainable features in a project, when the lifecycle costs do not represent good value then it remains a luxury item and will be cut. However, despite this it remained the strongest project in the review and was the most contemporary. Despite the bad position on the hospitals ranking, the San Miguel project team demonstrated awareness of the latest sustainable measures and included insulation and service measures higher than those required by regulations.

Table 2: Cost analysis of the four projects (in Euro)

<table>
<thead>
<tr>
<th>Hospital</th>
<th>Project Budget</th>
<th>Sustainability investment</th>
<th>%</th>
<th>Real investment</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Miguel</td>
<td>6,000,000</td>
<td>223,000</td>
<td>3.7</td>
<td>223,000</td>
<td>100</td>
</tr>
<tr>
<td>Virgen del Camino</td>
<td>5,487,075</td>
<td>406,259</td>
<td>6.9</td>
<td>406,259</td>
<td>100</td>
</tr>
<tr>
<td>Navarra</td>
<td>21,000,000</td>
<td>1,531,900</td>
<td>7.3</td>
<td>1,531,900</td>
<td>100</td>
</tr>
<tr>
<td>San Juan de Dios</td>
<td>41,000,000</td>
<td>4,005,314</td>
<td>9.8</td>
<td>2,230,014</td>
<td>54</td>
</tr>
</tbody>
</table>

Three broad themes emerged as drivers for inclusion of sustainability: 1) compliance with legislation, 2) growing stakeholder ecological awareness and 3) association of innovative technologies with operational lifecycle savings.

The significance of legislation and the marked change in practice following the introduction of CTE (2006) has been the clearest driver for sustainable design. The interviews revealed that in projects which remained active during the recession, features associated with the CTE were independent of the impact on austerity on decision making. However, it was clear that perceptions of the increased costs associated may have contributed to some projects being stalled or cancelled. A greater association with the regulation changes and operational cost savings has seen this perception become less influential amongst decision makers especially hospital project managers. Analysis of the projects in relation to the BREEAM criteria revealed that investment in sustainable measures is was predominantly focused on aspects which promote operational costs of the buildings, such as increased insulation, low energy lights or heating systems with renewable or low energy consumption. It seems this link has enabled decisions to be taken to support investment, but has also resulted in reductions of CO2 levels during the life cycle of the building.

The next key theme is the increasing ecological awareness of hospital managers and project teams. This can be seen in San Juan de Dios hospital which had the highest sustainability rating for the building and reflects large differences when compared to the others. As a private hospital, evidence from the interviews suggested that they have easier access to funds than public projects but importantly it also seeks customers and this has seen sustainability emerge as part of their marketing strategy. Public hospitals are showing little progress in advancing criteria outside of the CTE due to spending cuts, and have a wider problem to resolve associated with growing waiting lists. The private sector is becoming an option for those with wealth and is a growing market with their sustainability credentials seen as an important attraction.

The last theme reflects the role played by innovation and a maturing market for sustainable processes and materials in the evolution of the projects in a more sustainable way. The interviews revealed that this evolution is driven by a mix of compliance with legislation, the ecological awareness of stakeholders and technological advancements and
economies of scale observed through standardisation, with these allowing designers to include more sustainable measures for a lower price.

**CONCLUSIONS**

The levels of austerity seen in Spain since the economic crisis of 2008 have had a strong impact on hospital projects with many being cancelled, delayed or reduced in scale. The four projects explored in this research reveal that the economic situation has influenced the development of each with investment in sustainability actually increasing in the more contemporary projects. To many of the stakeholders who were involved in delivering the projects, including the lead author, this finding came as a surprise due to the dominant perception that the crisis would have seen sustainability features within a project as very vulnerable to budget cuts due to the common view that they were often expensive and seen as a luxury during times of austerity. The analysis revealed that the crisis has helped to focus design decisions on reducing operational costs of the buildings and this has led to sustainable design and construction measures being implemented to achieve whole life goals. It can also be argued that this context has been supported during this timeframe through the changes to the regulations through the CTE legalisation in order to achieve sustainability objectives set by the EU.

The economic crisis has affected the development of the projects, but not the mandatory sustainable measures which evidence suggests are helping to reduce operational costs although perceptions amongst all stakeholders haven’t yet fully acknowledged this. The San Miguel hospital was initiated during times of prosperity and when the crisis hit the stakeholders decided to even improve it by incorporating even more efficient services. This was a private project, and by contrast both public projects (Navarra and Virgen del Camino hospitals) suffered heavy cuts in addition to delays. However, despite this contrast in fortunes when compared to the private project most of the sustainable design elements were maintained when budget cuts were undertaken, and this reflected their inclusion as a requirement as part of the CTE legalisation. Despite the crisis, the level of investment in sustainability elements was still increasing. San Juan de Dios hospital was the most recent and analysis revealed that it was the most sustainable project in terms of intended budget; however it did suffer from the elimination of renewable energy subsidies resulting in the removal of the co-generation system and double roof from the design. This however was not because of a lack of funds but a view from the stakeholders that due to the national removal of the subsidies the whole life economic case didn't justify the initial cost. This reminds us that austerity has created a culture where the economic case has to be met in order to support the inclusion of sustainable features in a project beyond legislative requirements. Despite the improved economic picture in Spain, public health expenditure continues to face a challenging future. Despite this, decision makers are recognising the potential benefits of sustainability and are prepared to invest in it but only when it is associated with improved operational cost benefits (Adams et al., 2014; Sahamira and Zakariab, 2014).

**REFERENCES**


Influence of Austerity on Sustainability Performance


ENVIRONMENTAL SUSTAINABILITY INDICATORS IN DECISION-MAKING ANALYSIS ON URBAN REGENERATION PROJECTS: THE USE OF SUSTAINABILITY ASSESSMENT TOOLS

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A topical focus in research and policy shows that sustainability has emerged as one of the most critical aspects of urban regeneration, due to increasing problems related to human population, energy demand and climate change. However, the practical implementation of environmental sustainability is still inadequate. Urban regeneration projects require elaborate decision-making approaches, due to their complex and demanding context. The study explores the potential for established sustainability tools to be used as indicators in decision-making analysis frameworks on such projects. A survey was conducted with 36 expert stakeholders involved in construction projects in the UK. Sustainability assessment tools were viewed by a third of participants as ineffective in evaluating sustainability. Nonetheless, most participants valued universal assessment tools. The findings show that Sustainability Assessment Tools are suitable as environmental sustainability indicators in decision-making analysis for urban regeneration projects, but further development is indispensable in order to resolve the need for greater flexibility and context customization.

Keywords: sustainability, urban regeneration, decision-making, implementation

INTRODUCTION

In the last 50 years, urban regeneration (UR) has become a worldwide phenomenon (UN, 2001) and has received considerable attention from both academics and practitioners, due to the expanding urban decay and deterioration of building stock (Peng et al., 2015). Moreover, the increase in human population and its resulting complexities in terms of economic growth (Dixit et al., 2010), resources and energy demand, as well as climate change, have highlighted the importance of the sustainability aspect in UR. Gradually, sustainability has advanced from an ecologically focused direction to a holistic context, incorporating social, economic, cultural, physical and environmental aspects (Lee et al., 2010). Today, the new form of regeneration sustainability has adopted a long-term, multi-disciplinary perspective that emphasises the balance between economic, social and environmental aspects (Gullino, 2009). Despite the pervasiveness of discourses around sustainability, its practical implementation is still inadequate (Huge et al., 2011a). For this gap to be reduced, sustainability must be supported by appropriate decision-making frameworks, following the premise that “at the very heart of every action lies a decision” (Huge et al., 2011b). In order to do so, sustainability has to be assessed and measured. However, its holistic and multidimensional nature renders its measurement complex, additionally so, in the early conceptual stages of project design. Despite known

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weaknesses, the indicator system approach, an interconnected set of indicators that share
the same purpose, emerges as the most popular and efficient method of sustainability
measurement (Peng et al., 2015). Exploring the sustainability indicators used in the
decision-making of UR projects creates debates and raises questions regarding not only
the way in which the indicators are selected but also regarding their efficiency. These
questions are closely related to the implementation gap, as the indicators used in decision-
making are rarely the same as those used to assess the project after completion (Huge et
al., 2011a). This analysis addresses one aspect of the gap between theoretical
understanding and the implementation of sustainability. Specifically, it explores the
potential use of Sustainability Assessment Tools, commonly used to evaluate a project
after completion, as the environmental sustainability indicator in the early stage decision-
making analysis of UR projects.

LITERATURE REVIEW

Sustainable Development in UR Projects

UR is the process of rehabilitation of the existing built environment through the efficient
recovery of buildings and the reuse of urban land (Wang et al., 2014). UR projects
present additional complexities compared to the rest of construction projects, due to their
nature. They are large-scale complex ventures that have a significant development
duration, involve multiple stakeholders and are transformational (Flyvbjerg, 2014). These
projects present further complexities as they directly and indirectly affect
numerous people (Flyvbjerg, 2014).

Sustainable development has been described as the key concept of UR projects due to
their long-term effects and vast impact (Zheng et al., 2014). Sustainable development
may be defined as meeting “the needs of the present without compromising the ability of
future generations to meet their own needs” (WCED, 1985). As stated in the Brundtland
report, sustainable development necessarily encompasses three aspects: the economic, the
social and the environmental. Even though the term Sustainable Development is
characterised by an apparent vagueness and interpretative flexibility (Huge et al., 2011b),
it is defined by a rather stable set of characteristics. These characteristics may be
considered as principles and are the following: equity, which includes intra-generational
justice for future generations, interspecies, geographical and procedural equity; dynamics,
referring to the constant change of the environment and society, as well as the
uncertainties triggered by them; integration of the three sustainability aspects, and
normativity (Huge et al., 2011b).

Decision-Making Analysis

Decisions constitute selections of solutions that eliminate or reduce uncertainty.
Decision-making is a cognitive procedure leading to the selection of a specific option or
course of action among other alternatives. While considered a rational process, in reality
it is more “fuzzy” as it may be subject to other influencing factors such as ideology,
norms, interests and power relationships (Wang and Ruhe, 2007). Decision-making is
usually based on the application of evidence-based criteria of selection. These criteria
may be qualitative or quantitative. In order to evaluate the criteria, a common
measurement framework is needed, denominated as indicator.

Sustainability Indicators

Sustainability performance measurement through the use of indicators is considered a
critical step in sustainable development. Consequently, the creation and advancement of
sustainability indicators has gained significant attention and importance over the years
Egilmez et al. (2015) completed a literature review that demonstrates the prevailing themes and indicator categories identified in government reports. The themes comprise global warming, resource consumption, waste generation and quality of air, while the indicator categories incorporate energy and water consumption, air pollution, carbon dioxide emissions, recycling, waste generation, land use, building footprints and transportation. These themes are translated into quantified indicators. Established assessment tools such as BREEAM and LEED are based on a carefully selected system or set of indicators that aim to integrate different aspects of sustainability.

### Sustainability Assessment Tools

A review by Walton et al. (2005) identified more than 675 sustainability assessment tools. Ten years later, the number of these tools is incalculable (Yigitcanlar and Dizdaroglu, 2015). The tools assess projects of different scales, ranging from city and neighbourhood level, down to the single building scale. Reviews of these tools show that the environmental components dominate over societal and economical ones (Pope et al., 2004). Nevertheless, reviews focused on neighbourhood scale, in which UR projects are assessed, present different results (Berardi, 2012).

#### Neighbourhood Scale Sustainability Assessment Tools

Research conducted by Komeily and Srinivasan (2015) reveals that the sustainability assessment tools operative on neighbourhood scale encompass aspects of all three dimensions of sustainability. Assessment tools are widely used not only by academics but also by practitioners, for the evaluation of real projects. Some of the most used tools are LEED-Neighbourhood, BREEAM-Communities, DGNB-New Urban District and CASBEE-Urban Development (Ameen et al., 2015). There are multiple sources in the literature that praise the objective of these tools and the concomitant increase in awareness that they have facilitated (Kajikawa et al., 2011). Nevertheless, there are several authors that question their effectiveness in terms of delivering actual sustainability. Monterotti (2013) argues that these tools do not adequately tackle resource efficiency, renewables and other crucial environmental aspects. He adds that they do not consider any connection between the built environment and its context, and are thus inadequate in the medium- and long term. Ding (2008) proposes that their inflexibility is the major cause for their low performance in practice. This inflexibility may be proven unfavourable in UR projects, as their context is complex and demanding (Lombardi, 2011).

Despite these limitations, the structure of these tools makes their application as indicators valuable in a decision-making context, for a number of reasons. The tools consist of a predetermined, validated, universal set of criteria that attempt to operationalise and measure sustainability. They are used for assessment after completion, however they can be utilized from the early stages of the project to examine its potential performance and how it changes during each design phase. In doing so, the tools offer a potential framework to aid the complex decision making process of early project stages. In addition, the tools yield practical information directly relevant for the future certification of the project, and are compatible with existing operational procedures at governance level. Furthermore, they are accessible and easily comprehensible by all the stakeholders and can be used for comparison with other projects due to the universal structure (Keysar and Pearce, 2007).

#### Sustainability Indicators in Decision-Making Analysis of UR Projects

The use of sustainability indicators in decision-making analysis is compelling to numerous authors in the context of megaprojects (Waas et al., 2014), and more
specifically in UR (Lombardi, 2011) (Peng et al., 2015). Various authors have developed decision-making indicator systems that respond to the need of UR projects. Hemphill et al. (2004) have focused on the aspect of economy, work, resources, buildings and land use. Ng (2005) in research related to Hong Kong, advanced indicators focused on quality of life, while Winston (2010) utilized location, construction and design indicators in order to assess sustainable housing and regeneration in Dublin. The literature provides diverse valuable references, however decision-making frameworks still present some weaknesses. Most indicators are designed according to specific locations and contexts (Zheng et al., 2014), therefore cannot be used for comparison with other projects (Peng et al., 2015). Additionally, they cannot be easily understood by stakeholders and decision-makers not familiar with the location. Furthermore, the selection process of the decision-making indicator may be subjective, thus transparency issues emerge (Shen et al., 2011). This research explores the use of sustainability assessment tools, a commonly-used universal indicator system, as the environmental sustainability indicator in decision-making analysis, as a possible response to ambiguity, subjectivity and transparency issues, as well as a solution to reduce the gap between design and implementation, created by the use of different indicators in pre- and post-evaluation process.

METHODOLOGY
The conventional research method in sustainability studies is expert consultation through interviews (Laws et al., 2004). Although this method can be useful in addressing the multidimensional and uncertain nature of sustainability, there remains a gap on quantitative methods, which seek to measure and offer potential to generalise. In order to thoroughly comprehend respondents’ views, studies can use questions that measure both the attitude and its strength simultaneously (Bradburn et al., 2004). This study uses a 15-item questionnaire administered via email. In order to measure both the expert’s attitude and its strength, closed-ended questions that use five-point rating scales to diminish positivity bias, were used. Furthermore, participants were encouraged to develop their thoughts in the free-format comment section. Participants were experts in the field of sustainability; either currently working at the time of questionnaire completion, or had previously worked – in sustainable development, or they were involved – or had been involved – in research programmes related to sustainable development and UR. They were selected to represent a wide range of the following attributes: field of competence; responsibility and influence; diversity and accessibility (Feleki et al., 2016).

Profile of Respondents and Response Rate
The experts were recruited according to the aforementioned attributes. They were working in the following categories of institutions: government, from regional or borough agencies; academia, as university researchers on sustainability-related fields; practitioners, involved in sustainable projects; and policy-makers, in both public and private sectors. In total, 120 surveys were disseminated, with a response rate of 36.6%, which is in line with comparable non-mandatory surveys. The number of the respondents may limit the generalization of the findings of the study. This has been acknowledged in the discussion. The questionnaire was answered by 44 respondents, of which eight were excluded due to failing at the filter question that examined their familiarity with the subject matter of the questionnaire. The remaining 36 participants successfully completed the questionnaire. Of the sample, 8.3% had a Ph.D., 75% held a postgraduate- or professional degree, while 13.9% had an undergraduate degree. Participants were requested to state up to three areas of expertise. The most frequent provided option was
project management (33.3%), the second most frequent was sustainable or environmental design (27.8%) and the third was architecture (25%).

Other areas of expertise included stakeholder management, environmental engineering, building surveying and urban design. At least 38.9% of the respondents had an expertise in environmental engineering, sustainable/environmental design, environmental science, or sustainable development. The sample thus represented a wide range of professional expertise in sustainable development. The majority of participants (94.4%), had used sustainability assessment tools. This information increases the validity of this research as respondents that have worked on the subject of study are likely to have formed more concrete and extensive views (Laws et al., 2004). As expected, 85.7% of the interviewees had used LEED and 67.9% had used BREEAM. Few (14.3%) had used Green Star or Protocolo ITACA. This study examined the potential use of sustainability assessment tools as appropriate environmental sustainability indicators in the context of decision-making analysis in UR projects. Additionally, universality versus contextualization and indicator effectiveness, were considered.

**FINDINGS**

The majority (86.1%) agreed that sustainability assessment tools could serve as an appropriate environmental sustainability indicator, while 13.9% neither agreed nor disagreed. No interviewee expressed any opposition. More than one third of the respondents strongly agreed with the statement, with 46% expressing their views in the optional comment section. More than half of the interviewees (61.1%) agreed that there should exist a universal standardised environmental sustainability indicator – meaning an indicator applicable to all projects, regardless of their location –, while one third of the sample disagreed. Interviewee 1 noted that “there must exist a single international authority in governing environmental and sustainability standards in urban developments and industries”, extending the issue from a universal indicator to a universal governance. Around 53% of the interviewees agreed the guidelines for the selection of the environmental sustainability indicator in decision-making should be the same for all the projects, while 38.9% did not support this statement. Interviewee 2 indicated that “Consistency and transparency is absolutely fundamental in standards to provide certainty to developers and planners. Nevertheless a degree of flexibility needs to be built in, for planners to work according to the area”.

Turning to the view of the respondents on the effectiveness of sustainability assessment tools in a general context, nearly half of the respondents (47.2%) agreed the result of the sustainability assessment tools truly reflects how environmentally sustainable a project is, while 30.5% disagreed. Numerous respondents supported their negative response. Interviewees 3 and 4 stated that the tools are not focused on the performance on operation, while interviewee 5 commented on their inability to consider the location. Interviewee 6 stated that “tools are well and good, but in practice they are boxes that are just ticked rendering sustainability meaningless”. 22.2% neither agreed nor disagreed, while only 19.4% expressed a strong opinion (strongly agreed/disagreed). When questioned whether adapting the tools to the needs of the area of the project (climate, air pollution, traffic, type of area – residential or commercial – etc.), the result of the assessment will more accurately reflect how environmentally sustainable a project is, 86.1% of the interviewees responded positively. Only 5.6% somewhat disagreed.

Exploring whether the environmental indicators used in decision-making processes of UR projects should reflect the specific needs and requirements of the area in which the project is located, 75% of the respondents agreed that every area has different environmental
needs and requirements, such as air pollution, noise pollution and microclimate, while only 19.5% disagreed. This 19.5% consistently agreed that a universal indicator should exist and that the selection guidelines should be the same for all contexts. A large proportion (94.4%) agreed that the environmental indicator used in the decision-making analysis of an UR project should reflect the specific needs of the area where the project is located. Only 2.8% disagreed, one of whom (interviewee 7) stated: “a universal tool should be developed. It should be used routinely and in all circumstances. The acceptable results may be different for different circumstances, but the assessment should be the same”, thus supporting that a universal indicator should exist, but the benchmarks used should vary by context.

DISCUSSION

The potential use of sustainability assessment tools as environmental sustainability indicators in decision-making analysis of UR projects was examined. When asked about the general applicability of the rating tools, nearly half of the respondents agreed that they do indeed reflect how environmentally sustainable a project is, but one third disagreed. That is, a third of expert professionals with experience in sustainable construction or development believed that sustainability assessment tools do not effectively evaluate achievement of environmental sustainability, and a further 22% neither agreed nor disagreed. This suggests that sustainability assessment tools are not yet achieving the goal for which they were designed.

However, more than six out of seven interviewees agreed that the adaptation of the tools to the needs of the project area will better reflect how sustainable a project is, which partially contradicts the literature. While a number of studies highlight the advantages of the tools in terms of measuring performance (Ding, 2008), others argue that they fail to adequately assess resource efficiency, renewables and other crucial environmental aspects (Berardi, 2012). Most of those who disagreed with the effectiveness of the tools in this study worked in the sustainable construction sector. These findings are consistent with the research by Schweber (2013), focused primarily on BREEAM, where she found that the more knowledgeable the participants were, the less they perceived highly-rated buildings as green buildings. While the discussion on the tools’ effectiveness has been going on for a long time, no clear solution has yet been developed.

The findings of the main part of the study suggest that the respondents support the use of sustainability assessment tools as environmental sustainability indicators in UR projects. Nevertheless, they express conflicting opinions on how they should be applied. Should the environmental sustainability indicator be universal and standardised, and should its selection guidelines be the same for all projects? More than half of the interviewees supported the existence of a universal standardised indicator applicable to all projects, while one third disagreed. This inconsistency is evident in the literature as well. The development of a universal indicator has been considered as critical (Bell and Morse, 2008), due to the large number of existing indicators, their differences and the difficulty in testing their validity (Button, 2002). On the other hand, it is widely supported that indicators, particularly in decision-making, should be location based (UNCSD, 2002). As Sharifi and Murayama (2014) state, “one size doesn’t fit all” and customised tools, taking into account context-specific criteria and weightings, have to be applied. This finding along with the fact that more than half of the respondents agreed that the environmental sustainability indicator used in the decision-making process should be selected according to the same guidelines, shows that most of the experts express a need for universality, both in the indicator per se, and in its selection process. Having identical guidelines for
the selection of indicators promotes transparency, thus increases the value and scientific credibility of the result (Dale and Beyeler, 2001). As noted by interviewee 2, consistency and transparency are fundamental aspects of decision-making analysis. However, he/she adds that a degree of flexibility should be embedded in the guidelines. This is consistent with multiple views in the literature that support the development of selection guidelines but point out the need for flexibility (Niemeijer and de Groot, 2008).

Almost all of the respondents maintained that the environmental indicator in decision-making should reflect the different environmental needs and requirements specific to each urban subarea. This finding is consistent with the literature highlighting the importance of location and context (UNCSD, 2002) as well as with the research by Cole (2011) which suggests that these tools should move beyond a focus on the performance of the project as a bounded system. Instead Cole suggests that these tools should concentrate on the evaluation of the project within its proper context. These findings show a tension between answers regarding the indicator’s need to reflect context-specific needs and responses related to the universality of the indicator. While almost all respondents agreed that the indicator should reflect the needs of its context, three out of five also endorsed a requirement for a universal standardised indicator that does not consider the location of the project. The format of the questionnaire enabled these apparently paradoxical opinions to be expressed. This finding allows the conflicting need of universality and contextualization in sustainability assessment tools, to emerge. An additional remark by respondent 7 transferred the conflict to the contextualization of the benchmarks instead of the tools, maintaining in this way the pure universality of their structure. Regardless of this tension between universalization and contextualisation, the respondents still acknowledge that the tools can be used as environmental sustainability indicators in UR projects.

With the findings suggesting that domain experts support the use of such tools as indicators in UR, the broader fit of the tools merits consideration. The conflict between contextualization and universality is only one aspect of the tools’ broader considerations. The content of the tools presents a broader limitation that regards their applicability on social and economic criteria. The tools partially promote weak sustainability as they fundamentally contain environmental indicators. They lack appropriate assessment of social sustainability (Albino and Dangelico, 2012) and to a degree misrepresent economic sustainability (Berardi, 2012). Thus, the use of the tools in this context may be limited solely to environmental indicators. This significant limitation proposes that for decision-making tools to support strong environmental sustainability they need to assess the environmental, economic and social quote separately. An additional discussion emerges, regarding the competences of the actors that apply and assess the tools. Egan (2004) proposed that in order to deliver sustainable communities, actors should have generic skills and knowledge along with specialist and technical skills. It is evident that each component of sustainability requires a different skillset, thus making the proposition of the use of an all-in-one sustainability indicator potentially inadequate for the complex decision-making in UR. Based on our findings, we propose the use of the tools solely as an environmental indicator alongside with two other indicators regarding social and economic sustainability, acknowledging that all three pillars must be equally represented in the decision making process.

Future study in this area is essential in order to consult beyond the current relatively small sample of experts, and to examine how sustainability assessment tools may respond better to specific location needs without losing their key characteristics, thus their universality and standardization, to promote transparency and consistency. Contextualization could
be addressed through the addition of more flexible elements in the current rigid structure of sustainability assessment tools. Nevertheless, such an “invasion” should be performed with caution, in order not to distort the key characteristic of universality and the advantages that it offers. The less “invasive” way to achieve such contextualization is to customize the assessment benchmarks to location-related values, as suggested by one of the interviewees. In this way, a level of contextualization is achieved without modifying the structure of the tool. Another way to achieve this could be a modular system where the indicator themes are selected dependent on the context. This may require the contribution of the key stakeholders to the selection process. However, this will be possible only if the participation processes are transparent and consistent. An additional way to promote contextualization is the change of the indicator system according to the general characteristics of the location. Indicators may be added or subtracted and weights might vary, according to whether the project is in a developed or developing economy, in an urban, suburban or rural location, with tropical, dry, mild or continental climate, for example. Finally, future research should be focused on identifying means in which social and economic sustainability may be adequately assessed in a decision-making context, in order to promote strong sustainability instead of a weak, environmentally focused one.

CONCLUSION

The use of sustainability assessment tools as the environmental sustainability indicator in the decision-making analysis of UR projects offers a possible response to ambiguity, subjectivity and transparency issues, and as a solution to reduce the gap between theoretical frameworks and implementation of sustainable development. The study explored the views of sustainability experts on this notion. The findings suggest that sustainability assessment tools are suitable as environmental sustainability indicators to decision-making analysis in UR projects. Varying views in the results show that the existence of guidelines and a universal standardised indicator (such as these tools) is desired by most respondents, but at the same time, the tools need to allow flexibility and consider the project’s context. The research demonstrates that, as the needs and requirements of the project location vary, they need to be reflected in the set of indicators. This field, however, will benefit from further research. More specifically, research should focus on the applicability of frameworks that allow flexibility in universal standardised tools and on the contextualisation of these tools according to the project’s specific needs. Location-related benchmarks, modular selection and diversified sustainability assessment tools are suggested as ways to achieve this. Finally, it is essential to identify social and economic sustainability decision-making indicators to complement the environmental ones and promote strong sustainability.

REFERENCES


Toli and Murtagh


EMBEDDED EVALUATION? EXAMINING GREEN INFRASTRUCTURE EVALUATION IN THE NEIGHBOURHOOD MASTERPLAN JOURNEY

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Evaluative practice is described as an embedded part of urban design processes, where evaluation can establish, trace and refine design intentions. The assumption that evaluative practice may shape decision-making is also central to standardised evaluative frameworks, such as the UK sustainable neighbourhood masterplan standard, BREEAM Communities. There is a need to examine the relationships between evaluation, design and construction in real-world practice in order to better understand this concept of ‘embedded evaluation’, considering whether and how these relationships change in the transition from design to construction. Adopting an empirical lens of green infrastructure evaluation in masterplanning and an analytical framework of Strategy-as-Practice, the enactment of formal evaluative practices is examined. Using interviews, observations and document analysis, a single evaluative episode is presented, from a larger set of six UK case studies, to illustrate how different actors structure, enact and respond to evaluative practices. The analysis highlights dynamic relationships between different evaluation, design and construction practices. Four themes are identified that may affect these interactions: external drivers; agency and control; evaluative negotiation and reflexive response. Potential implications for green infrastructure evaluation and BREEAM Communities include the need to address dominant evaluative intentions, such as financial value, and to assign reflexive responsibility.

Keywords: evaluation, neighbourhood masterplans, standards, green infrastructure

INTRODUCTION

Neighbourhood masterplanning is a strategic approach used by urban designers to outline a vision, visualisation and programme for delivering a new or regenerated neighbourhood (Bell 2005, Cowen 2002). BREEAM Communities (BC) is one of a growing number of standards that seek to establish a common evaluative framework that evidences the sustainability of a neighbourhood masterplan. Various researchers have contrasted these standards (e.g. Sharifi and Murayama 2014, Joss et al., 2015), focusing particularly on how sustainability performance is defined and measured. The standards are still relatively new, making examination of their application more problematic, especially accounting for the long timeframes involved in many developments (Sullivan et al., 2014). Moreover, standards have been criticised for focusing primarily on technical definitions and less about how and why issues are identified, applied and whether they actually play in role in affecting decisions and material outcomes (Schweber and Haroglu 2014, Pettigrew 2012).

Evaluative practice is described as an embedded part of urban design processes, where evaluation can establish, trace and refine design intentions (van der Voordt and van Wegen 2005). BC, as a standard evaluative framework, also assumes that evaluating

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certain sustainability concerns early in a masterplan’s design will encourage the rational reflection and incorporation of these issues within design decisions (Sharifi and Murayama 2014). This paper examines the concept of ‘embedded evaluation’, considering whether and how evaluation is thought to influence what is designed and constructed in practice. The paper aims to address that question by focusing on the application of BC, using the lens of one issue assessed in the standard, ‘SE 11 Green Infrastructure’. This paper outlines the research approach, and presents an empirical illustration, analysis and tentative findings.

RESEARCH APPROACH

A previous review of literature examined accounts of sustainable urban design and standardised evaluative frameworks, such as BC, that seek to establish a common approach to how the sustainability of a neighbourhood is assessed (Callway et al., 2016). The degree to which a standard has a ‘tight fit’, embedded within organisational practice, or is simply a peripheral ‘tick-box’ exercise has been linked to four ‘C’s: commitment (ownership and continuity); capability (knowledge and resources); communication (between actors); and control (of standard interpretation and application) (Schweber and Haroglu 2014, Timmermans and Epstein 2010). The literature also points to extra-organisational ‘drivers’, such as coercive rules, normative principles, and mimetic habits that may affect the ‘embeddedness’ or strength of relationship between evaluation and other practices (Glover et al., 2014).

Flyvbjerg argues that a phronetic approach, looking at empirical ‘everyday’ enactment of practice, is helpful to consider the role of such potential drivers (Flyvbjerg 2001: 134). Strategy as Practice (SaP), drawing from process and practice theories, examines the ‘enactment’ of practice, and is therefore adopted as an analytical framework to help map out real-world practice (Jarzabkowski and Spee 2009, Whittington 2006, Langley 1999). SaP considers the interaction between organisational practice, practitioners or ‘actor groups’, and praxis, ‘the enactment of practice’ (Whittington 2006). Masterplanning appears to broadly fit the SaP framework in that it is a strategic project, where some masterplan practices are more ‘intra-organisational’ or core to the project e.g. urban design, construction and formal evaluative practices. ‘Extra-organisational’ practices and practitioners, outside the project, can also interact, including market guidance such as BC. A masterplan is more inter-organisational than Whittington’s conception however, enacted collaboratively by multiple actors in various organisations.

‘Evaluative practices’ are described as a less-researched aspect of SaP (Egels-Zandén and Rosén 2015, Beunen et al., 2013). This research is therefore of value as it examines how particular evaluative praxis are structured, enacted and responded to, within a context of inter, intra and extra-organisational practices and practitioners. This is examined empirically, looking at whether and how green infrastructure (GI) evaluation is perceived to contribute to neighbourhood masterplan design and construction. GI is adopted as an empirical thematic lens, partly because the concept is reported as becoming more established in terms of how it is understood by academics and practitioners. This includes perceptions of the potential contribution of GI to sustainability, through the provision of multiple anthropocentric and bio-centric ecosystem services (Mell 2017, European Commission 2012). In addition, BC contains a specific evaluative issue regarding GI ‘SE 11’, amongst 41 issues overall. BC has carries two specific social intentions for GI. First, the provision of good quality green space and second, promoting social inclusion by encouraging access for all. BC also contains a third broad intention of integration or ‘making things work together’ (Bowker and Star, 2011: 150). In terms of
GI, this is demonstrated by numerous direct and indirect references to GI in all but two of the other issues in the BC standard. This suggests considerable potential for holistic reflexivity, but also complexity, regarding how GI is evaluated when BC is applied.

A single evaluative episode is presented here, from a larger research project which examined six masterplanned developments across the UK. In each case study a broad question was considered: how do evaluative practices contribute to neighbourhood masterplanning design and construction decisions? Semi-structured interviews were conducted with 46 individuals, selected from those who commissioned, conducted or engaged in GI evaluation on the six sites e.g. local authorities, developers, housing associations, consultants, urban designers and residents. The interviews sought to clarify how formal evaluative practices were conducted, and to distil the intentions regarding particular aspects of GI and the wider masterplan that were addressed. Interviews also examined how different groups perceived evaluative practices, their relationship to those practice, and the roles and interplay of actors. The interviews were supplemented by an analysis of planning documents to cross-check accounts and fill-in gaps in information. Opportunistic observations of evaluative activities, e.g. public exhibits and site surveys, were also undertaken to provide a richer insight of evaluative praxis.

A combination of deductive and abductive coding was applied to the qualitative data, starting with two broad themes and a small sub-set of preliminary codes: firstly, the details of evaluative praxis e.g. actors involved, methods used, and timing; secondly, the different enabling or constraining themes reported to affect actors’ relationship with evaluative practices, based on the four C’s and external drivers that emerged from the literature review (see above). These initial codes expanded to over 100 through a reflexive process of adding, refining, and removing those topics that appeared to be commonly associated with how evaluative processes were applied in the six sites. This large set of codes was then consolidated into four themes: external drivers: rules, norms and mimetic culture that influence evaluative practice; agency, ownership and control: iterative (past), practical (present) and projective (future) evaluative intentions and power to affect change; evaluative negotiation: mediation of conflicting and synergistic practices; and reflexive learning and response; how information was understood and acted upon. These themes are discussed in the illustration below.

**EMPIRICAL EPISODE: A ROOM WITH A VIEW**

This episode focuses on an estate regeneration project in South London, where BC was applied. It is used to illustrate the application of SaP in conjunction with the four explanatory themes that iteratively emerged from the data coding. It focuses on the evaluation of the visual amenity derived from GI on the estate, hereafter named ‘Estate1’. Estate1 is a housing estate of over 7,000 people, constructed between the mid-1960s to 70s, replacing Victorian terraced streets. In 2001, residents voted to retain the buildings and keep them as social housing under local authority control. The local authority felt they could no longer afford to manage or refurbish the estate however, which was compounded by government pressure to provide an additional 50,000 homes in 20 years (a target established by a ‘strategic housing market assessment’ (SHMA)). In 2005, the authority decided to proceed with demolition and transfer the housing stock to a housing association (Council Report, 2005).

Numerous plans were proposed to regenerate the site. A seventh masterplan was agreed in 2010 (Interview 2, 16, 37). This was revisited in 2012 when the council decided to adopt a single plan, led by one housing association partner, rather than the piecemeal model adopted in 2010. The explicit aim was to build sufficient private homes to create
Green Infrastructure Evaluation

additional revenues to fund an overall increase in the total number of homes, from around 2,500 to 3,500 homes. An eighth outline masterplan and detailed first phase were given planning consent in 2014. In terms of green infrastructure (GI), the 28ha site overlooks a large park (46ha), which runs along the southern edge. Inside the estate are a series of small parks, playgrounds, allotments, vegetation and trees, estimated to make up a third of the estate (9.95ha) and two-thirds of the site is covered in hard surfaces (2010 masterplan). The 2014 masterplan proposed to reduce green spaces by 18% (1.77ha), in order to increase housing density (Landscape Statement, 2014). During the interviews a number of issues relating to GI evaluation were raised, including changes to the landscape and about the view over the large park (Interviews 2, 7, 37). This episode focuses on the evaluation of the park view, how it was situated in masterplan practice, and evaluated by different actors, and the perceived role of BC, based on nine interviews and planning documents. An initial analysis of planning application documents helped clarify the formal evaluative practices enacted in the masterplan. Table 1 lists some of the formal evaluative practices identified, considering whether and how they addressed GI.

Table 1. References to GI in ‘Estate 1’ evaluative practices and links to BREEAM Communities

<table>
<thead>
<tr>
<th>Evaluative practice</th>
<th>Master Plan Phase 1</th>
<th>Master Plan Phase 2</th>
<th>Links to BREEAM Communities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity surveys (buildings, landscape), financial viability and value management</td>
<td>Y</td>
<td>Y</td>
<td>Reports not public. BC requires a new issue to make financial assessment visible e.g. triple-bottom line reporting</td>
</tr>
<tr>
<td>Socio-economic assessment</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equality Impact Survey (Equalities Act 2010)</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utilities assessment</td>
<td>Y</td>
<td></td>
<td>No ref to street-based GI in ‘SE 09 Utilities’</td>
</tr>
<tr>
<td>Transport / highways and parking assessment</td>
<td>Y</td>
<td>N</td>
<td>No ref to role of GI in mitigating transport impacts, in ‘TM 01 Transport assessment’</td>
</tr>
<tr>
<td>Land survey (e.g. topography, contamination)</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Townscape / Landscape visual impact assessment (LFLA, in EIA)</td>
<td>Y</td>
<td>Y</td>
<td>No ref to timing of survey during design phase, in ‘LE 05 Landscape’</td>
</tr>
<tr>
<td>Heritage survey (in EIA)</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Archaeological survey (in EIA)</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flood risk, surface and drainage assessments</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>EIA (scoping, appraisal, mitigation) soil, noise, air, water</td>
<td>P</td>
<td>P</td>
<td>GI buffering functions (noise, air, visual) not linked to street design in ‘TM02 Safe &amp; Appealing Streets’</td>
</tr>
<tr>
<td>Ecology survey (in EIA, protected species mainly e.g. bats, slow worms, alien invasive species)</td>
<td>Y</td>
<td>Y</td>
<td>No ref to inclusive visual amenity of green infrastructure in ‘SE 11 GI’ and ‘LE 05’</td>
</tr>
<tr>
<td>Arboriculture (tree) survey</td>
<td>Y</td>
<td>Y</td>
<td>Arboriculture survey not linked to ecological objectives in ‘LE 01 Ecology Strategy’</td>
</tr>
<tr>
<td>Microclimate modelling (wind, shading, temp)</td>
<td>N</td>
<td>N</td>
<td>No ref to the BRE Guidelines on daylight assessment in ‘SE 06 Microclimate’</td>
</tr>
<tr>
<td>Daylight, sunlight and shading (in EIA)</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Light strategy and assessment</td>
<td>P</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Energy use modelling</td>
<td>Y</td>
<td>N</td>
<td>No link to role of GI in cooling and insulating buildings in ‘RE 01 Energy Strategy’</td>
</tr>
<tr>
<td>Waste assessment and strategy</td>
<td>Y</td>
<td></td>
<td>No ref to reusing viable trees or vegetation in ‘RE 02 Existing Buildings &amp; infrastructure’</td>
</tr>
<tr>
<td>Design review (in Design and Access statement)</td>
<td>Y</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Design and access statement</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Design and Client team meetings</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Resident and local actor consultations (workshops, exhibitions, walkabouts)</td>
<td>Y</td>
<td>Y</td>
<td>Refers to community engagement for SE 11 GI and LE 05 Landscape</td>
</tr>
<tr>
<td>Statutory consults</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>

P = partial reference to GI, Y = GI referred to, N = no reference, ? = no data accessible

Table 1 shows that most practices involved some consideration of GI, but also that certain evaluative practices, relating to financial appraisal, were not publicly reported. Table 1 therefore provides a gap analysis of issues where BC might bring additional clarity, including the principle of ‘inclusive visual amenity’ in ‘SE 11 and LE 05 issues.

Inclusive access to the park view was raised as a concern by an estate resident who was a member of a residents’ organisation on the estate. The resident contrasted the evaluation of the view with an earlier evaluative practice. The local authority and design team had convened various participative events for residents during an early ‘plot 1’ pilot development, prior to the 2010 masterplan being agreed. At one event, residents were asked their preferences about the internal layout for the plot 1 flats. A full-size mock-up
flat was created in a community hall and residents were invited, over a series of weekends, to walk around and vote for the layout they preferred; “we asked residents to vote which one they liked and it turned out a third, a third, a third….So actually that’s what we built” (interview 16, architect). This is presented as the first praxis box in Figure 1 below. The dotted circle indicates an open and reflexive response in design and construction practice to the evaluative praxis regarding the internal layout options.

The second praxis was an in-house evaluation regarding flat allocation. The residents were not involved and no social flats in plot 1 were allotted a view over the park. The lack of resident involvement is indicated by a full circle for ‘closed’ reflexive praxis box 2 in Fig 1. The resident described a loss of trust due to this decision, and they felt the developer was biased toward private tenants:

...the private goes up when the social housing is done so that the private isn’t living with a building site while the social housing goes up, OK? But what they did was, the result of that was that the private housing got built in the park and the social housing got built behind” (Interview 37, resident).

A Landscape Visual Impact Assessment (LVIA) was conducted in 2012 in preparation for the first phase of the 2014 masterplan. It was carried out by a landscape architect within the design team. They did not consult directly with residents, and no major design change was reported, depicted by the ‘closed reflexivity’ circle on the fourth praxis box in Fig 1. The LVIA was conducted as part of a formal Environmental Impact Assessment (EIA) which considered the development impact on two ‘receptors’: the potential effects on landscape; the effects on people’s visual experience of that landscape (O’Connor 2015). The formal practice of LVIA structures people as a single group and does not consider the distributive impact for different people, nor does it require local consultation. LVIA practice is shaped by coercive (rules), normative (expectations) and mimetic (culture) institutional drivers (Glover et al., 2014, Battilana and D’Aunno 2008). For example, EIA requirements are defined in an EU Directive (1987) and the UK Town and Country Planning Act (2010, updated in 2015), neither of which refer to local consultation for LVIA. The European Landscape Convention (2000) prescribes principles regarding landscape policy and management but is not specific about LVIA

Figure 1. Estate 1 evaluation of visual amenity as SaP (adapted from Whittington 2006)

The second praxis was an in-house evaluation regarding flat allocation. The residents were not involved and no social flats in plot 1 were allotted a view over the park. The lack of resident involved is indicated by a full circle for ‘closed’ reflexive praxis box 2 in Fig 1. The resident described a loss of trust due to this decision, and they felt the developer was biased toward private tenants:

...the private goes up when the social housing is done so that the private isn’t living with a building site while the social housing goes up, OK? But what they did was, the result of that was that the private housing got built in the park and the social housing got built behind” (Interview 37, resident).

A Landscape Visual Impact Assessment (LVIA) was conducted in 2012 in preparation for the first phase of the 2014 masterplan. It was carried out by a landscape architect within the design team. They did not consult directly with residents, and no major design change was reported, depicted by the ‘closed reflexivity’ circle on the fourth praxis box in Fig 1. The LVIA was conducted as part of a formal Environmental Impact Assessment (EIA) which considered the development impact on two ‘receptors’: the potential effects on landscape; the effects on people’s visual experience of that landscape (O’Connor 2015). The formal practice of LVIA structures people as a single group and does not consider the distributive impact for different people, nor does it require local consultation. LVIA practice is shaped by coercive (rules), normative (expectations) and mimetic (culture) institutional drivers (Glover et al., 2014, Battilana and D’Aunno 2008). For example, EIA requirements are defined in an EU Directive (1987) and the UK Town and Country Planning Act (2010, updated in 2015), neither of which refer to local consultation for LVIA. The European Landscape Convention (2000) prescribes principles regarding landscape policy and management but is not specific about LVIA

---

2 Fig.1 presents reported practice, praxis and practitioner involvement, based on interviews and public documents. It is a simplification of praxis, e.g. consolidating practices in the masterplan processes.
methods. The UK LVIA Guidelines (2013) contain ‘non-prescriptive’ principles of conduct and leave it to an assessor’s discretion as to whether to consult publically. Looking to BC, the masterplan commits to evaluate Landscape (LE 05) and GI (SE 11) issues amongst other BC issues (Sustainability statement 2014: 30). LE 05 aims to encourage a landscape evaluator to consider ecological impacts. SE 11 calls for inclusive access to green spaces, and notes how ‘good quality’ GI can make places ‘visually stimulating’. However, neither issue considers who accesses the visual amenity of GI. Thus, neither rules, guidance nor BC ask evaluators to consider the distributive impact of a development on visual amenity.

Separate to LVIA praxis, a number of resident consultations were conducted. Based on their experience of the earlier plot 1 events, the resident interviewee indicated they and other residents called for social housing with views over the park. The resident had been involved in consultative processes over a number of years, so their view was also situated with some reflection on past events, including the local authority overriding the residents’ vote to retain public ownership of the estate. This historical experience, combined with the experience from plot 1, had compounded their determination; “one of the major things that I would tie myself to railings for is that people now living in social housing have a view of [the] park” (Interview 37, resident). Both the design team and local authority indicated that, as a result of these resident requests, the principle of an inclusive park view would be applied (Interviews 7, 28). This response to community views is indicated by the ‘open reflexivity’ circle around the fifth praxis box and design change in Figure 1.

No formal decision or statement about what proportion of affordable units would have a park view was proposed however, as detailed by ‘uncertain outcome’ from the sixth praxis box for the 2014 Masterplan evaluation. The Statement of Community Involvement writes that the first phase would include ‘target rent homes on the park edge’ (p3) and the Affordable Housing Statement states that ‘target rent and shared ownership homes’ (p14) would have a park view. Neither these, nor the interviews, specify the proportion of affordable homes involved, leaving this question either intentionally or unintentionally undecided. The Landscape Statement refers to ensuring ‘nearly’ every home has a view of open space (page 75) but makes no reference to the park or tenure arrangements. Also there were no references in the Design and Access or Sustainability Statements to this commitment, and an ‘inclusive view’ also appears to be subject to financial concerns. A barrister, representing private tenants in a Compulsory Purchase Order (CPO) inquiry, referred to an estate-wide Equality Impact Assessment (2005) which suggested the park view raised the value of the flats. The barrister argued that the increased value of homes with a park view, meant the local authority would not be able to adequately compensate existing residents for the loss of their properties. He said this raised cost made the phase unviable and thus undeliverable (CPO inquiry, 2015).

Figure 1 refers to a separate evaluative actor, a consultant viability assessor, because this emerged as a dominant evaluative practice, impacting decisions throughout the masterplan. This dominance was alluded to by the plot 1 designers, landscape architect, developer, planning officer, EIA assessor and resident, who all referred to the financial pressures placed on the client and contractors (Interviews 4, 7, 8, 16, 28, 37). The EIA assessor noted how financial viability was continually appraised and updated by the same consultant throughout the process (Interview 4). In contrast, landscape evaluation came late in the design process, was more intermittent, and involved different contractors at each phase, highlighting differences in evaluative continuity and commitment.
Focusing more generally on the role of BC in the masterplan process, it was clear that the design team who proposed to adopt BC seemed more concerned with legitimising the work they were already doing, than affecting their practice; “In order to win the project, it helps to then use something standard like BREEAM Communities... it gives people confidence that we know what we’re talking about and that we’re going to deliver and demonstrate best practice. Local government in particular like that, they like to hear that. So, when we’ve used BC it’s often as part of a bidding process” (Interview 6, in-house BC assessor). Neither the developer nor local authority referred to BC in interview, until directly asked. The developer didn’t feel BC had made them do anything differently, rather; “it was more kind’ve confirming that we were doing the right sort of things.” (Interview 8, developer). The local authority also thought BC requirements were already addressed elsewhere, but they saw a potential value in the consolidation of policies; “I think what the BREEAM does is it collates all that stuff, regulatory requirements, into a sort of evaluation profile” (Interview 28, local authority).

**ANALYSIS**

A dominant theme running throughout this episode is of a ‘practical evaluative’ (Jarzabkowski 2005) negotiation of differing evaluative intentions within and between different actor groups in the context of GI. The residents reflexively learnt from the allocation of flats with a view of the park in plot 1. This past experience fostered their commitment to press for an inclusive view of the park for future phases. The residents ‘projective agency’ was increased by regulatory (planning policy and EIA) and normative (BC) requirements for community engagement and accountability, but undermined by a normative and mimetic culture for conducting LVIA’s late in the design process, without resident engagement (Glover et al 2014, Batillana and D’Aunno 2009). The local authority needed to encourage the developers to take on the project and build a sufficient number of private units, in order to finance the construction of affordable homes and meet government housing targets. This constrained the authority’s ‘projective’ agency and capacity to respond to residents, despite being encouraged to do so by planning rules (and BC). Providing an inclusive view would have a commercial impact, reducing the number of higher-value private flats overlooking the park. Residents were not consulted over decisions where the developer felt unable to respond to demands, including the allocation of flat tenures in plot 1 and regarding the proportion of social housing with a park view in future phases. The design team were keen to show their responsiveness to residents for planning purposes but they had to negotiate this with the conflicting financial intentions of their clients. The developer and local authority agreed a ‘practical evaluative’ compromise, referring to the principle of inclusive visual amenity but without a specific commitment about the proportion of affordable homes involved.

The use of BC in this case seems to fit what Schweber and Haroglu (2014) described as a ‘bolt-on’ exercise, where a standard is used to ‘legitimise’ rather than ‘transform’ practice. The late timing of BC and LVIA and lack of resident engagement in the LVIA, also suggest a similar tick-box enactment. Both the LVIA and BC evaluations were conducted in-house by the same design team, posing questions about conflict of interest, where they were paid by those they assessed and may have faced pressure from their client regarding the prioritisation of different evaluative intentions.

A complex web of interactions emerges from this episode, where evaluative practices are affected by external drivers, and differing modes of agency, evaluative negotiation and reflexivity. Figure 2 summarises these enabling and constraining themes which seem to influence how evaluative practices were structured, enacted and responded to.
The episode points to two particular challenges for GI evaluation and BC, regarding: dominant or deeply embedded strategic evaluative intentions (e.g. finance); and responsibility for validation. First, BC seeks to rebalance intentions towards social and environmental ends, including the provision of GI, but explicitly avoids the very area it aims to counterbalance, financial viability which, in this episode at least, carries greater evaluative embeddedness. Second, it is uncertain whether the local authority retains sufficient control to affect the delivery of affordable homes with a park view once the phase constructed and handed over to the developer. Simply introducing some form of post-construction evaluation to track the fulfilment of the commitment would not of itself ensure that a failure to follow-through would be addressed. Reflexive responsiveness depends on the assignment of responsibility to respond to the post-construction evaluation findings, with allocation of sufficient resources to enable a response. Early findings, from this and other episodes, suggest that the assumption of a rational ‘embedded’ and reflexive link between evaluative practice and design and construction decisions is complicated by these four interrelated themes: external drivers; agency, control and ownership; negotiation, and reflexive response between differing agendas. Potential areas where BC might strengthen evaluative embeddedness include:

**Filling the gaps:** a new issue addressing sustainable value management or triple-bottom-line reporting; a new credit for inclusive visual amenity in LE04 or SE11;

**Transparent transitions:** encourage ties between evaluation and other practice, e.g.

- require the assignment of responsibility to respond to findings;

**Empowering ownership:** promote greater deliberation over evaluative intentions throughout the masterplan journey, allowing sufficient space for emergent learning, engagement and response.

The early analysis aligns with accounts in SaP literature. SaP has been a useful analytical tool to help map out strategic practices, identify responses and resistance to change, consider key actors (Egels-Zandén and Rosén 2015), as well as examine the collaborative extra and intra-organisational processes or ‘strategic intermediation’ (Medd and Marvin 2010, Vaara and Whittington 2011) that occurs in masterplanning. The relationship between evaluative practice and other strategic practices can be dynamic and transactional, where evaluation can both influence, and be influenced by, other strategic practices (Jarzabkowski and Spee 2009: 18). The role of ‘strategic actor groups’ (Whittington 2006) seems central to this. The case studies highlight that practitioners do
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much more than ‘act’ (Battilana and D’Aunno 2009); they can adopt differing modes of agency, negotiation and reflexivity through which they shape, enact and respond to evaluative practice and wider processes, and they do this as active agents within a mutable context of ‘external’ rules, norms and cultures. This has implications for GI evaluation in general and BC in particular, recognising that whilst standards may affect the scope of evaluative practices, these four themes will affect the strength of influence or embeddedness of evaluation in its relationship with other practices.

CONCLUSION

Although this is only one illustration, all six sites in the wider UK study contain numerous examples of interdependency between enabling and constraining external drivers, agency, reflexivity and negotiation of evaluative practices. These interactions are complex, and inevitably require compromise, especially as projects move from design to construction stages. BC is a normative and ‘projective’ evaluative framework that seeks to influence masterplan practices and practitioners subject to these dynamic influences, and therefore BC may face significant obstacles as a transformative tool.

In terms of research approach, the interviews and informal observations provide rich insights into social structures that underpin evaluative practice, particularly regarding the constraints and enabling themes that affect how evaluative strategies are structured, applied and responded to. Planning documents provide additional checks and detail to unpack practice. It is necessary to acknowledge an awareness of researcher and participant bias however, as well as recognise the process of codifying and mapping out episodes requires reflexive filtering and abstraction of events. As such there remain alternative representations of ‘reality’ which may differ from what is characterised here.

Empirically, the research helps identify opportunities to enhance BC and GI evaluation, e.g. visual amenity of GI is relevant to social inclusion and dominant evaluative intentions (finance) need to be explicitly addressed. Theoretically it points to four themes that may affect the influence or embeddedness of evaluative practices: external drivers; agency; evaluative negotiation; and reflexivity. Further research is required, to better understand the challenge of transparency in the negotiation of evaluative compromise during the design to construction transition, to further examine the mediating practices (Jarzabkowski 2005) that different practitioners adopt to address this challenge.

REFERENCES


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PRECAUTIONARY ACTION AGAINST OVERHEATING IN ENGLISH HOMES: WHAT INFLUENCES HOUSEHOLDERS’ INTENTIONS?

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Temperate zones including the UK and mainland Europe continue to be exposed to increasing temperatures and more frequent heatwaves as global warming continues. The built environment can mitigate the risk and recommendations for precautionary actions have been published by government and others. A key player in improving resilience is the householder, who determines whether precautionary measures will be installed in their home. Previous research on flooding has applied Protection Motivation Theory to examine determinants of householder engagement. However, flooding risks differ from those of overheating in several ways. The current study builds on this work to address the gap on understanding householder propensity to install precautionary measures against overheating. A large-scale survey (n = 1,007) of householders was conducted in the south of England. The findings show that householders are ill-prepared to deal with predicted temperature rises. While perception of threat risk and severity has an influence on their intention to take action, their appraisal of their ability to make changes, of the effectiveness of the changes and of convenience are stronger factors, particularly for flat dwellers. Policy recommendations include raising awareness of specific measures for mitigation and of effectiveness of recommended actions, and targeting older householders.

Keywords: resilience, occupational behaviour, protection motivation theory, overheating

INTRODUCTION

By 2016, global warming had already exceeded 1.1°C above late 19th century levels (NASA, 2017) and is likely to surpass a 2°C threshold even if national commitments pledged at COP21 to reduce greenhouse gas emissions are achieved (Rogelj et al., 2016). One of the many consequences of warming planetary systems is the increased risk of higher temperatures, and the likelihood of increased frequency and severity of heatwaves for many geographical locations. Traditionally hot places have experienced record high temperatures in recent years but more temperate zones including the UK and mainland Europe have also been exposed to hotter weather.

The risk to public health from higher temperatures was evidenced by the August 2003 heatwave in Europe which led to 15,000 excess deaths (PHE, 2015a). Climate projections for the UK suggest that mean daily temperatures will increase over the coming decades, up to 4.9°C in southern England by the 2080s (central estimate, UKCP, 2009). Likelihood of extreme temperature events also increases, with the probability of a...
heatwave as severe as that in 2003 estimated already to be between twice and four times more likely due to human influence on climate (Stott, Stone, and Allen, 2004).

Excess deaths due to higher temperatures have been estimated in the UK at 75 extra deaths per week per degree increase (PHE, 2015b). Evidence from research in London suggested that excess deaths can be calculated when temperatures rise beyond 19 °C (Hajat, Kovats, Atkinson, and Haines, 2002). Individuals especially vulnerable to the effects of higher temperatures include older people, infants, those with chronic or severe illnesses or alcohol/drug dependence, and those living in south-facing flats or in urban areas (PHE, 2015b). It is notable that, depending on the severity and duration of a heatwave, adverse effects can strike healthy, fit and able-bodied adults and children.

The built environment can exacerbate the risks from overheating or help to mitigate the adverse effects. In the UK, it is estimated that people can spend over 90% of their time indoors (Schweizer and al., 2007) thus the resilience of the building stock to overheating has a major role to play in protecting occupants from excessive heat. While there has been investigation of the contribution of building regulations and Passivhaus standards to overheating, particularly for new build (Lomas and Porritt, 2017), the focus here is on weather-related overheating in existing domestic building stock. Having set out the evidence for the probability of overheating, the risk to public health and role of the built environment, a summary of the relevant literature is now discussed.

LITERATURE REVIEW

Within the construction literature, the issues around overheating in current stock have received growing attention. A number of studies across England, including some dating back to 2007, have found evidence for overheating in homes even during cool summers (Beizaee, Lomas, and Firth, 2013; Lomas and Kane, 2013; Mavrogianni et al., 2017). The importance of passive mitigation was underlined by Porritt et al., (2011) who argued that Victorian terraced dwellings (a common form of UK housing dating from the late 19th century) could avoid overheating even in medium-high scenarios for 2080 through passive measures alone, which included provision of exterior shutters, wall insulation and a pale exterior surface. Although Gupta and Gregg (2012) disagreed that overheating in a 2080 scenario could be fully mitigated through passive measures, they concurred with Porritt and colleagues (2011) on factors that could enhance resilience, with external shading the most effective. Albeit in small scale studies, empirical evidence has already demonstrated the occurrence of overheating in homes, and evidence for the effectiveness of passive mitigation measures.

Based on such research, a number of reports have proposed modifications to existing homes which can provide effective mitigation of overheating, including solar reflective or pale coatings to external façades, wall insulation especially external, maintaining exposed thermal mass, external shading such as shutters and awnings, effective ventilation and managing the microclimate adjacent to the building through provision of green spaces, trees and water features (Mylona, 2013; PHE, 2015b).

The UK domestic built environment is characterised by a predominance of old stock and a low rate of new build. Boardman (2007) has proposed that 87% of the dwellings that will be in use in 2050 are already built. The existing housing stock therefore merits attention as the primary target for measures to mitigate overheating. Although a number of studies have examined the measures that can be taken, the few studies that have considered occupant behaviour have been limited to reactive responses to high temperatures (Coley, Kershaw, and Eames, 2012; Mavrogianni et al., 2017) However,
such studies failed to recognise the behavioural aspects of commissioning retrofit measures to minimise overheating.

The householder is a critical gatekeeper who determines whether or not ‘hard’ adaptation will be conducted on an existing home. In seeking to understand how the current building stock can be upgraded to become more resilient to the warming climate, it is necessary to examine householders’ propensity to take action to upgrade the home. In this, the overheating literature is some way behind that of flooding, in which the need for precautionary behaviours is better understood (Bubeck, Botzen, Kreibich, and Aerts, 2013; Grothmann and Reusswig, 2006; Poussin, Botzen, and Aerts, 2014). From the perspective of construction research, precautionary behaviour is of special importance in that the building sector may act as the agent through which a householder achieves greater resilience.

The focus in this paper is on preparation or precautionary action taken in anticipation of a possible future event, that is, action triggered by the householder to install mitigating measures. Research on climate change preparedness has established that objective factors only partially determine what precautionary action is taken and that actions are risk-specific (Grothmann and Patt, 2005; Porter, Dessai, and Tompkins, 2014). Harries’ (2012) work on flooding examined four belief types as mediating factors between experience of flooding and action, and found perception of probability to be a factor. A more extensive framework applied in other research on flooding preparedness is that of Protection Motivation Theory (PMT).

Applied widely in risk research since the 1970s, it has proven valuable in recent times in examining influences on preparedness for particular aspects of climate change (Dang, Li, Nuberg, and Bruwer, 2014; Truelove, Carrico, and Thabrew, 2015) and expands on Harries’ (2012) framework. PMT postulates that protection motivation or ‘adaptation intention’ (Grothmann and Patt, 2005), that is, the intention to enact a particular behaviour to mitigate a threat, is a proximal determinant of behaviour and is itself primarily determined by threat appraisal and coping appraisal. Threat appraisal encapsulates the individual’s evaluation of threat risk with two measures: probability of the specific threat and severity of outcome if the threat is realised.

Coping appraisal, termed ‘adaptive capacity’ by Grothmann and Patt (2005), combines three constructs: self-efficacy, that is, belief in one’s own capacity to enact the behaviour; response-efficacy, that is, belief in the effectiveness of the action; and cost, that is, time, effort and monetary cost to undertake the action. Thus people with a high level of coping appraisal for an action feel that they have the personal resources to complete the action, that the action will be effective in reducing the threat and that the personal cost will be worth the effort. PMT posits that high threat appraisal and high coping appraisal predict intention to undertake the adaptive behaviour.

Grothmann and Reusswig (2006) applied PMT to examine the question of why some householders take action to protect themselves against the risk of flooding while others do not. They tested socioeconomic characteristics and previous flood experience alongside the psychological variables in PMT. While home ownership increased the level of adaptation intention, experience of flooding, and both threat and coping appraisal influenced the level of intention, although the contribution of threat appraisal was small. Income and age were not related to intention. In contrast, Zaalberg and colleagues (2009) found that neither self-efficacy, a component of coping appraisal, nor previous experience were related to intention to undertake preventative action against flooding. Looking at what they termed structural changes to the home to increase protection against flooding,
Bubeck *et al.*, (2013) found that self-efficacy but not response-efficacy related to intention. Previous experience and level of income also showed a positive relationship with intention. Thus, although PMT has proved useful in considering precautionary action against flooding, evidence is mixed and this may be due to different types of behaviour of interest.

The perception of threat from overheating is different from the case of flooding in terms of the frequency of extreme events, visibility and vulnerable populations. With the theoretical understanding that evaluation of threat and of adaptive capacity may influence the likelihood of intention to undertake precautionary action, and that these subjective evaluations are threat and action specific, there is a clear need to examine the determinants of actions to mitigate overheating in preparation for future events. To our knowledge, the current study is the first to apply PMT to precautionary behaviour of householder in this domain. The study examines determinants of precautionary behaviour aimed at mitigating the threat of overheating in homes. Further, all buildings are not equally susceptible, for example, flats can be at higher risk (PHE, 2015a). All households may not have the same freedom of action (cf. tenant versus homeowner differences, Grothmann and Reusswig, 2006; Poussin *et al.*, 2014). Finally, intention and action may vary with action type, and this has not yet been investigated in depth to our knowledge. The current research aimed to answer the following questions:

- What are the determinants of intention to take precautionary action against overheating?
- How do these differ between
  - Homeowners and tenants?
  - Occupants of flats and houses?
  - Different types of action?

**METHOD**

Selecting the south and midlands of England as more threatened by increasing temperatures, an online survey was conducted in September 2016, using an established market research organisation. A total of 1007 completed questionnaires were collected. Rather than retrospectively assessing response rate, representativeness was achieved through completion of quotas mirroring national ratios for key criteria: criteria for UK national representativeness were set and met for gender, age, home owner versus tenant and house type.

Four types of questions were asked, summarised in Fig. 1. Characteristics of the property and occupier included age of home, house type (see Table 1), and owned or rented and whether the householder was planning to move home. Sociodemographics included age, personal income and level of education. Proposed predictor variables were measured as follows. Measurement of threat appraisal was based on Poussin *et al.*, (2014) with two items measuring threat risk and two item measuring threat severity. Cronbach alpha was .89, indicating a reliable scale. Based on national guidelines for reducing overheating in homes (DECC, 2015; NHBC, 2012), nine actions were selected and grouped as insulation (walls, roof), ventilation (including night ventilation), shutters/awnings, pale exterior and planting (trees, grass, water features near the external walls).

Coping appraisal for each of the five action groups was measured through two items assessing self-efficacy, two items assessing response efficacy, and one item for convenience of implementing the action. These formed reliable scales (all Cronbach
alphas greater than .7). Respondents were asked whether they had experienced overheating in their current home (scale of 1 to 6). Awareness of the recommended actions to mitigate overheating was measured on a scale of 0 to 12 (nine recommended actions and three exacerbating items). Finally, the dependent variable in the analysis was ‘intention’: participants were asked if they intended to take each action in the next three years. The responses were aggregated by action groups and summed to provide an overall score of intention. Of the responses on intention, 70% were 0 indicating no intention, and the aggregated measure was converted to a dichotomous variable of zero and non-zero.

Fig. 1 Model of determinants of intention to undertake mitigating action

FINDINGS

Table 1 summarises participant and property characteristics (n = 1007) and Table 2 presents descriptive statistics for the key variables. Two thirds of the sample had experienced overheating on at least a few occasions. Perception of threat from overheating was moderate to low (range 1 - 6, mean 2.71, std. dev. 1.21) whereas coping appraisal was slightly higher but still moderate (range 1 - 6, mean 3.51, std. dev. 1.06). Awareness of mitigating actions was moderately low (range 0 - 12, mean 4.91, std. dev. 2.92) and intention to undertake some or all of the nine recommendations to mitigate overheating was very low (range 0 - 9, mean .84, std. dev. 1.72).

Logistic regression analyses were run for intention, conducted sequentially in the order: property and occupier characteristics, sociodemographics, personal characteristics (experience of overheating, awareness of recommended actions) with threat and coping appraisal as the final step. Table 2 presents the significant findings for owners and tenants; and for house and flat dwellers.

In the sequential regression, before threat and coping appraisals were added, overheating experience was significant for owners (B = .22, p < .05) and for house dwellers (B = .19, p < .05), and awareness of mitigating actions was significant for house dwellers (B = .09, p < .05), remaining marginally significant when threat and coping appraisal were included, as shown in Table 2.
Precautionary Action Against Overheating in English Homes

Table 1 Sociodemographic and property-related variable: descriptive statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Female</td>
<td>50.8%</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>49.2%</td>
</tr>
<tr>
<td>Participant age</td>
<td>Mean</td>
<td>50.58</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>18 - 85</td>
</tr>
<tr>
<td>Income (personal monthly net)</td>
<td>Less than £1,000</td>
<td>23.2%</td>
</tr>
<tr>
<td></td>
<td>£1,001 - £2,000</td>
<td>35.2%</td>
</tr>
<tr>
<td></td>
<td>£2,001 - £3,000</td>
<td>17.4%</td>
</tr>
<tr>
<td></td>
<td>£3,001 - £4,000</td>
<td>8.0%</td>
</tr>
<tr>
<td></td>
<td>Over £4,001</td>
<td>6.2%</td>
</tr>
<tr>
<td></td>
<td>Not given</td>
<td>10.0%</td>
</tr>
<tr>
<td>Home ownership</td>
<td>Owner</td>
<td>66.0%</td>
</tr>
<tr>
<td></td>
<td>Tenant</td>
<td>31.8%</td>
</tr>
<tr>
<td>Property type</td>
<td>Flat</td>
<td>24.9%</td>
</tr>
<tr>
<td></td>
<td>Mid-terrace</td>
<td>26.8%</td>
</tr>
<tr>
<td></td>
<td>Semi-detached</td>
<td>27.9%</td>
</tr>
<tr>
<td></td>
<td>Detached</td>
<td>18.9%</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

Table 2 Regression of Intention for Owners and Tenants, and House and Flat Dwellers

<table>
<thead>
<tr>
<th>Intention</th>
<th>B (Unstandardised coefficient)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Owners (N = 600)</td>
</tr>
<tr>
<td>Property type</td>
<td>-.22*</td>
</tr>
<tr>
<td>Participant age</td>
<td>-.04***</td>
</tr>
<tr>
<td>Awareness of mitigating actions</td>
<td>-</td>
</tr>
<tr>
<td>Threat appraisal</td>
<td>.45***</td>
</tr>
<tr>
<td>Coping appraisal</td>
<td>.69***</td>
</tr>
</tbody>
</table>

Notes: Only significant coefficients presented. * Non-significant; X not included in analysis. *** p<.001; ** p < .01; * p<.05; † p < .1. Larger values of Cox and Snell R2, Nagelkerke R2 indicate higher levels of variance explained by the model.

For both owners and tenants, threat and coping appraisal were the primary determinants of intention in line with PMT. Age also contributed a small amount of variance and,
interestingly, was negatively related to intention, that is, the older the participant, the less likely they were to intend to carry out actions to minimise overheating. A negative relationship with property type suggests that intention was more likely for occupiers of terraced properties and semi-detached than detached. A similar pattern held for the sample split into house and flat dwellers: coping appraisal was the strongest factor followed by threat appraisal, except for flat dwellers where threat appraisal became non-significant, with significant difference between the coefficients for threat and coping appraisal ($z = 3.37$).

Regressions were additionally conducted by action type (see Table 3).

Coping and threat appraisal contributed to intention to undertake all five action types. Age made a consistent small, negative contribution to all actions. To ensure that this negative relationship was not an artefact of older householders having already completed actions and therefore indicating no future intention, regressions were re-run for each of the nine actions, excluding respondents who indicated that they had already carried out the action: the pattern of results remained the same.

**Table 3 Regression of Intention for Action Types**

<table>
<thead>
<tr>
<th></th>
<th>Insulation</th>
<th>Ventilation</th>
<th>Shutters/Awnings</th>
<th>Plants</th>
<th>Pale exterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>348</td>
<td>332</td>
<td>781</td>
<td>580</td>
<td>559</td>
</tr>
<tr>
<td>Property age (newness)</td>
<td>-</td>
<td>-</td>
<td>.08***</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Age</td>
<td>-.05***</td>
<td>-.05***</td>
<td>-.03***</td>
<td>-.03***</td>
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<td>Awareness of specific mitigating action</td>
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<tr>
<td>Threat appraisal</td>
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<td>Coping appraisal</td>
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Notes: As Table 2

For insulation and planting, awareness that these are mitigating actions was positively related to intention. The occupiers of newer properties were slightly more likely to intend to install shutters or awnings. Before threat and coping appraisals were included in the regression, overheating experience was significantly positively related to intention regarding shutters, planting and a pale exterior, but not insulation or ventilation.

**DISCUSSION**

The findings from this large-scale survey show that perception of threat and awareness of mitigating actions are moderate to low, and that measured intention to undertake precautionary action to mitigate the effects of weather-related overheating is very low. Indeed it is possible that actual intention may be even lower than measured, as some participants may never have considered precautionary action until prompted by the research. This would indicate that the occupants of English domestic building stock are unprepared for a warming climate.
The PMT variables of threat and coping appraisal were the strongest predictors of intention to undertake precautionary action, over and above property characteristics and sociodemographic variables. However, for flat dwellers, coping appraisal alone was statistically significant as had been found for householders in general in studies on flooding (Poussin et al., 2014). This suggests that although recognition of threat is a factor, perception of one’s capacity to take action and of the anticipated effectiveness and convenience of the action are more important determinants of mitigating behaviour. This is particularly the case for flat dwellers who may face more constraints on building changes than house dwellers.

When it came to specific actions, for installation of shutters, awnings or overhangs or painting the external façade of the property a pale colour, threat appraisal was a stronger predictor than coping appraisal, that is, perception of the risk of threat and its likely severity was more important than one’s perception of self-efficacy to take action, effectiveness of the action or convenience. This appears logical for actions which are relatively easier for householders to undertake.

The significant and negative (albeit small) relationship of age to intention to take precautionary action is of concern, indicating that older residents are less likely to plan changes to their home to cope with overheating. Given the vulnerability of the elderly to the adverse effects of overheating, a policy focus on older householder is warranted.

In the overall analyses, awareness was marginally significant for house dwellers. The findings by action type showed that awareness of specific actions for mitigation raised intention to carry out changes: this held for insulation and planting but not for ventilation, shutters or a pale exterior. The implication was that, while knowledge and awareness may be important to encourage some actions, they were not strong determinants for others. This aligns with earlier findings on flooding, that while awareness is a factor, intention to act depends on perception of probability and consequences (Lamond and Proverbs 2008).

Interestingly, we did not find a relationship between income and intention to undertake actions to protect against overheating, either in the overall analyses or examining intention to undertake specific actions. This suggests that financial constraints may not be a primary barrier to installing mitigating measures, echoing Harries' (2012) finding for flooding of no correlation between financial factors and action. The absence of a strong relationship between income and action or intention provides evidence for non-financial motivations which offer scope for ways beyond pecuniary incentives to encourage further precautionary action.

CONCLUSION
Householders in southern England are ill-prepared for the predicted increase in summer temperatures and heatwaves, with very low intention to undertake building changes to mitigate the risk. However, the application of PMT suggests guidelines for policy initiatives to address the challenge. For house dwellers, greater awareness of the increasing risk of overheating and the severity of impact of rising temperatures may encourage greater intention to act. Awareness alone is insufficient however. More importantly, for all householders, initiatives to enhance coping appraisal are likely to foster increased intention to implement mitigating actions. Enhancement of coping appraisal could include providing information on the effectiveness of recommended actions to enhance response efficacy. Campaigns to raise awareness of specific actions such as increased insulation and planting near the external walls may also be successful as
the findings showed that intention to act was related to such awareness. Targeting older citizens appears particularly important as the findings imply lower intention to act in older age groups. With potentially greater constraints on their scope of action, a focus on flat dwellers should emphasise what can be done, to strengthen self-efficacy. Combined with knowledge of recommended actions, it could be possible for flat dwellers collectively to pursue the installation of awnings to all glazing on a southern façade, for example. Finally, in recognition of somewhat different factors influencing different types of building changes, advice on mitigating actions by housing type, and particularly for flats, could raise both awareness and coping appraisal leading to greater action by householders.

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The concept of the service ecosystem is increasingly being drawn upon to explain the drivers, occurrences and consequences of socio-economic actors’ service exchanges towards value creation. Existing research has proposed how service ecosystems may successfully transform, but no work to our knowledge has examined how transformations may fail. To address this gap, this paper conceptually examines how a service ecosystem fails to transform and survive by developing a theoretical framework based on the concept of entropy from systems theory. A series of propositions are formulated, linking inadequate management of entropy to a service ecosystem’s subsequent state of disorder and collapse. The theoretical framework is illustrated through a unique case: the introduction and demise of the Green Deal in the UK. We propose that entropy is intrinsically embedded in systems’ trajectories and can be understood as the tendency towards loss of value co-creation. The viability of a service ecosystem depends on its capacity to reduce entropy, which requires continuous action to import resources from the environment, achieve heteropathic resource integration and/or re-institutionalise. Where systemic actors and networks of actors within the system fail to manage increasing entropy, resources from the system are dissipated back to the environment and institutional arrangements collapse.

Keywords: service ecosystem, entropy, survival, institutions, resource integration

INTRODUCTION

One of the most significant current discussions in the construction industry is the capacity of service ecosystems, particularly newly introduced climate change mitigation business innovations to succeed. Indeed, it is becoming increasingly difficult to ignore the changes that climate change has on the construction industry. As Pulkka et al., (2016) argue, the co-evolution of construction service ecosystems towards sustainable development, especially for energy efficiency, is fundamentally driven by wider socioeconomic transitions and are marked by changes in regulation, client and user expectations, or market conditions (Wilson and Rezgui 2013).

Scholars have been increasingly returning to the concept of a service ecosystem to explain the drivers, occurrences and consequences of socio-economic actors’ service exchanges towards the achievement of a common goal: value creation (Vargo and Lusch 2016). Seen as complex collaborative systems (Taillard et al., 2016), a service ecosystem is defined as a “relatively self-contained self-adjusting system of resource-integrating actors connected by shared institutional logics and mutual value creation through service exchange” (Vargo and Lusch 2016: 10). A service ecosystem conceptualisation offers a dynamic, comprehensive and systemic perspective of value co-creation (Wieland et al., 2012), based on the service-dominant logic definition of service as an application of
resources for the benefit of another party (Vargo and Lusch 2008). In this view, service is the fundamental basis of exchange where actors exchange the application of resources rather than resources themselves (Vargo and Lusch 2008). The service ecosystem perspective zooms out from an individual’s behaviour (i.e., individual-level) and dyadic relationships (i.e., micro-level) to include network, regional (i.e., meso-level), societal and national (i.e., macro-level) actors (Leroy et al., 2013). Therefore, value co-creation at each level influences and is influenced by the integration of resources at other levels and among other actors in the ecosystem (Akaka et al., 2013). Value co-creation is guided and limited by actor-generated institutions including policy, culture, regulations, norms and meanings (Vargo and Lusch 2016). It is a strategic perspective that is underpinned by the premise of the “complementarity of the service ecosystem as a whole and its individual parts” (Taillard et al., 2016: 2979). Value is seen as a holistic property of the system and its fundamental integrative concept (Meynhardt et al., 2016).

In attempts to understand how service ecosystems come into being, Taillard et al., (2016) suggest that service ecosystems emerge through processes of shared intention among its actors. Service ecosystem transformation can also be enabled by the emergence of resources such as technological advances or the changes in the institutional arrangements such as a new policy (Vargo et al., 2015). Wieland et al., (2012) referred to service ecosystem’s transformative processes when they conceptualised value as change in the viability of a system. According to Wieland et al., (2012), each occurrence of resource integration and value co-creation induces change in the nature of the system itself and hence creates a new context for the following episode of value co-creation. Two important assumptions appear to underpin such approaches. First, the emergence of different service ecosystems through transformation of existing is implicit. We propose that this is a property of service ecosystems: seemingly new service ecosystems are in fact transformations of existing service ecosystems. Understanding that value is socially constructed and must be understood within its social context (Edvardsson et al., 2011), any new or refined value co-creation influences existing meaning by changing the social context. For example, the development of the phone as a new product evolved from existing communication practices centred on the telegraph. In fact, social actors in a service ecosystem institutionalise emerged solutions through maintaining, changing and disrupting the existing institutions (Vargo et al., 2015). Second, previous research has primarily addressed the emergence of stable service ecosystems (Ben Letaifa et al., 2016; Taillard et al., 2016), ignoring the susceptibility of service ecosystem transformations to tensions and conflicts (Banoun et al., 2016). If not resolved, these tensions may lead to value co-destruction in the shape of relationship decoupling, and misuse or withdrawal of resources (Mills and Razmdoost 2016).

The literature, then, has made a promising start in describing the transformation of service ecosystems embedded in different markets but is silent on how a service ecosystem may not survive a transformation and ultimately collapse. This highlights the need to develop theory on the dynamics of service ecosystem transformation, considering not only the processes of their survival in the long term but the processes by which they fail to thrive. Exploring the question: How does a service ecosystem not survive a transformation? This research harnessed a fundamental concept from systems theory, that of entropy (e.g. McGuinness 1974; Markina and Dyachkov 2014; Daft et al., 2010). We formulate a theoretical framework and a series of propositions linking entropy to service ecosystem transformation. The theoretical framework is illustrated through a specific case: the introduction and demise of the Green Deal (GD) in the UK (2013-2015). This conceptual
description offers insight to service ecosystem theory into unsuccessful service ecosystem transformation, contributing to the literature on service ecosystems viability.

The paper is structured as follows: the next section introduces the concept of entropy, followed by a set of propositions linking entropy to service ecosystem transformation. The UK GD is then described as an illustrative example. A final section draws out implications for policy and practice and outlines directions for future research.

**BUILDING A THEORETICAL FRAMEWORK: ENTROPY IN SERVICE ECOSYSTEMS**

First applied in thermodynamics, the concept of entropy was used to explain deterioration and decay in the process of energy transformation. Entropy may be defined as a measure of the amount of disorder in the system (McGuinness 1974). According to the second law of thermodynamics, in an isolated natural system, entropy will always tend to stay the same or increase. Widely applied in social systems including organisations (Markina and Dyachkov 2014) and management (Daft et al., 2010), entropy has not yet been explored in relation to service ecosystems.

In this paper, we propose that service ecosystem transformation is an entropy driven process. A service ecosystem is a social system and the law of entropy acts to increase the instability of the system (Bratianu and Orzea 2012). Indeed, value has been viewed as being in a continuous state of flux, moving from order to disorder and back again (Meynhardt et al., 2016). Disorder is characterised by systemic uncertainty and instability and is witnessed during phases of competing and conflicting perspectives of value among systemic actors. Under these conditions of high entropy, value co-creation processes may discontinue or, in severe cases, value destruction may take place (Mills and Razmdoost 2016). We postulate that the amount of value-co-creation is a measure of order and stability in the service ecosystem, while entropy is a measure of a system’s disorder and instability, witnessed by the destabilisation of the dominant view of value. We see entropy as a system property, describing the tendency of the system to move towards instability and the destruction of systemic value. We posit the following proposition:

- **Proposition 1:** Entropy is a fundamental property of a service ecosystem representing its instability.

The viability of a system is determined by its contextual value co-creation (value-in-context; Wieland et al., 2012). Value-in-context has also been seen as an increase in the ability of a system to adapt to its environment, i.e. its survivability and well-being. Thus entropy can indicate the ability of a service ecosystem to survive (Martínez-Berumen et al., 2014). If the level of instability, which is determined by uncertainty and discontinuity of value co-creation, is high, then the system lacks viability. The capacity for long-term survival of the service ecosystem is at risk as entropy increases. Hence, to ensure the sustainability of a service ecosystem, entropy should be kept to a minimum.

Walker (2015) argues that open systems, that is, systems which interact with their external environment, succeed at preventing a descent into a chaotic and disorganised state by developing negative entropy (negentropy): a process of superior organisation and higher capacity to transform resources. The objective of negentropy is to support the system in reaching a more stable state of order and is achieved by bringing in the needed resources (human, material, energy and information) from the system’s environment. Without these fresh supplies of resources, the system will eventually die (Daft et al., 2010). Hence, viewed as dynamic, open, adaptive systems, a service ecosystem is
capable of improving its own state by importing resources from its environment (Wieland et al., 2012). Vargo and Lusch (2008) differentiated between operand and operant resources. Operand resources are usually physical such as machinery, buildings and raw materials on which an operation is performed. On the other hand, operant resources are those that act on other resources, such as the specialist skills and knowledge of individuals as well as organisational culture, norms and routines. Hence, we propose the following:

- Proposition 2: A service ecosystem must continuously offset the entropic process by importing new operand and operant resources from its environment.

Previous research has pointed to the need for deliberate mechanisms in order to reduce entropy in a system (Daft et al., 2010; Bratianu and Orzea 2012). Heylighen (1990) also underlines the need for internal control mechanisms, termed effectors which remove or offset potentially damaging disturbances and import the required energy and resources from the environment. Hence, we propose that a service ecosystem can act to reduce its entropy, counteracting the consequence of increasing entropy through the activation of a number of effectors.

We propose that these internal effectors involve two main mechanisms: heteropathic resource integration and re-institutionalisation. Heteropathic resource integration is an outcome of emergent resource-integration processes, resulting in an increase in new resource properties or new resources developed from existing (Peters, 2016). In addition, alongside value, institutions and institutional arrangements are the binding elements of a service ecosystem enabling value co-creation (Vargo and Lusch 2016). In particular, Banoun et al., (2016) illuminate a service ecosystem evolution as a process of ‘re-institutionalization’ and describe it as the development of new rules that become common place among systemic actors and act as critical coordination mechanisms. Hence, we make the following proposition:

- Proposition 3: A service ecosystem can counteract the consequence of increasing entropy through the activation of internal effectors: heteropathic resource integration and re-institutionalisation.

Hence, to remain sustainable with entropy maintained at controlled levels, the service ecosystem must have subsystems to ensure these effectors are activated. These subsystems include actors and networks of actors which determine value creation (Vargo and Lusch 2016). In the face of environmental turbulence, these value co-creation networks need to maintain sufficient resilience and flexibility to allow the ecosystem to adapt to changes inflicted by market conditions. Acting as a complex adaptive system allows the networks of actors to reconfigure and self-organise ‘at the edge of chaos’ (Prigogine 1978). The ability of network participants to co-evolve is paramount in this context (Vargo and Lusch 2016). Thus, the following proposition is posited:

- Proposition 4: For entropy to be maintained at controlled levels, the service ecosystem must have subsystems to ensure the effectors are activated. These subsystems include actors and networks of actors.

However, as Martínez-Berumen et al., (2014) argue, when such effectors are weakened, entropy will increase and the system’s institutions start to degrade. We propose that an indication of a service ecosystem’s decay is the dissipation of its operand and operant resources back to the environment through the loss of actors and the disentanglement of the network of actors. Maximum entropy, characterized by discontinuity in value-co-creation and perhaps value destruction, will result in the system’s collapse. Hence, the following proposition is posited:
• Proposition 5: Without adequate effectors, the service ecosystem will surrender to the influence of entropy, dissipate its operand and operant resources back to the environment, and its institutional arrangements eventually collapse.

AN ILLUSTRATIVE CASE: THE UK GREEN DEAL (GD)

The theoretical framework and propositions developed above will now be illustrated through the case of the UK GD. An illustrative case can help the reader to envisage how a conceptual argument may be applied in practice (Siggelkow 2007). The UK GD was chosen as a well-documented example of a failed service ecosystem. The illustration is based on a selective review of peer-reviewed articles and government reports published between 2013 and 2016. The review was not systematic, but selective, and the illustrative case study is not intended as an empirical case or as a point of reference for all the issues surrounding the GD. It should also be noted that, with all theoretical generalisations, the inferences we make must rest as propositions until proven or disproven by further evidence.

Overview of the Green Deal (GD)

Driven by the national Climate Change Act (2008), the UK Government introduced the GD as a flagship policy (DECC 2011). Fully live from 28th January 2013, it was intended to offer a mechanism for homeowners to enhance the energy efficiency of their properties without an upfront cost and to make solutions available to households irrespective of their financial resources. The scheme was intended to support energy efficiency improvements through private finance, shifting responsibility away from government and the public purse and onto individual homeowners. Clear targets were not set (NAO 2016) but the government spoke of 10,000 completions in the first year, leading to 14 million by 2020 (DECC 2011). Further, the scheme was expected to stimulate growth in the energy efficiency sector, leading to an increase in jobs in the sector from 27,000 in 2010 to quarter of a million (Huhne 2010). The cost of the works was covered by a loan from the GD Finance Company and repayment was through a surcharge on the property’s energy bill. The loan was therefore attached to the property and the individual homeowner was responsible for repayments only while occupying the property. Eligible improvements were required to comply with the ‘Golden Rule’ that the cost of the work would be fully repaid by the projected savings in energy bills over the loan period. The scheme has replaced previous schemes including Warm Front (2000-2013), Carbon Emissions Reduction Target (CERT; 2008-2012) and Community Energy Saving Programme (CESP; 2009-2012). A critical driver of the scheme was legislation on ‘consequential improvements’: the requirement for householders improving their property to spend an additional 10% of the project cost on energy efficiency improvements. This would have required around 2 million households to consider these improvements (Guertler et al., 2013). However, due to adverse media coverage, the policy was dropped in the run-up to launch of the GD.

By December 2015, 14,000 homes had had improvements through the GD although only 1% of these were funded by GD finance (NAO 2016). In the first year of operation, loft insulations decreased by 90% and cavity wall insulations by 77% (Hayman 2013). Rates of these installations had been running at 700,000 per year subsidised by CERT and CESP, but no longer qualified for subsidy under the GD. Funding for the GD was withdrawn in July 2015, effectively terminating the scheme.
The Green Deal Service Ecosystem

The GD Service Ecosystem involved a complex network of economic and social actors engaged in reciprocal direct and indirect service exchanges who needed to integrate their multiple resources successfully in order to co-create value. The main actors included the Department for Energy and Climate Change (DECC), the instigator of the GD transformation and householders, the focal actors in the GD who initiated their involvement by first commissioning as assessment from a GD advisor. The GD advisor’s role was to provide a Green Deal Advice Report detailing the improvements that could be undertaken under the GD such as double glazing, loft insulation, boiler replacement and wind or solar renewable energy. The householders then chose a GD provider who puts together a GD Plan detailing the costs for the works involved, interest rates and repayment terms. The work is then completed by a GD Installer and the cost of the works was covered by a loan from the GD Finance Company. Repayments were through a surcharge on the property’s energy bill collected by energy suppliers. Figure 1 presents a simplified view of the primary actors and exchanges in the GD service ecosystem.

![Diagram of primary actors and exchanges in the GD service ecosystem]

The introduction of the GD was a complex undertaking with high uncertainties and was reliant on multiple subsystems to align and co-create value successfully, including the support of other policies, enticing new types of businesses to participate in the energy efficiency market, facilitating training and accreditation, ensuring quality, and encouraging private finance (Guertler et al., 2013).

The propositions applied to the Green Deal

Having summarised the key aspects of the GD, more detail is now discussed in support of each of the propositions above.

Proposition 1 and the Green Deal

As a social system (Bratianu and Orzea, 2012), the natural law of entropy was active in increasing the instability of the GD Service Ecosystem (SES) and its transformation. Particularly, and from the outset, the GD SES suffered from mismatched perspectives on...
the value to be realised by the service. The most critical disparity was that between Government and householders, who were assumed to adopt the role of ongoing drivers, in line with an ecological modernisation rationale that economic utility impels action (O’Keeffe et al., 2016). Government aimed, through the GD, to improve energy efficiency and reduce greenhouse gas (GHG) emissions in a measurable way that could facilitate meeting legal targets. Householders however were more interested in convenience and household warmth than GHG emissions (Marchand et al., 2015) and other motivations such as health, well-being and comfort were ignored (Rosenow and Eyre 2016). The utilities companies sought to safeguard their reputation, avoid fines and minimise costs but their costs increased (NAO 2016) and they applied pressure to Government to change their targets and focus. Although the GD Finance Company was not-for-profit, interest rates on GD loans were set at around 7%, well in advance of interest rates available in retail banks at the time (Rosenow and Eyre 2016). In addition, there were issues around trust and quality of the installation work completed and indeed these were the primary cause of failure alluded to by government: whereas the householders expected quality installations by approved trades, the primary objective of some installers was profit, at the expense of customer satisfaction. Thus the GD service ecosystem began and continued with high entropy from major misalignments of the values to be realised among systemic actors.

**Proposition 2 and the Green Deal**

As an open system, the GD Ecosystem could have reduced the entropic process by bringing in the needed resources (human, material, energy and information) from the system’s environment (Walker, 2015; Daft et al., 2010; Wieland et al., 2012). The resources and institutions that could have been harnessed from the wider context include:

- **Financial**: Uptake of the scheme was very slow from the start and Government loans were necessary to aid start-up (£25m in 2013), to prevent collapse of the GD Finance company (£34m in 2014; Rosenow and Eyre 2016) and to facilitate training (£3.5m in 2012; Guertler et al., 2013). Cashback and subsidies to householders were offered in 2014-2015 to stimulate demand: these grants were capped and were fully subscribed. The capped amounts meant that insufficient external resources were applied to counteract the increasing entropy.

- **Knowledge**: practical knowledge from actors in previous SES such as the SMEs in the energy efficiency sector; and theoretical knowledge from academic commentators were not harnessed. Expert opinion on the economics of the value proposition, on the politics of introducing another energy efficiency scheme and on the social demand for such schemes was available to policy makers while the GD was being designed and throughout its duration (Rosenow and Eyre, 2016). Indeed, almost the opposite took place with the Government continuously denying the problems associated with the GD (Guertler et al., 2013).

- **External economic and social actors**: while major retailers such as supermarkets and DIY stores could have become important actors in the GD SES as they enjoy a large customer base and wide reach across the UK population, due to the uncertainties surrounding the scheme, they were reluctant to join the scheme and failed to support it. This further reduced overall consumer confidence in the scheme (Guertler et al., 2013).

Hence, the failure to inject sufficient additional financial inducements, to harness knowledge and expertise and to attract new actors to take part in the GD represent a system that was significantly isolated from its environment.
Proposition 3 and the Green Deal
As time progressed and problems became more visible, there was scope to encourage key actors collectively to identify alternative means to co-create value through heteropathic resource integration (Peters, 2016) and Re-institutionalisation (Banoun et al., 2016). However, opportunities for heteropathic resource integration were unrealised. Governance systems were determined at the outside, with roles for GD Providers, GD Finance, GD installers, training providers, etc., and were positioned in a static network of responsibilities. Re-institutionalisation has not taken place, which could have included the consequential improvement regulation, and the previously successful CERT and CESP programmes.

Proposition 4 and the Green Deal
In order to achieve greater viability, system actors should seek compatible and harmonious relationships (Wieland et al., 2012). However, relationship building was adversely affected by poor communication among GD actors, and most significantly the public with lack of public awareness characterising the GD for its duration (Guertler et al., 2013). Actors in the system (installers, utilities, householders) were also confused on policy (O’Keeffe et al., 2016). The Government ability to monitor and remedy the problems was exacerbated by its weak institutional capacity at the time. In early 2012, government departments had undergone institutional change and were institutionally immature. In addition, throughout the GD’s course, supporting actor networks have suffered considerable instability and decline. Funding for energy agencies, such as the Energy Saving Trust, the Carbon Trust and the Energy Efficiency Partnership for Buildings, was substantially reduced.

Proposition 5 and the Green Deal
Entropy continued to increase, with perception of value decreasing for the primary actors: installers were gaining little additional business despite, in many cases, having invested in training (O’Keeffe et al., 2016); utilities found their costs increasing (Morse 2016); householders remained largely unaware of the scheme and the Government achievement of energy efficiency was showing dramatic reduction compared to previous schemes (Hayman 2013). The loss of 4,000 jobs in the retrofit and insulation sectors had caused a significant loss of resources from the system (Guertler et al., 2013) and the service ecosystem for the GD was increasingly deemed as “failed” (Goodall 2013). The formal withdrawal of finance from the scheme by the government in July 2015 was perhaps the ‘killer blow’, representing an overwhelming failure of the system.

CONCLUSIONS
Investigating the question: How does a service ecosystem not survive a transformation?
We examined the processes by which service ecosystems may fail to reach stability and ultimately collapse. We proposed extensions to the service ecosystem theoretical conceptualisation by introducing the concept of entropy from systems theory to explain service ecosystem instability, disorder and ultimate collapse. The case of the GD vividly illustrates a service ecosystem’s failed transformation. The findings of this study have important implications for policy-makers, management and marketing practitioners:

- The service ecosystem concept offers a strategic perspective that underlines the systemic nature of service provision. Indeed, in terms of service, markets should be understood as a myriad of open, self-organising, co-evolving and interacting service ecosystems.
- The introduction of a new policy or market mechanism should be understood as a service ecosystem transformation; one that is prone to entropic processes of
disorder and instability and failure. Service ecosystems can, however, be stabilised through deliberate internal actions by systemic actors through the activation of effectors.

- The insight that most seemingly new service ecosystems are in fact transformations of existing systems carries the implication that any new policy initiative must consider how best to use what has gone before if it is not to undermine its new arrangements.

Through the introduction of the concept of entropy, this paper contributes to a greater understanding of the systemic and contextual nature of value co-creation and its full implications in service ecosystems. Further research is needed to explore operationalisation of entropy and to develop models for its assessment in service ecosystems. The entropy of the service ecosystem can then be employed to assess the risks faced by a newly introduced initiative regarding its sustainability in the long term.

REFERENCES


THE REQUIRED SKILLS FOR THE DELIVERY OF ENERGY EFFICIENT BUILDINGS: A SOCIO-TECHNICAL NETWORK APPROACH

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As buildings consume approximately 40% of energy demand in the United Kingdom, there are significant policy pressures on the construction sector and its clients to improve the energy performance of buildings. The need for an ‘up-skilling’ of the workforce, where ‘new’ skills are required to deliver energy efficient buildings, has been identified as a key challenge for the construction sector and its clients to address these pressures. The required type of skills, along with their associated definitions, however, have largely been taken for granted and have not been subject to empirical investigation. The research presents a case study of a school retrofit building project, where a socio-technical network approach has been adopted to investigate the required skills for the delivery of energy efficient buildings by examining the interests of the key actors, interactions and negotiations present within the project. Data collection consisted of interviews and observations with actors involved in the retrofit project, and a review of relevant organisational documentation. The key findings highlight the complexity of the network surrounding the delivery the energy efficient building. The results identified primary actors groups within the network and the association of different meanings for the required skills and further evidenced the demand for both ‘new’ and ‘existing’ skills during the delivery of the project.

Keywords: energy efficient buildings, Socio-Technical Network Approach, STNA, skills

INTRODUCTION

The United Kingdom (UK) is committed to a raft of requirements to create a low carbon economy, which include changes to the transport systems, buildings, and energy generation (DECC 2011). Buildings consume approximately 40% of UK energy demand (DCLG 2014). As a consequence, any improvement in the energy performance of buildings can significantly contribute to the delivery of a low carbon economy. There are a significant number of policy pressures on the construction sector and its clients to deliver energy efficient buildings.

In connection to the demand for energy efficient buildings, prevailing literature and policy makers claim there are ‘skills gaps’ within the construction industry, for which an ‘up-skilling’ of the workforce is required (Construction Skills 2010). The skills challenges are associated with the need for ‘new’ skills, ‘green’ skills and ‘low carbon’ skills for the construction sector and its clients during the development of energy efficient buildings, which links to the changes occurring surrounding the energy efficient building design (RIBA, 2008), and the construction and post-completion stages (Home Building Skills 2013). Furthermore, the challenges of required skills can be linked to the uptake of renewable technology for energy efficient buildings, and additional training to be carried out by the construction sector and its clients. There is little detail, however, on what the

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new skills, green skills and low carbon skills actually consist of, a lack of agreement on how those required skills are defined; and, little empirical evidence or examples for the application of green skills. As a result, there are only partial insights on how the construction sector and its clients can respond to the skills challenges and, if green skills do exist, what action is required to obtain the necessary skills.

This paper presents a case study of a school retrofit building project, which has adopted a socio-technical network approach (STNA) (Elzen, Enserink et al., 1996, Schweber and Harty 2010) to gain a better understanding of the research area and empirical setting for data collection. The approach establishes a socio-technical network (STN) which highlights key actors, their interests, interactions and further negotiations within the delivery of energy efficient buildings.

The structure of this paper is as follows. First, the skills literature will be reviewed to offer the ideas associated with the concept of a skill and further, the construction skills literature explored to gain insight on the skills challenges for the construction sector and its clients. Second, the methodology applied to the research is explained. Third, key findings for the investigation are presented. Finally, results are discussed in terms of empirical contribution to skills theory and STNA methodology, and conclusions from the investigation are drawn.

RESEARCH SETTING

A key challenge highlighted within the prevailing construction literature is associated with 'skills issues' for the UK construction industry (CIOB 2013), where discussions are linked to the concern of 'skills shortages' (Dainty et al., 2007) and 'skills gaps' (Construction Skills 2010) within the sector. More specific to the delivery of energy efficient buildings, the 'skills issue' is coupled with the requirement of 'new' skills (Construction Skills 2010), ‘green’ skills and ‘low carbon’ skills. The accounts of the type of skills required, the skill definitions and ideas around what the skills actually consist of, however, are vague. The concept of a ‘skill’ will be briefly introduced, followed by a review of current construction skills literature to explore the skills challenges associated with the delivery of energy efficient buildings.

Classifications of a ‘skill’

Literature suggests a skill is connected to the ability to carry out a daily task, and can also relate to a specific role within the workplace (CBI, 2013). To extend this idea, a skill can be referred to as a particular job or activity (Clarke and Winch 2006), tasks to be carried out by an individual (Aggarwal et al., 2007), and linked to particular skills that are needed to fulfil a position in the work place (UKCES 2009). Furthermore, a skill can be defined through evidence of an individual's attributes (...on occasions personal attributes), qualifications, a knowledge and experience of the job / occupation required to be undertaken, or the ability to perform the required tasks and utilise specific tools for the role (Clarke et al., 2013).

In broad terms, three skill classifications are evident within the literature: ‘generic’ or ‘specific,’ ‘existing’ or ‘new’ and ‘hard’ or ‘soft’. Although, the classification boundaries are not definite and there are particular skills that may be included in two or more classifications. In the first classification of generic versus specific skills, ‘generic’ skills are categorised as numerical skills, professional communication skills, problem solving skills and computer skills (Felstead. A et al., 2012), but also associated with interpersonal skills (communication, team work, ability to negotiate), and the ability to use technology (OECD 2011). The diverse range of skills within the generic
classification also include ‘employability’ skills, which is linked to an individuals’ ability to complete a job, tasks or, more extensively, a role within the workplace (UKCES 2009). In comparison, ‘specific’ skills are connected to activities that are associated with individuals’ specialist skills or ‘speciality’ (Edum-Fotwe and McCaffer 2000). The second classification is ‘new’ versus ‘existing’ skills. ‘New' skills are primarily related to an ‘up-skilling’ of the workforce to undertake new roles within the workplace, carry out different methods or techniques of working, and the use of more advanced equipment (HM Government 2010). While ‘existing’ skills are described as those that an individual / workforce already possesses, but can also be referred to in connection with the requirement for training to further develop these skills. The final classification is the distinction between ‘hard’ and ‘soft’ skills. ‘Hard’ skills appear to be linked to the knowledge of carrying out an activity, possibly specific to a role, and require a form of learning (e.g. training for skills development) (Rongraung et al., 2014). In contrast, ‘soft’ skills, such as communication and interpersonal skills, are suggested to be personal to the individual, associated with the building of relationships within the workplace, the ethics or culture related to a person (Ingason and Jónasson 2009) and occur though a more progressive manner.

**Skill challenges for the delivery of energy efficient buildings**

The primary focus and emphasis within existing investigations relates to the concepts, and the requirement, of new skills, green skills and low carbon skills. There are ideas that associate the different types of skills to the technology adopted for energy efficient buildings (e.g. renewable technology, energy efficient measures: EEMs), the variety of project stakeholders involved in the building process (e.g. clients, developers, contractors, local authorities, end-users) and the different stages of the development, construction and post-completion of the building, which immediately highlights the complexity of the ideas associated with the type of skills required. The need for new skills, for example, is not only linked to the changes in relation to the building design and construction (Home Building Skills 2013), but also the requirement of skills for clients of the construction sector during the delivery of energy efficient buildings (SDC 2010). Whereas green skills can be linked to the adoption of technology within buildings (Aldersgate Group 2009) or in reference to a skill required to reduce carbon emissions (Bird and Lawton 2009). To add to the confusion, a green skill is classified as both ‘generic’ (Bird and Lawton 2009) and ‘specialist’ (Energy UK 2014) in nature, where there are indications the workforce require the aid of training to achieve green skills of the specialist classification. Similarly, a degree of uncertainty is associated with the idea of low carbon skills. Low carbon skills definitions refer to a combination of skills and knowledge required that focus solely on the design stages (RIBA 2008), such as skills employed by an energy assessor. There are further extensive ideas that refer low carbon skills to the entire life-cycle and use of energy efficient buildings (Construction Skills 2011). Much the same as green skills, low carbon skills include reference to the requirement of both new and existing skills for the construction sector and its clients, but little information on how to gain the new skills (HM Government 2010). It is valuable to mention that the prevailing research states there is a need for skills for energy efficient buildings, but does not specifically refer to these skills as new skills, green skills or low carbon skills. Previous studies involving the retrofit of energy efficient buildings, for example, highlight the need for technical skills for the construction sector, which is linked to the use of advanced technology and extensive policy knowledge. There is no indication, however, of the required skills being associated with green or low carbon skills. As a consequence of the diverse views and speculation of whether green skills actually exist, complications arise
with regards to understanding the exact meaning and type of skills associated with the green skills classification.

**Skill development**

In an attempt to engage in the skills issue, prevailing literature investigates the possible routes to skill enhancement for the construction industry (Clarke and Wall 1998). Key discussions tend to be associated with the dominant means of training, mainly apprenticeships and formal qualifications (e.g. National Vocational Qualifications) (Brockman *et al*., 2008), the type of skills desired (i.e. the move away from ‘craft’ skills) and the effective outcome of attempts to develop construction skills (Hogarth and Gambin 2014). The role of gaining experience, however, cannot be overlooked (Edum-Fotwe and McCaffer 2000). Furthermore, key challenges for the ability to gain the appropriate skills are prevalent within the literature, primarily linked to the funding of training courses (i.e. lack of government funding and the expense for the employer), the availability of suitable means of training for the required skills (Agapiou *et al*., 1995) and the desire by the construction workforce to embark on skill progression (Dainty *et al*., 2005).

As demonstrated within the literature, there are a wide range of ideas in terms of what a skill consists of, vague accounts of new skills, green skills and low carbon skills, and complexity associated with possible solutions of how the construction sector and its clients can obtain the required skills. The research problem lies with little consensus in terms of the skills required by the construction sector and its clients for the delivery of energy efficient buildings, and lack of clarity surrounding the meaning of specific skills. There is a need to better understand the types of skills required by the construction sector and its clients during the delivery of energy efficient buildings, and gain insights of skills challenges experienced.

**METHODOLOGICAL LENS**

A socio-technical network approach (STNA) was adopted for the research, which mobilised the investigation (i.e., stated how to carry out the empirical work) and provided a lens to understand the required skills for a network of actors during the delivery of the energy efficient building. The STNA investigates a ‘social’ network of actors (Elzen *et al*., 1996), which allowed the identification of key actors / actor groups, along with their interests, interactions and negotiations that surrounded the delivery of the energy efficient building. The application of STNA also provided a bounded network during data collection, the socio-technical network (STN) (see figure 1 below). The STN is defined as “an analytic tool or method … been developed to explore a range of different research questions … features include a focus on the interactions between social and material entities, and the practices through which they are developed and mobilized” (Schweber and Harty 2010: 658). The STN acted as a focus and boundary for the empirical work during the identification of actors involved within the school retrofit building project. Furthermore, STNA promotes human agency where an actor is not classified as independent of the technology within the STN and, in contrast to other approaches; for instance, social network analysis, key actor / actor group interactions with the technology (i.e., the artefact) can then be explored. The key concepts of STNA consist of artefacts, nodes, intermediaries and interpretative flexibility (Elzen *et al*., 1996), which are briefly described below:

Artefacts can be physical / material objects, non-physical actions or a mixture of both physical and non-physical elements within the network.

Nodes are actors or groups of actors within the network.
Intermediaries or exchanges occur between actors within the network. Intermediaries can be both tangible (e.g. emails of contracts) and intangible (e.g. conversations relating to meetings / actions) elements within the network.

Interpretative flexibility relates to how individual actors can have different interpretations or meanings attached to the same artefact within the network.

Figure 1 illustrates how the STN was created through the principles of STNA using the interaction between the two nodes (1) (i.e. School end-users and LA energy team) as an example. The arrow line represents the principal interests (2) of the two actor groups, while the texts included between the two arrow lines indicate the negotiations between actors / actor groups that provided insight into the required skills for the delivery of the energy efficient building (3) during the interaction.

**Figure 1: The socio-technical network (STN) diagram**

**DATA COLLECTION AND ANALYSIS**

Data collection consisted of semi-structured interviews with actors / actor groups within the STN of the school retrofit building project, observations surrounding the delivery of the energy efficient building (e.g. project meetings and EEM installations) and a review of relevant company documentation (e.g. LA Carbon Management Plan and handover end-users EEM guides). The interviews were primarily conducted face-to-face with those involved in the retrofit project or, if this was not possible, interviews were carried out over the telephone. Prior to interviews, a semi-structured interview protocol was prepared and pretested. Each interview was around one to two hours in length and carried out either on-site (the school building) or office buildings. Data collection was captured using a tape recorder (interviews) and note taking (interviews or observations). Interviews were then transcribed verbatim, made anonymous and sent to the interviewee. A software programme known as Nvivo 10 was used during data analysis, where the content analysis technique was employed to analyse the data collected (i.e. interview transcripts, written word documents, PDF files, images and audio files). Guided by the research aim and objectives, key themes that emerged within the data and presented by the STN diagrams (see figure 1) were coded. Three ‘levels’ were used to code the data within Nvivo as representation of actors / actor groups (level 1) identified from the STN, the actors’ interests (level 2) indicated by interactions within the STN and the skills employed by actors / actor groups (level 3) revealed by negotiations in the STN surrounding the delivery of the school retrofit building project.

**KEY FINDINGS**

**Description of the case study**

The case study is a retrofit of a primary school that has one permanent building and two temporary buildings. Due to the need to meet LA energy reduction targets (i.e. 15% by 2015 and 40% by 2050), an energy audit was carried out by the local authority (LA) energy assistant. Energy efficient lighting, double glazing and a half hourly meter were
installed within the school building, in addition to energy education provided to end-users of the school. Cavity wall and loft insulation surveys were also carried out by an insulation surveyor and suggested as a potential further energy efficient measure (EEM) for the building.

**Energy efficient building project socio-technical network (STN)**

The key findings highlight the complexity of the network (the STN) surrounding the development and the implementation of the energy efficient building. Results reveal seven actors / actor groups present within the STN of the school retrofit building project. The key actor groups identified were the local authority, the EEM contractors and the school end-users, where each actor group had a specific role(s) during the delivery of the energy efficient building.

The STN also provided insight to the ten main interactions occurring between the key actor groups within the network. Interactions demonstrated the interests of the actors / actor groups surrounding the development and implementation of the energy efficient building. The main interest of the local authority was to reduce energy consumption of the building in order to comply with local authority energy targets. This was captured by the LA energy assistant who stated: “So if we can save them [schools] money that’s great but we also save them energy it’s even better for us to meet our targets…” Primary negotiations present between each actor / actor group during the school retrofit building project were also highlighted within the network, which evidenced the required skills for the delivery of the energy efficient building.

**Required skills for the energy efficient building project**

The findings suggest the term 'required skills' related to the skills needed to carry out a particular task associated with the retrofit of the school building project and more specifically, a 'skill' was recognised as the ability to achieve the right end product. The skills required for the local authority consisted of energy management skills, project management skills and communication skills; the EEM contractors required technical skills and communication skills; the school end-users required communication skills, research skills, project management skills and basic IT skills. The results also reveal the actors associate different meanings for the required skills. The local authority, for instance, required project management skills to support and contend with a number of challenges during the delivery of the school retrofit building project. The school end-users, however, required project management skills for tasks connected to the ability to organise and evaluate funding for the EEM.

The findings further indicate the primary skills required by the key actor groups were a combination of both new skills and existing skills. 'Existing' skills were skills that were possessed by the key actors / actor groups involved in the retrofit building project (i.e. no demand for additional skill development), and were connected to more of a basic nature, such as the ability to communicate. In contrast, 'new' skills were associated with the necessity of further training by the key actors / actor groups to gain knowledge and experience for the adoption of the EEM for the retrofit building project. The primary new skills were associated with energy management skills and technical skills, and both linked to the EEM being adopted within the energy efficient building. This was evidenced by the electrical engineer who mentioned: “You have to have good electrical knowledge for the whole thing to work out what light fittings you can and cannot do … one thing you have to have and be aware of, and do, is lighting design.” Through training, new skills may also be associated with skills that require improvement. For example, although
development of required skills
Training was primarily associated with the eem integration in the form of information to eem contractors surrounding the tools for eem installation, or understanding for the use of the eem for school end-users. skill development was also essential for the LA energy assistant, which highlighted learning can be of a formal (e.g. an energy management training course) and informal nature (e.g. in-house training by the LA energy officer). in addition, formal training was evidenced by the PV supplier as expressed: "...we give a lot of training, marketing support and sales support…we support the partners [installers] with training and given the talks to be able to answer those questions." Whereas more informal conversations to gain the required skills to adopt the eem were present as the school business manager mentioned: "I think what we were looking for was the fit and that was the information we got from the energy officer and the school governor." Furthermore, informal conversations and more formal energy education for the school end-users were revealed, which suggests the significance of appropriate learning environments that may relate to the different actor groups or the type of skills that require development.

Discussion
The key findings indicate the value associated with the adoption of socio-technical network approach (STNA) as a methodological lens to study the required skills for the actors / actor groups during the delivery of energy efficient buildings. The STNA allowed the identification of key actors / actor groups within the project network, their interests and recognised the negotiations between these actors / actor groups involved in the retrofit project. The presence and complex nature of the STN, due to the actor / actor group interactions, highlights the degree of freedom for tangible and intangible exchanges required by actors for the delivery of the energy efficient building. The STN for the school retrofit project further demonstrated the contrasting interests of actor / actor groups during the school retrofit project, which highlighted the concept of interpretative flexibilities within the network.

As actor / actor group interactions, more specifically negotiations, were evidenced within the school retrofit project, the key skills required by actors become apparent. As a result, the identification of required skills offered an insight and ideas associated with ‘green’ skills, and also an understanding of meanings and definitions of the key skills needed by the actors / actor groups. The intermediaries (i.e. tangible and intangible exchanges) that occurred between actors within the network, the diverse negotiations and the complexity of the network for the school retrofit project further provided information on the potential issues surrounding the delivery of energy efficient buildings. The investigation highlighted key challenges associated with the required skills for the retrofit of the school building. First, the variation of actor / actor group meanings associated with the required skills, which posed concerns in terms of the identification of the skills needed by the construction sector and its clients. There were both similar meanings (i.e. communications skills) and contrasting ideas (i.e. project management skills) associated with the required skills for the delivery of the energy efficient building, which were linked to actor / actor group roles. Second, the understanding of the required skills and association of whether new or existing skills were required by actors / actor groups
involved in the school retrofit project. Finally, following the acknowledgement of the required skills in order to deliver the school retrofit project, the demand for training required by actors / actor groups was evident, which resonates with the existing literature (HM Government 2010). The need for training offered indications of both new skills required for the construction sector and its clients, but also training to enhance existing skills. In reference to the required skills being that of ‘green’ skills, the views and actions involved with ‘technical’ skills and ‘energy management’ skills, similar to previous building retrofit reports (Killip 2008), captured a connection to the need for knowledge and understanding of the EEM adopted and in many instances, the use of specific tools during the EEM integration. Due to the connection to the EEM and similar to the ideas of green skills within the literature (Energy UK 2014), there are indications both technical skills and energy management skills can be associated with that of a green skill.

CONCLUSIONS

The investigation demonstrates the complex network of actors / actor groups involved, their interactions and negotiations that surround the delivery of energy efficient buildings. The adoption of socio-technical network approach (STNA) as methodology provides guidance of the empirical work, in addition to insights of the required skills for actors / actor groups involved in the development and implementation of a school retrofit building project. The case study findings highlight the ability to identify principle actors / actor groups (the local authority, the energy efficient measure (EEM) contractors and school end-users) by the application of STNA, and detail of the actor / actor group meanings’ of the required skills for the delivery of the project. The research results further evidence the need for both new and existing skills during the development and the implementation of the energy efficient building.

The findings indicate two potentially fruitful areas for future research. First, it would be valuable to investigate the feasibility of skill development and methods of learning employed to gain the required skills, more specifically the attainment of new skills surrounding knowledge and experience for EEM integration in buildings. Second, to further expand on the skills theory, and recognised by Oliveira et al., (2015) as essential for the future construction sector, it would be advantageous to understand the type of skills and knowledge needed beyond energy efficient buildings, such as planning, architecture and broader sustainability within the built environment.

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Bevan, Lu and Sexton


HEALTH, SAFETY AND WELLBEING
SAFE CONSTRUCTION SITES: A COMPARATIVE OF WORKER AND MANAGEMENT PERSPECTIVES FROM INDIA

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A developing country like India faces huge challenges in construction worker safety. The importance of safety culture, management responsibility in safety is well established in literature. However, the perspectives of the construction workers are under-studied. Hence, the objective of the present study is to understand the perspectives of workers as compared to management on construction safety. To this end a questionnaire survey was conducted across different construction sites in India on 22 parameters of safety identified from extensive literature survey. Responses were elicited from representatives of management and the construction workers on site. A total of 44 responses were collected and analyzed in SPSS using TOPSIS, a technique for multi-criteria decision making to rank the preferences of the respondents on these parameters. While provision of PPE, maintenance of injury records and new worker orientation are paramount from workers’ perspective; awareness of top management, penalties for non-compliance and communication are considered important by management. The results indicate a move towards cultural dimensions and transparency. However, while the management still looks at penalties to enhance safety, the workers emphasize on pro-active measures. Thus, this study illustrates some of the context-specific characteristics of safety management in developing countries like India.

Keywords: proactive safety, management system, safety strategies, workers' perspective

INTRODUCTION

Construction industry is a key sector in driving the economies of countries around the world. The sector is involved in creating and maintaining key infrastructure that range from personal homes to large scale infrastructure like dams and bridges which fuel the economic development. The challenges in executing and delivering these projects on the three classic principles of time, cost and scope pose significant challenges to the project managers in construction around the world. Now, the industry has realized that safety is an important dimension of the project management, perhaps more significant than other dimensions of project management. The construction sector is traditionally considered a risky industry to work for. This notion is reflected by the high number of injuries and fatalities recorded in the construction project sites across the world both in the developing as well as developed countries. Lingard (2013) and Namian \textit{et al.}, (2016) highlighted that annually more than 60,000 fatalities reported all over the world.

The increasing complexities in scope of projects to be delivered combined with reduction in timelines to deliver them is posing greater and newer challenges to construction safety management. There is a consistent number of accidents (fatal and non-fatal) reported across the world. The ranges of fatalities vary from about 985 in USA (according to

\begin{thebibliography}{9}
\bibitem{Lingard} Lingard (2013)
\bibitem{Namian et al.} Namian \textit{et al.}, (2016)
\end{thebibliography}

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United States Bureau of Labor Statistics) to 350 fatalities reported by Taiwanese construction companies (Chen et al., 2013). The average number of non-fatal injuries in construction industry as compared to other industries is also significant higher consistently across the world. For example, according to the United Kingdom's Labor Force Survey, the rate of the reportable non-fatal injuries were on average 1600 per 1,00,000 workers between 2004 to 2007, which is significantly higher than the all industry average of 950 reportable injuries per 1,00,000 workers (Hallowell 2010). The Indian construction industry is also facing significant challenges associated with worker injuries that result in either fatality or permanent/temporary disability. According to Indian Labour Statistics (2014), the construction industry is responsible for 265 fatalities and 573 total injuries in year 2010, similarly 190 fatalities and 270 total injuries in year 2011. These numbers attracted the focus of research community for finding solutions to reduce these numbers as much as possible.

Construction safety management practices are evolving in India. Reasonable maturity has been achieved in terms of provision of PPE to construction workers across medium to large construction companies in the country. The Government of India promulgated standards related to employee safety which are applicable to construction industry. The first of these standards which is related to construction practices and safety is the 'National Building Code of India' published in year 1970. This code was revised in 1983 and 2005 to incorporate greater scrutiny regarding safety in construction. About 55 standards pertaining to various aspects of safety practices and use of protective equipment are now existing in the country. The focus of the standards is now shifting to a more systematic based management of safety and the emphasis now laid upon the processes to ensure safety rather than provision of PPE to construction workers. For example, section 3, part 7 of the National Building Code of India 2005 (Bureau of Indian Standards, 2007) states that “the safety of personnel engaged in building construction should be ensured through a well-planned and well organized mechanism”. Despite the advances and innovations in the construction industry, a glance at the trends of number of accidents on construction site present a bleak picture of the truth that no significant reductions have been achieved in the construction worker injury especially in the context of developing countries. Such safety concerns have huge significance in terms of managing large construction projects.

Stringent regulations now being implemented in India would impose huge penalties both in terms of time and cost to construction sites where the accidents are reported. From a project economic perspective, the workers compensation cost against injuries adversely affects profit margins and project success (Namian et al., 2016; Zou and Sunindijo 2015). Past research has shown that unsafe site environment has a significant impact on total worker cost, poor employee performance, absenteeism, and early exit from the construction industry (Bergstrom et al., 2007; Oude et al., 2012; Townsend et al., 2016). Apart from the economics, the accidents have significant impact on the moral of project teams and dampen the work culture on construction sites.

The development of a robust construction safety management systems on project sites is highly necessary to counter the disturbing trends in construction safety. However, such development is not a trivial task. Such systems incorporate processes for ensuring stringent worker compliance to personal protective equipment (PPE) to provision of safety trainings to putting in place systems to perform root cause analysis for accidents etc. The effectiveness of such systems are dependent on the culture and attitude of the site personnel involved. Thus, understanding the safety culture is paramount to success of any safety management systems in construction.
LITERATURE REVIEW

Construction safety research has been the focus of researchers for a long time. Researchers uniformly agree that measures like provision of PPE to workers form the last line of defence and are not sufficient for safety management. A significant amount of literature tried to understand the root causes of various construction accidents occurring on project sites. Studies have attributed wide ranging causes for construction accidents. On one hand studies have attributed the causes predominantly to the workers on site like alcoholism on site, skill levels of workers, reckless operations etc. (e.g. see Alwan 2011, Townsend et al., 2016). The risk taking mind-set, bad emotional state, lack of safeguarding, messy site condition, and work intensity exerts a negative impact on worker behaviour. On the other hand, other studies indicated the responsibility of management in site safety like poor safety awareness of top managers, reluctance to allocate budgets for safety, lack of effective supervision system etc. (e.g. see Chen et al., 2013).

It is increasingly being accepted that both the management and the workers are equally responsible to improve the safety management of site (Poon et al., 2008). Such responsibilities are usually manifested as the safety culture which is prevailing in the construction sites. Thus assessment of safety culture and the perceptions of the management as well as the workers about the safety climate on a construction site becomes paramount. This is further reinforced by studies which indicate that the prime causes of accidents are more organizational, managerial and human factors rather than purely technical failures (Langford et al., 2000; Mohamed 2002; Weick et al., 1999).

Such factors other than the technical factor are often reflected in the safety culture of the site. It should be noted that assessment of safety culture on a site involves a fundamental shift in assessment of safety on construction sites. The usual reactive measures (lagging indicators) like accident rates, near misses etc. might prove insufficient compared to the proactive leading indicators such as assessing the safety climate on a construction site (Flin et al., 2000; Mohamed 2002). In fact, Gilkey et al., (2012) and Zohar (2010) states that, the relationship between positive safety culture and role of injuries is inversely proportional. Researchers now believe that greater efforts need to be taken for positive safety culture to have safe construction sites (Gilkey et al., 2012). However, some of the studies has limitations such as they did not include leading indicators such as injury prevention efforts (Hallowell 2010). Namian at al., (2016) considered one representative per project for evaluation, but more representative from same project can touch different aspects of the safety culture.

Safety culture is the attitude, beliefs, perceptions and values that employees share in relation to safety in the workplace (Cox, S J and Cox T R 1991). The managers and the construction workers the two main stakeholders whose behaviour significantly influence the safety on construction site. The role of managers and workers in construction site safety is widely studied. Some studies have stated that the managers can indirectly influence the safety culture in a construction site (Lingard et al., 2012). Gillen et al., 2004 highlighted the challenges faced by managers in reinforcing safety cultures on sites. Though the managers are usually aware of the hazards and are motivated to foster safety culture, they usually felt the need improve their managerial skills to manage workers better from a safety perspective. The need for having to move away from traditional hierarchical safety management culture to a new corporate culture which will be more inclusive taking into account the workers viewpoints is highlighted (Haupt 2003). Such safety culture can be characterized by open communication, top management support, mutual trust between workers and managers, willingness of management of organization
to introduce and support the necessary changes. Thus, the management and workers play a major role in defining the safety culture present on a construction site.

Such safety culture is influenced by the perceptions of workers as well as managers towards the construction safety. It is important to assess and analyse these perceptions and whether they vary between the construction managers and workers. Such a study would give us an understanding on the maturity of the safety culture on the construction site. Thus, understanding the perceptions of these two significant stakeholders becomes significant especially in a developing country like India where the safety culture is still maturing by helping the researchers to comparatively understand the differences and similarities in perceptions of these stakeholders to the construction safety thus helping to identify the maturity of the various stakeholders to the construction safety. Also, implications can be drawn based on such comparative analysis to understand how the perspectives of managers and workers prove to be challenges/enablers on achieving safe construction sites. This became the motivation of the present study and the research objective of the present study is to identify the perspectives of workers and managers from Indian construction sites. A related sub-objective then would be to compare and analyse these perspectives to understand the safety culture in Indian construction industry.

**RESEARCH METHOD**

The present study uses survey research method as an appropriate method to address the above objective. To this end, a questionnaire was designed to elicit responses from managers and workers on Indian construction sites. Data was collected from various construction sites across the country. The data was then analysed using Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) a method of Multi Attribute Decision Making to rank the perspectives of managers as well as those of workers. The results of this analysis were then discussed and implications were drawn for construction safety management in developing countries. The following sections elaborate on these aspects of the study.

**Questionnaire Design**

A questionnaire was designed with the objective of determining most important parameter from worker’s and the manager’s perception to boost the safety performance in current scenario. Two separate questionnaires were framed for managers and workers. The parameters included in questionnaire are collected from extensive literature survey. Table 1 illustrates the parameters considered in the questionnaire survey. The questionnaire to managers had 14 parameters from literature which were found relevant from the management's perspective. The questionnaire for the workers had 22 parameters which were considered important from a worker's perspective. The parameters consisted a mix of proactive (leading indicators) as well as reactive measures (lagging indicators) of safety culture on construction site. For example, injury record is a lagging indicator whereas new employee orientation can be considered as a leading measure of safety culture on site. Respondents were asked to rate each parameter on a five point Likert scale, where 1 = least important and 5 = most important from a construction site safety perspective. The respondents also asked to mention the factors that are more important, but not considered in the questionnaire.

**Data Collection**

The questionnaire so designed was distributed to workers and managers across the country. The managers’ responses are collected using both online forms as well as offline survey forms. The collection of data from workers posed significant challenges. The
access to various construction sites and interaction with workers was not often not allowed in Indian construction sites. The various parameters of the questionnaire were then explained to workers often in their mother tongue as many workers are not familiar with English. After such efforts, a total of 44 responses were collected from 23 number of sites from different part of India. Out of total responses, 24 responses from managers and 20 responses from workers. The respondents have significant work experience in construction industry. Some respondents worked in different states, and some respondents are from different states of India. So, such sampling helped in collecting different inputs and providing uniform output for Indian construction industry.

Table 1: Parameters considered in questionnaire design

<table>
<thead>
<tr>
<th>Parameters for Managers</th>
<th>Parameters for Workers</th>
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</thead>
<tbody>
<tr>
<td>1 Organizational Commitment</td>
<td>1 Safety signs / Warning Signs</td>
</tr>
<tr>
<td>2 Workers Training</td>
<td>2 New Employee Orientation</td>
</tr>
<tr>
<td>3 Protective Equipment</td>
<td>3 Injury Record</td>
</tr>
<tr>
<td>4 First Aid Measure</td>
<td>4 Drinking Water Facility</td>
</tr>
<tr>
<td>5 Top Management Safety Awareness</td>
<td>5 Sanitary Facility</td>
</tr>
<tr>
<td>6 Enforcing Preventive Safety Measures</td>
<td>6 Job Related Training</td>
</tr>
<tr>
<td>7 Communication with Stakeholders</td>
<td>7 Fire Extinguisher Training</td>
</tr>
<tr>
<td>8 Construction schedule (Duration)</td>
<td>8 Personal Protective Equipment Training</td>
</tr>
<tr>
<td>9 Budget on safety investment</td>
<td>9 Personal Protective Equipment</td>
</tr>
<tr>
<td>10 Penalty for safety non-compliance</td>
<td>10 Fire Extinguisher</td>
</tr>
<tr>
<td>11 Per day working hours of workers</td>
<td>11 First Aid Kit</td>
</tr>
<tr>
<td>12 On site worker behaviour</td>
<td>12 Emergency Contact Numbers</td>
</tr>
<tr>
<td>13 Worker experience and skill</td>
<td>13 Housekeeping</td>
</tr>
<tr>
<td>14 Prevention of intoxication on site</td>
<td>14 Well Defined Traffic Route</td>
</tr>
<tr>
<td></td>
<td>15 Regular Disposal of Waste and Trash</td>
</tr>
<tr>
<td></td>
<td>16 Stability of Material in Storage</td>
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<td></td>
<td>17 Storage of Flammable Liquid</td>
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<td></td>
<td>18 Open Ditches Protection System</td>
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<td></td>
<td>19 Dust Protection System</td>
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<td></td>
<td>20 Fire Alarm System</td>
</tr>
<tr>
<td></td>
<td>21 Fall Protection System</td>
</tr>
<tr>
<td></td>
<td>22 Safety Meetings</td>
</tr>
</tbody>
</table>

Data Analysis and Results

The data so collected was then analysed using Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) a method of Multi Attribute Decision Making. It works on the principle that the best alternative has least distance from positive ideal solution and farthest distance from the negative ideal solution. The steps are calculating normalization of matrix, weights of attributes, weighted normalized matrix, positive ideal solution and Negative ideal solution, separation measures and relative closeness of alternative with respect to positive ideal solution (Rao RV 2007). The separation measure
**Si+, Si- for each alternative has been calculated with the help of positive ideal value $V_j^+$ and negative ideal value $V_j^-$.**

\[
Si^+ = \sqrt{\sum_{i=1}^{M}(V_{ij} - V_j^+)^2} \quad i = 1, 2, \ldots N \quad \ldots \ldots \ldots (1)
\]

\[
Si^- = \sqrt{\sum_{i=1}^{M}(V_{ij} - V_j^-)^2} \quad i = 1, 2, \ldots N \quad \ldots \ldots \ldots (2)
\]

The relative closeness ($P_i$) of each alternative ‘$i$’ with reference to negative ideal measure $S_i^-$ calculated. The $P_i$ value will lie between 0 to 1. The higher the $P_i$ value, the better is the alternative.

\[
P_i = \frac{S_i^-}{(S_i^- + S_i^+)} \quad \ldots \ldots \ldots (3)
\]

Table 2 and Table 3 illustrates the results obtained by the TOPSIS analysis.

**Table 2: Ranking of parameters from managers’ perspective**

<table>
<thead>
<tr>
<th>Parameters for Management</th>
<th>$Si^+$</th>
<th>$Si^-$</th>
<th>$Pi$</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Management Safety Awareness</td>
<td>0.006448</td>
<td>0.011501</td>
<td>0.640774</td>
<td>1</td>
</tr>
<tr>
<td>Penalty for safety non-compliance</td>
<td>0.006982</td>
<td>0.011536</td>
<td>0.622953</td>
<td>2</td>
</tr>
<tr>
<td>Communication with Stakeholders</td>
<td>0.006897</td>
<td>0.010694</td>
<td>0.60793</td>
<td>3</td>
</tr>
<tr>
<td>Enforcing Preventive Safety Measures</td>
<td>0.007888</td>
<td>0.011087</td>
<td>0.584297</td>
<td>4</td>
</tr>
<tr>
<td>On site worker behaviour</td>
<td>0.00813</td>
<td>0.011049</td>
<td>0.576103</td>
<td>5</td>
</tr>
<tr>
<td>Budget on safety investment</td>
<td>0.005832</td>
<td>0.007529</td>
<td>0.563508</td>
<td>6</td>
</tr>
<tr>
<td>Workers Training</td>
<td>0.003938</td>
<td>0.005051</td>
<td>0.56191</td>
<td>7</td>
</tr>
<tr>
<td>Organizational Commitment</td>
<td>0.006471</td>
<td>0.007822</td>
<td>0.547294</td>
<td>8</td>
</tr>
<tr>
<td>Worker experience and skill</td>
<td>0.006287</td>
<td>0.007439</td>
<td>0.54196</td>
<td>9</td>
</tr>
<tr>
<td>Construction schedule (Duration)</td>
<td>0.009948</td>
<td>0.011549</td>
<td>0.537243</td>
<td>10</td>
</tr>
<tr>
<td>Prevention of intoxication on site</td>
<td>0.010288</td>
<td>0.011843</td>
<td>0.535138</td>
<td>11</td>
</tr>
<tr>
<td>Per day working hours of workers</td>
<td>0.007888</td>
<td>0.007288</td>
<td>0.480232</td>
<td>12</td>
</tr>
<tr>
<td>First Aid Measure</td>
<td>0.008972</td>
<td>0.007093</td>
<td>0.441518</td>
<td>13</td>
</tr>
<tr>
<td>Protective Equipment</td>
<td>0.006563</td>
<td>0.003465</td>
<td>0.345511</td>
<td>14</td>
</tr>
</tbody>
</table>

**DISCUSSION**

The analysis revealed some interesting aspects related to the perceptions of the managers and workers towards construction safety in Indian construction scenario. All the parameters in the survey are regarded important in the extant literature. However, the rankings obtained from the analysis illustrate the relative importance attributed to these factors by the managers and construction workers in India.

From the managers' view point, the results indicate a mix of both lagging and leading indicators in terms of safety culture. The managers considered that the buy-in of the top management in accepting safety as a key goal in the organization and emphasizing safety as equally important objective compared to time and cost on a project is paramount. The top management awareness is key to streamline the processes and the systems from a safety perspective. The managers felt this parameter is important as the management provides consistent safety policy across construction projects which are separated
spatially and temporally. Thus the top management awareness could help in having consistent safety management systems in an organization. This confirms the findings that if top management is aware about safety and management involvement results in positive impact on construction workers' safety behaviour as reported by Zhang et al., (2016).

Table 3: Ranking of parameters from workers' perspective

<table>
<thead>
<tr>
<th>Parameters for Workers</th>
<th>$S_i+$</th>
<th>$S_i-$</th>
<th>$P_i$</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Protective Equipment</td>
<td>0.000459</td>
<td>0.002001</td>
<td>0.813395</td>
<td>1</td>
</tr>
<tr>
<td>Injury Record</td>
<td>0.002066</td>
<td>0.003579</td>
<td>0.633975</td>
<td>2</td>
</tr>
<tr>
<td>New Employee Orientation</td>
<td>0.002191</td>
<td>0.003652</td>
<td>0.625</td>
<td>3</td>
</tr>
<tr>
<td>First Aid Kit</td>
<td>0.002589</td>
<td>0.003662</td>
<td>0.585786</td>
<td>4</td>
</tr>
<tr>
<td>Job Related Training</td>
<td>0.003871</td>
<td>0.005442</td>
<td>0.584367</td>
<td>5</td>
</tr>
<tr>
<td>Fire Extinguisher Training</td>
<td>0.005929</td>
<td>0.008148</td>
<td>0.578835</td>
<td>6</td>
</tr>
<tr>
<td>Fall Protection System</td>
<td>0.00242</td>
<td>0.003247</td>
<td>0.572949</td>
<td>7</td>
</tr>
<tr>
<td>Fire Alarm System</td>
<td>0.005875</td>
<td>0.007765</td>
<td>0.569265</td>
<td>8</td>
</tr>
<tr>
<td>Personal Protective Equipment Training</td>
<td>0.002759</td>
<td>0.003507</td>
<td>0.559661</td>
<td>9</td>
</tr>
<tr>
<td>Regular Disposal Of Waste and Trash</td>
<td>0.002716</td>
<td>0.003136</td>
<td>0.535898</td>
<td>10</td>
</tr>
<tr>
<td>Open Ditches Protection System</td>
<td>0.002827</td>
<td>0.003232</td>
<td>0.533483</td>
<td>11</td>
</tr>
<tr>
<td>Drinking Water Facility</td>
<td>0.006652</td>
<td>0.007533</td>
<td>0.531047</td>
<td>12</td>
</tr>
<tr>
<td>Safety Signs</td>
<td>0.004639</td>
<td>0.005129</td>
<td>0.525063</td>
<td>13</td>
</tr>
<tr>
<td>Safety Meetings</td>
<td>0.003124</td>
<td>0.00332</td>
<td>0.515165</td>
<td>14</td>
</tr>
<tr>
<td>Emergency Contact Numbers</td>
<td>0.004859</td>
<td>0.004859</td>
<td>0.5</td>
<td>15</td>
</tr>
<tr>
<td>Dust Protection System</td>
<td>0.004859</td>
<td>0.004859</td>
<td>0.5</td>
<td>16</td>
</tr>
<tr>
<td>Stability Of Material In Storage</td>
<td>0.00506</td>
<td>0.004789</td>
<td>0.462287</td>
<td>17</td>
</tr>
<tr>
<td>Sanitary Facility</td>
<td>0.005263</td>
<td>0.004727</td>
<td>0.460971</td>
<td>18</td>
</tr>
<tr>
<td>Storage Of Flammable Liquid</td>
<td>0.005635</td>
<td>0.004845</td>
<td>0.460971</td>
<td>19</td>
</tr>
<tr>
<td>Well Defined Traffic Route</td>
<td>0.005553</td>
<td>0.004749</td>
<td>0.460971</td>
<td>20</td>
</tr>
<tr>
<td>Housekeeping</td>
<td>0.004166</td>
<td>0.002881</td>
<td>0.408831</td>
<td>21</td>
</tr>
</tbody>
</table>

The results from data analysis are Top management awareness, Penalty for safety non-compliance, and Communication with stakeholders from a manager’s perspective (See Table 2); whereas provision of personal protective equipment, keeping an injury record, and new employee orientation (See Table 3) are the paramount according to the worker’s perspective and need to be focusses more on the construction site for enhancing the safety performance. The top 3 parameters which were considered important by management and workers are discussed in next section.

When it comes to workers' role in safety, the managers felt the imposing stringent penalties on unsafe behaviour will offer sufficient deterrence to unsafe practices thus reinforcing safety culture on sites. The general notion is that the workers become concerned about safety when the financial penalties resulting in salary cuts were imposed. This parameter indicates the attitude of the management towards the workers on construction sites in India. While the managers feel the need for a strong pro-active leading measure like good top management awareness as important when the relationship with their superiors in the organization are concerned, they resort to lagging indicators as
important while dealing with their reports in an organizational structure. The results point out to this disciplining behaviour on the bottom part of the organizational hierarchy as a key finding in the Indian safety culture. Thirdly, the managers felt the sufficient channels of communication should be present to understand the concerns of the stakeholders. This indicates a healthy leading pattern to safety culture. But, further discussions with the managers indicated that the communication channels were predominantly needed by them to convey their concerns to top management and discipline their reports. Hence, again the results point to the hierarchical pattern of safety culture in Indian context where the managers rely predominantly on disciplinary measures using lagging indicators on the workers to achieve construction safety compliance.

On the other hand, workers' perspective revealed the importance of defence mechanisms as well as both leading and lagging measures to ensure safety. The use of PPE was found to be paramount. This shows the general maturity of safety on Indian construction sites where the PPE are increasingly becoming mainstreamed across construction sites. However, it is interesting to note that PPE form least priority to managers thus indicating some disconnect with the needs of the workers and aspirations of the managers. The maintenance of injury records was considered the second most important factor by the worker. This lagging factor of safety indicates some interesting dynamics in the Indian safety culture. First, it indicates the element of mistrust between the workers and management where the workers suspect the management is not presenting a real scenario of safety on site. Second, it also indicates the intellectual appetite of the workers to understand and assess the hazards involved in the various activities and urge to analyse the root causes to educate the co-workers for possible remedial actions. Finally, the workers felt that the leading measure like new employee orientation is a key element to safety on the site. The result supports the finding of previous studies that indicates higher engagement of safety training is associated with higher level of hazard recognition (Namian et al., 2016). This ranking preference indicates the inclination of the workers to a more pro-active association with construction safety than being disciplined by the management.

Thus comparing the priorities of the managers to that workers reveal some interesting trends about the maturity of safety culture in Indian construction sites. Also, the results also support that managers and workers do not tend to share the same safety perception reported by Hallowell (2010). The Indian construction industry is progressing on the path to safety where the PPE became a norm and demanded by the workers themselves. Thus, the provision of PPE has reduced in its priority to managers as it is mainstreamed. The managers are now concentrating of infusing safe worker behaviour on construction sites. Whereas, the workers want a more pro-active role in ensuring safe working conditions. The organizational hierarchical systems of safety management which relies on awareness of upper levels of management and disciplining of lower levels is prevalent at present in the Indian construction industry. However, the present study is limited by the number of responses collected.

**CONCLUSION**

The current research identified the perspective of workers and managers for safe construction sites by performing questionnaire survey. Use of personal protective equipment, keeping an injury record, and new employee orientation are paramount from the worker’s perspective. Top management awareness, penalties for safety non-compliance and communication with the stakeholders are considered to be important by management. These results indicate the dynamics of the safety culture in a developing
country like India. The maturity levels in terms of using of PPE is now existing across the country and thus has dropped down the list of priorities from a manager's perspective. The safety culture right now can be classified as highly hierarchical system which bases compliance on disciplinary actions rather than proactive involvement of the construction workers. Further studies are required to confirm the trends and understand the implications of such safety culture on the worker behaviour in construction sites.

REFERENCES


SAFETY LEADERSHIP IN THE CONSTRUCTION INDUSTRY: WHAT IS MISSING?

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\textsuperscript{2} Department of Civil & Environmental Engineering, University of Maryland, College Park, Maryland 20742, USA.

Although research has shown that safety leadership is a strong predictor of safety outcomes in the construction industry, the factors that affect safety leadership are under-explored. Consequently it is unclear how to develop effective interventions to promote safety leadership. This paper addresses this void by adopting the Job Demand-Resource (JD-R) model grounded in positive psychology to examine how organisational and personal factors influence construction leaders’ engagement in safety leadership. Based on the JD-R model, the study investigates how risk perception, work autonomy, social support, and psychological capital (PsyCap) could affect leaders’ engagement in safety leadership. The model was tested using survey data from 383 construction leaders in a large U.S. construction firm. Structural equation modelling showed that work engagement significantly influences safety leadership, while psychological capital (PsyCap), social support, work autonomy, and risk perception significantly contribute to work engagement. These results indicate that the JD-R model can be extended to study safety leadership, and work engagement on safety leadership can be improved by enhancing organisational and personal resources. The limitations, needed future research, and practical implications conclude the article.

Keywords: safety leadership, job-demand resources model, psychological capital, SEM

INTRODUCTION

Given the high financial and human costs involved in occupational injuries, researchers have devoted considerable effort to studying workplace safety. They have repeatedly pointed out that safety leadership is a critical factor affecting safety performance (e.g., Flin and Yule, 2004). Although ample research has been conducted on safety leadership, few attempts have been made to understand how organisational and personal factors can affect construction leaders’ engagement in this role (Conchie \textit{et al.}, 2013). This knowledge gap could seriously hinder us from developing effective interventions for developing effective safety leadership.

In general, safety leadership is defined as leaders’ positive behaviour in handling organisational safety issues (e.g., Slates, 2008), which in turn is regarded as a positive organisational behaviour. Models relating job-related and personal factors to positive organisational behaviour are prevalent (e.g., Bakker and Demerouti, 2007). The job-demand resources (JD-R) model in Figure 1 is one of the well-established models that serves this purpose. Yet, little attention has been given to apply such a model in studying the potential factors affecting safety leadership.

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This paper aims to use the JD-R model framework to model how psychological capital (PsyCap), work autonomy, social support, and risk perception may affect construction leaders’ engagement in safety leadership.

JOB-DEMANDS-RESOURCES (JD-R) MODEL

Although the JD-R model contains of two psychological processes, work engagement and strain, to generate personal or organisational outcomes, this paper focuses on looking into the path of work engagement as it leads to positive organisational behaviours. In the work engagement process, the JD-R model assumes that positive work behaviours result from work engagement, while work engagement is affected by job-related and personal factors (Schaufeli and Taris, 2014). Work engagement is the centrepiece of the model. It is a psychological state that captures a positive, fulfilling, and work-related state of mind, resulting in various work behaviours. In particular, it is characterized by vigor, dedication, and absorption. ‘Vigor’ refers to having high energy levels and mental resilience during work. ‘Dedication’ is characterized by having a strong involvement in one’s work and experiencing a sense of significance, enthusiasm, inspiration, pride, and challenge; and ‘absorption’ refers to being totally concentrated on and happily engrossed in one’s work while time passes quickly, and one has difficulties in detaching oneself from work (Schaufeli and Bakker, 2004).

For job-related factors, the model categorizes them into the two types: job demands and job resources (Schaufeli and Bakker, 2004). Job demands refers to “physical, psychological, social, or organisational aspects of the job that require sustained physical and/or psychological (cognitive and emotional) effort or skills and are therefore associated with certain physiological and/or psychological costs” (Demerouti and Bakker, 2011: 2). On the contrary, job resources refer to “those physical, psychological, social, or organisational aspects of the job that are: (1) functional in achieving work goals; (2) reduce job demands and the associated physiological and psychological cost; or (3) stimulate personal growth, learning, and development” (Demerouti and Bakker, 2011: 2). In addition, the JD-R model assumes that each individual possesses different levels of personal resources that help him or her to control and impact his or her environment successfully (Xanthopoulou et al., 2007).

Specifically, the model depicts job and personal resources have motivational potential and thus lead to high work engagement and positive behaviours in one hand. On the other hand, job demands plays a negative role in this motivational process because they could lead to exhaustion and excessive stress, which deplete one’s energy and capacity to engage in work. Although safety leadership is regarded as a positive organisational behaviour, its antecedents have not been considered for study using the JD-R model. We believe that this study is the first empirical test whether work engagement processes relating to safety could be explained by the JD-R model. Figure 1 depicts the work engagement path in the JD-R model.

SAFETY LEADERSHIP

As one of the positive organisational behaviours, safety leadership is generally defined as leadership behaviour that has positive impact on employees’ safety behaviour. Specifically, the two most studied leadership styles in the safety leadership literature are transactional and transformation leadership. Transactional leadership refers to the use of rewards and punishment to motivate followers (Podsakoff et al., 1982), while transformational leadership refers to employing influence and enthusiasm to motivate followers to work for the benefit of an organisation (Bass, 1990). This study focuses on
transformational leadership, or more precisely, safety-specific transformational leadership (SSTL), because it is a more predictable indicator of safety outcomes than transactional leadership in the construction industry (Hoffmeister et al., 2014). SSTL refers to transformational leadership behaviours that specifically promote and develop a safe work environment.

**Figure 1** Job-demands resources (JD-R) model based on Bakker and Demerouti (2008)

**APPLY THE JD-R MODEL TO SAFETY LEADERSHIP**

**Relationship of Job Resources to Work Engagement**

The JD-R model proposes that higher levels of job resources evoke a motivational process that leads to higher levels of work engagement, and vice versa. This study looks at how job resources, work autonomy and social support, could affect construction leaders’ engagement in SSTL. Work autonomy and social support are the two most frequently examined job resources in the JD-R model. Work autonomy refers to the extent that an individual feels in control of the ways to get his or her job done (Breaugh, 1999). Social support can come from co-workers, supervisors and top management. In fact, work autonomy and social support are also found to promote safety in general, such as lower accident rates, taking safety responsibilities, and properly handling safety risk (e.g., Grote and Künzler, 2000). Based on the above insights from the research reviewed in mind, this study hypothesises that work autonomy and social support are key job resources positively associated with work engagement.

*Hypothesis 1a:* Work autonomy is positively correlated with work engagement.

*Hypothesis 1b:* Social support is positively correlated with work engagement.

**Moderating Role of Personal Resources on Job Resources and Work Engagement**

In the JD-R model, personal resources are generally considered as a mediator Xanthopoulou et al., (2007) or moderator (Van den Broeck et al., 2011) affecting the relationship between job resources and work engagement. This study focuses on the moderation effect of personal resources. Specifically, it examines how personal resources, psychological capital (PsyCap), could moderate the association between job resources (work autonomy and social support) and work engagement.

PsyCap has emerged as an important personal resources studied in positive organisational behaviour (Donaldson and Ko, 2010). It is a high-order construct that consists of four psychological resources, namely hope, optimism, resilience, and self-efficacy (Luthans et
A person high in PsyCap is characterized as: (1) having the confidence (self-efficacy) to put in necessary effort to complete challenging tasks; (2) making positive attributions (optimism) about succeeding now and in the future; (3) persevering toward goals, and redirecting paths to goals (hope) in order to succeed whenever necessary; and (4) bouncing back and even beyond original states (resilience) to achieve success when encountering adversity.

**Hypothesis 2a:** PsyCap moderates the relationship between work autonomy and work engagement.

**Hypothesis 2b:** PsyCap moderates the relationship between social support and work engagement.

**Relationship of Job Demands to Work Engagement**

The JD-R model proposes that high levels of job demands could develop excessive job stress, and thus lead to depletion of one’s work engagement. In the JD-R model, risk perception is regarded as a source of job demands because it could be a significant work stressor that causes burnout and disengagement in workplace (Nahrgang et al., 2011; Nielsen et al., 2011). Risk perception is generally defined as the perceived likelihood that an individual will experience the effect of danger and the severity of the danger (Short, 1984). Indeed, risk perception is also considered as a significant work stressor in the construction industry (Perlman et al., 2014). Based on the JD-R model, this study hypothesised that risk perception is negatively correlated with work engagement. In other words, when construction leaders’ experience high levels of risk perception, they may become so overwhelmed and experience excessive stress that in turn leads to lower their engagement level.

**Hypothesis 3:** Risk perception is negatively correlated with work engagement.

**Relationship of Work Engagement to Safety-Specific Transformational Leadership (SSTL)**

In the motivational process of the JD-R model, work engagement is positively associated with positive behaviours. As previously discussed, safety-specific transformational leadership (SSTL), is generally defined as leaders’ positive behaviour in handling organisational safety issues (e.g., Slates, 2008), which in turn is regarded as a positive organisational behaviour. Thus, this study hypothesised that work engagement is positively associated with SSTL. Figure 2 is the proposed theoretical model that summarises the above hypothesised relationships.

**Hypothesis 4:** Work engagement is positively correlated with SSTL.

**METHOD**

**Sample and Procedure**

The study took place in a large privately owned construction company in the United States. In October 2016, an online survey was sent to all of the company’s 639 in management positions. A total of 386 questionnaires were returned, thus producing a response rate of 60%. Deletion of missing values and unengaged responses resulted in a usable sample of 383 employees (60%), of which 90% (N=345) were male. With respect to race, this sample was predominantly white (89%, N=340), with a few Asian (1%, N=4), Black (2%, N=7), Hispanic (5%, N=21), and unknown (3%, N=11) respondents. The workforce was relatively experienced with 72% (N=274) having worked in the construction industry for over ten years. Regarding job status, all participants are in
managerial level positions with job titles distributed as follows: construction executive (4%, N=14), director (1%, N=2), executive (2%, N=7), manager (2%, N=6), project executive (10%, N=40), project manager (20%, N=77), safety director (1%, N=4), safety manager (4%, N=17), senior project manager (15%, N=59), senior safety manager (3%, N=13), senior superintendent (7%, N=25), senior vice president (3%, N=11), superintendent (18%, N=69), and vice president (10%, N=39).

Figure 2. Proposed Theoretical Model

Measures

The theoretical model shown in figure 1 contains six variables. Each of them was measured by specific and existing measurement scales as shown in Table 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Name of construct</th>
<th>No. of questions</th>
<th>Point of Scales</th>
<th>Sample questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Social support</td>
<td>Management Attitude Toward Safety Scale, Mueller et al. (1999)</td>
<td>9 (3 dimensions: top management, supervisor and co-workers)</td>
<td>5-point scale (‘strongly disagree’ to ‘strongly agree’)</td>
<td>“Top management seems to care about my safety”; “My supervisor seems to care about safety”; “People in my work group emphasize working safely and make sure others do the same.”</td>
</tr>
<tr>
<td>2. Work autonomy</td>
<td>Work autonomy scale, Breughe (1999)</td>
<td>3</td>
<td>5-point scale (‘never’ to ‘always’)</td>
<td>“I am allowed to decide how to get about getting my job done.”</td>
</tr>
<tr>
<td>3. Psychological Capital</td>
<td>Psychological Capital Questionnaire, Luthans et al. (2007)</td>
<td>24</td>
<td>6-point scale (‘strongly disagree’ to ‘strongly agree’)</td>
<td>“At the present time, I am energetically pursuing my work goals”; “I feel confident presenting information to a group of colleagues”; “I can get through difficult times at work”; “when things are uncertain for me at work I expect the best.”</td>
</tr>
<tr>
<td>4. Work Engagement</td>
<td>Utrecht engagement scale, Schaufel (2002)</td>
<td>9 (3 dimensions: vigor, dedication, and absorption)</td>
<td>7-point scale (‘never’ to ‘always’)</td>
<td>“At my work, I feel energetic”; “My job inspires me”; “Time flies when I am working.”</td>
</tr>
<tr>
<td>5. Safety-Specific Transformational Leadership</td>
<td>Safety-specific transformational leadership scale, Barling (2002)</td>
<td>10</td>
<td>5-point scale (‘not at all’ to ‘always’)</td>
<td>“I show determination to maintain a safe work environment.”</td>
</tr>
<tr>
<td>6. Risk perception</td>
<td>Risk perception attitude framework, Rimal and Rea (2003)</td>
<td>2</td>
<td>5-point scale (‘not at all likely’ to ‘completely likely’)</td>
<td>“The likelihood of getting injured at work is...”</td>
</tr>
</tbody>
</table>

Control Variables

In line with previous research on work engagement and safety leadership, gender and work tenure in the construction industry were used as the control variables.
Analysis

Structural equation modelling techniques was used to test the hypotheses. The first step involved validating the reflective measurement model using an exploratory factor analysis in SPSS 24 and then a confirmatory factor analysis in AMOS 24. The final step involves creating composite variables from latent variable scores in AMOS to test the structural model.

RESULTS

Measurement Model

Exploratory (EFA) and confirmatory (CFA) factor analysis (using Maximum Likelihood) were conducted to establish the reliability and validity of the construct measurements. All loadings in the pattern matrix were above the 0.300 threshold recommended by Hair et al., (2013) with sample size greater than 350. All Cronbach’s alphas are above the recommended threshold of 0.700 for factor reliability (Fornell and Larcker, 1981). The total variance explained was 59.13% for the 12-factor model. The CFA confirmed the factor structure established during the EFA and provided additional measures for validity and reliability. To establish convergent validity, the AVEs should be greater than 0.500 (Kline et al., 2012). All factors, except for SSTL (which is right on the border at 0.406), meet the threshold. Although SSTL is below the recommended threshold, the factor was remained as it met the criteria for discriminant validity and reliability. To establish discriminant validity, the square root of the AVE should be less than any correlation with another factor. All of the factors achieve this criterion. Table 2 presents the correlations between factors, the AVE (average variance extracted) and CR (composite reliability).

Table 2. Construct correlation matrix

<table>
<thead>
<tr>
<th></th>
<th>CR</th>
<th>AVE</th>
<th>Risk</th>
<th>SSTL</th>
<th>WA</th>
<th>EG</th>
<th>PsyCap</th>
<th>SS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk</td>
<td>0.747</td>
<td>0.599</td>
<td>0.774</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSTL</td>
<td>0.869</td>
<td>0.405</td>
<td>0.169</td>
<td>0.636</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WA</td>
<td>0.593</td>
<td>0.824</td>
<td>0.102</td>
<td>0.419</td>
<td>0.908</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EG</td>
<td>0.502</td>
<td>0.566</td>
<td>0.013</td>
<td>0.433</td>
<td>0.423</td>
<td>0.752</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PsyCap</td>
<td>0.855</td>
<td>0.598</td>
<td>0.213</td>
<td>0.470</td>
<td>0.543</td>
<td>0.721</td>
<td>0.773</td>
<td></td>
</tr>
<tr>
<td>SS</td>
<td>0.837</td>
<td>0.632</td>
<td>0.232</td>
<td>0.392</td>
<td>0.423</td>
<td>0.487</td>
<td>0.510</td>
<td>0.795</td>
</tr>
</tbody>
</table>

Table 3. Model fit of the measurement

The goodness of fit statistics of the final measurement model is in Table 3. All thresholds from Hu and Bentler (1999) are met indicating that sufficient model fit is achieved.

Structural Model

To test the hypotheses in the structural model, the structural model fit statistics was firstly test, and then the hypothesised dependence relationships were examined using p-values.
and R squares. The structural models achieved adequate goodness of fit, CFI (Comparative fit index) = 0.972; GFI (Goodness of fit index) = 0.969; SRMR (Standardized Root Mean Square Residual) = 0.048. The total variance explained is satisfactory for the endogenous variables: $R^2$ is 72% for work engagement, and is 24% for SSTL.

Four of the six hypotheses were significant. The positive effect of social support (H1a) on work engagement was significant. The interaction effect of PsyCap (H2a) on the relationship between social support and work engagement was significant. As what was expected, risk perception (H3) has significant negative effect on work engagement. Finally, the positive effect of work engagement on SSTL was significant. Table 4 summarizes these findings.

**Table 4. Summary of hypothesis testing**

<table>
<thead>
<tr>
<th>Factors/constructs</th>
<th>Standardized Beta</th>
<th>p-value</th>
<th>Hypotheses Testing Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engagement $\leftarrow$ Social Support</td>
<td>0.118</td>
<td>0.001</td>
<td>H1a: positive relationship (accepted)</td>
</tr>
<tr>
<td>Engagement $\leftarrow$ Work_Autonomy</td>
<td>-0.081</td>
<td>0.021</td>
<td>H1b: positive relationship (rejected)</td>
</tr>
<tr>
<td>Engagement $\leftarrow$ PsyCap $\times$ Social Support</td>
<td>-0.156 ***</td>
<td></td>
<td>H2a: interaction effect (accepted)</td>
</tr>
<tr>
<td>Engagement $\leftarrow$ PsyCap $\times$ Work_Autonomy</td>
<td>0.070</td>
<td>0.078</td>
<td>H2b: interaction effect (rejected)</td>
</tr>
<tr>
<td>Engagement $\leftarrow$ Risk_Perception</td>
<td>-0.136 ***</td>
<td></td>
<td>H3: negative relationship (accepted)</td>
</tr>
<tr>
<td>SSTL $\leftarrow$ Engagement</td>
<td>0.454 ***</td>
<td></td>
<td>H4: positive relationship (accepted)</td>
</tr>
</tbody>
</table>

*** p < 0.001

**DISCUSSION**

The SEM results indicate that the JD-R model could be extended to explain SSTL. In particular, work autonomy, social support, PsyCap, and risk perception could act through work engagement, and influence SSTL. Unexpectedly, contrary to the proposed positive relationship, there was a small negative correlation between work autonomy and work engagement. One possible explanation is that the effects of work autonomy and work engagement might be contingent on personal factors. For example, previous study suggested that individuals who have higher levels of personal resources such as self-efficacy perceive their job resources more positively thus leading to higher levels of work engagement (Lorente et al., 2014).

**Theoretical Implications**

The findings of our research have theoretical implications for both the JD-R model and occupational safety research. First, our findings provide empirical support for the applicability of the JD-R model to safety leadership. Furthermore, while personal resources was added to the JD-R model in recent years (Bakker and Demerouti, 2008), researchers are still not clear on how to integrate this factor into the model. In particular, there is relatively little research on the moderation effects of personal resources in JD-R research (Bakker and Sanz-Vergel, 2013). PsyCap has emerged as the most important measure of personal resources studied in the positive organisational behaviour literature.

Second, the study found that work engagement plays an important role in safety leadership, while PsyCap, social support, work autonomy, and risk perception contribute significantly to work engagement. These are valuable discoveries because they provide us with the insights into what affecting safety leadership that are missing in the field.
Last but not least, PsyCap and social support were found to have a substitute interaction effect on construction leaders’ work engagement. To our knowledge, this is a new finding in the construction research. Indeed, the 3D Function Grapher (Kaskosz, 2004) was used to plot the interaction effect in three dimensions (see figure 2). Based on figure 2, the study found that the marginal benefit of improving PsyCap is higher than social support in terms of work engagement. Moreover, when the level of social support increases, individuals who are high in PsyCap become less engaged in work. This insight is similar to the finding of the social support research in social psychology (e.g., Howland and Simpson, 2010). Studies base in that discipline have found that receiving social support entails emotional costs like inefficacy and indebtedness. Thus, the benefits of social support may be maximized when it is given invisibly. Likewise, the emotional costs imposed by social support might be the reason why people become less engaged at work when they receive a higher level of social support. Thus, future research can further investigate how invisible support affects work engagement.

![Figure 2: Interaction effect of PsyCap on social support and work engagement](image)

**Practical Implications**

The results of the study have some practical implications on training and management. First, the substitute interaction effect between PsyCap and social support on work engagement means engagement can be improved by allocating resources to either improve social support or provide training to improve PsyCap. Second, based on figure 2, a 3-D representation of the interaction effect of PsyCap and support on work engagement, the study found that the marginal growth of work engagement is higher when improve PsyCap instead of social support is improved. This could indicate that managers should focus their resources on PsyCap training in order to obtain optimal levels of engagement. Finally, similar to previous research findings, the results confirmed the negative relationship between risk perception and work engagement, while work engagement is positively related to safety leadership. In other words, when leaders encounter an increasing level of risk perception, his engagement in safety leadership diminishes, which could result in more occupational accidents and fatalities taking place. One solution to it could be controlling risk perception through various safety programs and thereby improve their overall impression of safety and their skills in handling safety issues.
LIMITATIONS AND FUTURE RESEARCH
Although the research provides a number of important insights, it has some limitations. First, the use of a cross-sectional design limits causal inferences based on the data. A longitudinal or experimental design is needed in future studies in order to differentiate such causal relationships. Second, the study is based on self-reporting measures. This could raise the possibilities of having common method bias. Although the research design and analysis process did impose different measures to control for this, it is recommended that future studies to use multiple sources for each data point in order to address this issue. Finally, our study focused on the construction industry, and so it is unclear whether the findings can be generalized to other context.

CONCLUSIONS
The majority of safety leadership studies have focused on how safety leadership affects safety performance and safety climate. The current study adopted a different focus and concentrated on studying what factors affect safety-specific transformational leadership by using the JD-R model as the framework. The results showed that JD-R model can be extended to explain safety leadership. Specifically, work engagement plays an important role in safety leadership, while PsyCap, social support, work autonomy, and risk perception contribute significantly to work engagement.

REFERENCES
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Cheung and Cui


HAPPINESS FOR PROJECT MANAGERS: FRAMEWORK AND EMPIRICAL ANALYSIS

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In the past decade, organisations and governments have become increasingly interested in measuring how people feel, such as 'Happy Planet Index', 'the Well-Being index' and 'Gross National Happiness'. Indeed, practitioners and researchers have found that happiness, subjective well-being, is a strong predictor of various work outcomes including job performance, employee retention, workplace accidents, absenteeism, customer engagement, and profitability. To improve the levels of happiness, models were developed to examine antecedents of happiness; however, very few have focused on studying project managers (PMs), who play important roles in driving project success in the sector like construction. This study addresses this limitation by investigating the relationships among organisational factors, personal resources, and PM levels of happiness. Self-reported data was collected from 227 project management professionals, and was analysed using structural equation modelling. The results suggested a seven-factor PMs' happiness model. In particular, the mediating role of personal growth, positive work relationships, and meaningful work in the relationship between work environment and happiness at work was supported. In addition, work environment and meaningful work were found to be strong predictors of PM's happiness.

Keywords: subjective well-being, happiness, structural equation modelling

INTRODUCTION

In the past decade, organisations and governments have become increasingly interested in measuring how people feel, such as 'Happy Planet Index', 'the Well-Being index' and 'Gross National Happiness'. In 2006, the New Economics Foundation (NEF), a British think-tank, introduced the Happy Planet Index to measure human well-being globally. In 2008, Gallup, Inc., an American multinational consulting company initiated the Well-Being Index to provide an in depth and nearly real-time view of Americans' well-being. In 2010, the British government announced to measure the happiness levels of the country which is called 'Goss National Happiness' as part of a £2 million a year well-being project. Since then, an annual national happiness report has been published to guide the public policy making process. These moves recognise that happiness, subjective well-being, is as important as economic growth and prosperity to make human flourishing. In fact, practitioners and researchers have found that happiness is a strong predictor of various work outcomes including job performance, employee retention, workplace accidents, absenteeism, customer engagement, and profitability (e.g., Fisher, 2010; Pryce-Jones and Lindsay, 2014; Lyubomirsky et al., 2005). In this paper, happiness, happiness at work and subjective well-being were used interchangeably.

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To improve levels of subjective well-being, models have been mainly developed in the field of occupational health and psychology to examine antecedents of happiness. However, very few of them have focused on studying project managers (PMs), who play important roles in driving project success in the sector like the construction industry. Eaves et al., (2016), James et al., (2012); Love and Edwards (2005) tried to narrow such a knowledge gap by studying the factors affecting well-being of construction workers and project managers; however, they all simply reduced the concept of happiness to health, job satisfaction and work-life balance. These studies, as a result, may provide an incomplete picture on what leads to happiness of project managers. This paper addresses this limitation by investigating how previously identified antecedents - including work environment, personal resources, meaningful work, work-life balance, personal development, and positive work relationship could possibly explain project managers' happiness at work in a more holistic definition.

**Definition of Happiness**

Based on previous literature, happiness has been viewed through two general perspectives: a hedonic approach or a eudaimonic approach. Hedonic happiness refers an abiding sense of satisfaction with life by the individual considering overall and domain-specific life experiences (Ryan and Deci, 2001; Ryff and Singer, 2008). In the hedonic view of happiness, life satisfaction is accompanied by new positive emotional experiences over time, meaning that the individual experiences more positive than negative emotions in their life (Diener, 2000). The second major view on happiness, the eudaimonic view, is concerned with the individual living a good life in a moral sense, being true to themselves, acting morally, doing meaningful activities, and growing as a person.

Diener and Seligman (2002) combined these two views of happiness into one, noting that hedonic happiness, while necessary, is limited by genetic inheritance and subject to the hedonic treadmill (the highs and lows of hedonic happiness are transitory). He postulates that hedonic happiness is insufficient and authentic happiness is derived by the partnering of hedonic and eudaimonic happiness. Eudaimonic happiness is not limited by genetically inherited predispositions to the experience of the vital yet transitory pleasant emotions that are definitive of hedonic happiness. There are also no limits to the experience of eudaimonia through work that is congruent with the self-actualization of the individual, attainment of important self-set goals, and contributing to the greater good.

Happiness at work is often conceptualized as transient and measured on the person level or unit level (Fisher 2010). Transient happiness-related constructs include: transitory affect and mood as well as state affect, flow, mood, engagement, task engagement, and intrinsic motivation. Person level happiness includes physical and emotional health, engagement, job involvement, job satisfaction, and personality-based predispositions. At the unit level, the happiness of teams, organizations, and other work units frequently encompasses group level engagement, morale, satisfaction, emotional tone, and mood. Happiness at work is the result of the individual, the work, and the social environment (the team and the organization as a whole) (McNulty 2012).

**THE HAPPINESS MODEL AND HYPOTHESES**

This section outlines the rationale for developing a theoretical model of happiness for project managers. The model is presented in Figure 1 below. Work environment and personal resources have been consistently shown to have a significant influence on an individual's happiness (e.g., Chaiprasit and Santidhiraku, 2011; Culbertson et al., 2010; Fisher, 2010). Although happiness as described above relates to the individual, the
environment in which people work more broadly has an impact on their ability to experience happiness (Deci and Ryan, 2008). For instance, by working in a healthy, respectful, and supportive work environment, individuals tend to get more positive affective experiences in the workplace (Warr, 2011). While work environment could provide a stage for people to experience happiness at work, each individual could obtain different levels of happiness based on their levels of personal resources such as confidence, optimism, and vitality. For example, optimistic people tend to define their positive experiences at work as permanent events, while pessimistic people are likely to define positive experiences as something temporary. Optimistic individuals thus could experience higher levels of happiness than pessimistic people do. For these reasons, in the model work environment and personal resources are hypothesised as positively related to happiness at work.

Hypothesis 1: Work environment is positively related to happiness at work for project managers.

Hypothesis 2: Personal resources are positively related to happiness at work for project managers.

Fig 1. Proposed Theoretical Model

Although previous literature showed that work environment and personal resources are related to happiness, limited research has examined the factors that mediate such relationships. To narrow this knowledge gap, in this model personal growth, meaningful work, positive work relationships, and work-life balance were examined as the mediators that may explain the effect of work environment and personal resources on happiness at work.

Personal growth is a process of developing one's potential to grow and learn new knowledge and skills in a workplace (Irving and Williams, 1999). Both work environment and personal resources have a leading role in this process. For instance, in a supportive work environment, individuals are likely to receive training for developing necessary skills to do their job. Moreover, individuals with high levels of personal resources such as vitality tend to mobilize their energy better in order to achieve personal growth (Kashdan et al., 2004). In turn, personal growth could drive happiness at work if for no other reason than that it enhances one's capabilities to achieve his or her performance goals, and thus get higher levels of job satisfaction. In summary, the positive effect that work environment and personal resources have on happiness at work is explained through personal growth.

Hypothesis 3: Personal Growth mediates the effect of work environment on happiness at work for project managers.
Hypothesis 4: Personal Growth mediates the effect of personal resources on happiness at work.

Meaningful work means an individual thinks that her job has a positive impact on others’ lives. Alexander and Douthit (2016) found that when people perceive their organizations to be socially responsible through their work environment, they have a stronger sense of meaning at work. As they feel their job is something meaningful to work on, they feel happier at work (Ryan and Deci, 2001).

Hypothesis 5: Meaningful work mediates the effect of work environment on happiness at work.

Positive work relationships refer to warm and trusting interpersonal relations between an individual and her colleagues. Researchers generally believe that a positive work environment, which contains a high level of trust among co-workers and relatively reduced rate of selfish acts, helps to build better work relationships. With positive work relationships, people tend to have a stronger sense of belonging to the team and organization, which is a significant motivation for human beings, a source of happiness.

Hypothesis 6: Positive work relationships mediate the effect of work environment on happiness at work.

Work-life balance is a state of equilibrium between the demands of work and the demands of family or personal life (Tausig and Fenwick, 2001). Both work environment and personal resources help to achieve work-life balance. Lambert et al., (2006) found that autonomy and flexibility at work help in realizing work-life balance. In addition, according to Kirchmeyer (2002), to achieve work-life balance, personal resources such as vitality, time, and commitment are required to be well distributed across all life domains. When individuals are able to maintain a work-life balance, they are less likely to get overstressed, while they are more likely to enjoy their work and thus feel happy about what they do (Nordenmark et al., 2012)

Hypothesis 7: Work-life balance mediates the effect of work environment on happiness at work.

Hypothesis 8: Work-life balance mediates the effect of personal resources on happiness at work.

METHOD

Participants
The participants were 227 project management professionals attending an annual Project Management Institute (PMI) chapter educational event in Montgomery County, Maryland, USA. They completed the survey online in the fall of 2014 before the event and then attended a debriefing held at the event. The total response rate was 57%. The demographic information of the sample is shown in Figure 2.

Measures
Antecedents of happiness at work were collected using the Happiness at Work Survey (Marks, 2011), which was developed by the New Economic Foundation 12 years ago to measure happiness internationally across different industry sectors. The survey consists of 40 statements to which responses are made on a seven point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree). Some items are negatively worded to balance the questionnaire.
**Analytic strategy**

Structural Equation Modelling (SEM) is ideally suitable to explore theoretical paths of influence among antecedents of happiness at work and testing the theoretical model as a holistic system. The technique has been used on a number of occasions (e.g., de Guzman *et al.*, 2014; Mogilner, 2010; Momeni *et al.*, 2011). SEM was performed using SPSS 24 and AMOS 24.

**Exploratory factor analysis (EFA)**

The factorial structure of the Happiness at Work Survey was tested with raw responses (n=227) to preserve statistical power. Responses to negatively worded states were reverse coded. Maximum Likelihood with Promax rotation was performed using SPSS 24.

**RESULTS**

All loadings were above the 0.400 threshold recommended by Hair *et al.*, (2013) for sample sizes greater than 200. Cronbach's alpha values are reported for each factor in Table 1. All Cronbach’s alpha values are above the recommended threshold of 0.700 for factor reliability (Fornell and Larcker, 1981). The factor analysis identified a seven-factor solution that incorporated 33 survey items and accounted for 58.82% of variance in happiness scores. This was regarded to be a statistically acceptable foundation to test for structural linkages between factors using this data set. During the EFA, some items were dropped due to poor loadings or cross loadings.

The seven factors reflect the underlying dimensions or antecedents of happiness as measured by the Happiness at Work Survey in this study. To interpret and label these factors, a group of human factors experts and practitioners were given the relevant questions grouped as factors and asked to provide a unifying label for each factor. A thematic analysis was then conducted to generate a set of generally accepted factor labels. The resulting factor labels are presented as Table 1, along with example questions and the proportion of total variance accounted for by each factor.

---

*Fig 2 Demographics of sample*

All loadings were above the 0.400 threshold recommended by Hair *et al.*, (2013) for sample sizes greater than 200. Cronbach's alpha values are reported for each factor in Table 1. All Cronbach’s alpha values are above the recommended threshold of 0.700 for factor reliability (Fornell and Larcker, 1981). The factor analysis identified a seven-factor solution that incorporated 33 survey items and accounted for 58.82% of variance in happiness scores. This was regarded to be a statistically acceptable foundation to test for structural linkages between factors using this data set. During the EFA, some items were dropped due to poor loadings or cross loadings.

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Confirmatory factor analysis (CFA)

The CFA confirmed the factor structure established during the EFA and provided additional measures for validity and reliability. The construct correlation matrix in Table 2 offers the correlations between factors, the average variance extracted (AVE), and composite reliability (CR). To obtain convergent validity, the AVEs of each factor should be bigger than 0.500 (Kline et al., 2012). We meet this threshold for all factors. To establish reliability, the CR of each factor should be greater than 0.700. We meet this threshold for all factors. Finally, to achieve discriminant validity, the square root of the AVE should be less than any correlation with another factor. All of the factors achieve this criterion. In addition, the CFA generated the goodness of fit statistics for the final measurement model, including CMIN/df = 2.149, CFI=0.916, and SRMR=0.056. All the statistics met the thresholds from Hu and Bentler (1999).

**Table 1 Happiness factors and example items**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Label</th>
<th>Example item</th>
<th>% total variance</th>
<th>Cronbach's alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Happiness at work</td>
<td>Do you feel happy when you are at work?</td>
<td>34.32%</td>
<td>0.91</td>
</tr>
<tr>
<td>2</td>
<td>Positive work relations</td>
<td>To what extent do you like the people within your team?</td>
<td>4.73%</td>
<td>0.77</td>
</tr>
<tr>
<td>3</td>
<td>Work Environment</td>
<td>Is it safe to speak up and challenge the way things are done within your organisation?</td>
<td>4.81%</td>
<td>0.89</td>
</tr>
<tr>
<td>4</td>
<td>Personal growth</td>
<td>Have you been able to learn new skills at work?</td>
<td>6.40%</td>
<td>0.85</td>
</tr>
<tr>
<td>5</td>
<td>Personal resources</td>
<td>To what extent do you feel full of energy in life?</td>
<td>3.10%</td>
<td>0.80</td>
</tr>
<tr>
<td>6</td>
<td>Work-life balance</td>
<td>Do you feel you have a balance between the time you spend on your work and the time you spend on other aspect of your life?</td>
<td>2.80%</td>
<td>0.74</td>
</tr>
<tr>
<td>7</td>
<td>Meaningful work</td>
<td>Do you think the job you do is beneficial to society in general?</td>
<td>2.60%</td>
<td>0.85</td>
</tr>
</tbody>
</table>

**Structural model**

To test our hypotheses, we analysed our model using AMOS 24. The model achieved adequate goodness of fit: GFI = 0.945, CFI = 0.958; CMI/df = 5.461. The total variance explained is ideal for the endogenous variables in the model: R-squared= 85% for happiness at work. To further test the mediation effects hypothesised in the model, we used Bootstrapping method to do resampling for 2000 times in order to construct a 95 percent confidence interval for detecting the indirect effect.

**Table 2 Construct Correlation Matrix (square root of the AVE on the Diagonal)**

<table>
<thead>
<tr>
<th></th>
<th>CR</th>
<th>AVE</th>
<th>WB</th>
<th>HW</th>
<th>PWR</th>
<th>WE</th>
<th>PG</th>
<th>PR</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work-life balance</td>
<td>0.712</td>
<td>0.601</td>
<td>0.775</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Happiness at work</td>
<td>0.903</td>
<td>0.651</td>
<td>0.371</td>
<td>0.807</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive work relation</td>
<td>0.767</td>
<td>0.528</td>
<td>0.212</td>
<td>0.656</td>
<td>0.727</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work environment</td>
<td>0.891</td>
<td>0.625</td>
<td>0.373</td>
<td>0.754</td>
<td>0.646</td>
<td>0.790</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal growth</td>
<td>0.847</td>
<td>0.582</td>
<td>0.257</td>
<td>0.786</td>
<td>0.673</td>
<td>0.685</td>
<td>0.763</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal resources</td>
<td>0.765</td>
<td>0.540</td>
<td>0.370</td>
<td>0.380</td>
<td>0.193</td>
<td>0.260</td>
<td>0.293</td>
<td>0.735</td>
<td></td>
</tr>
<tr>
<td>Meaningful work</td>
<td>0.858</td>
<td>0.751</td>
<td>0.214</td>
<td>0.699</td>
<td>0.442</td>
<td>0.503</td>
<td>0.580</td>
<td>0.229</td>
<td>0.867</td>
</tr>
</tbody>
</table>

We found support for five of the eight hypotheses. The direct effects of work environment (H1) and personal resources (H2) on happiness at work is significant. Additionally, the bootstrapped indirect effects of H3, H5, and H6 were significant. These
Happiness for Project Managers

indicate that personal growth, positive work relationships and meaningful work mediate the effect of work environment on happiness at work. Figure 3 and table 3 summarizes these findings.

**DISCUSSION**

To understand what predicts happiness at work for project managers, this study examined the factors including work environment, personal resources, personal growth, meaningful work, positive work relationships, and work-life balance. The results showed that all these factors have significant positive effects on project managers' happiness at work. In addition, personal growth, meaningful work, and positive work relationships mediate the effect of work environment on happiness.

![The Structural Model](image)

**Table 3 Summary of Findings**

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Direct Effect</th>
<th>Standardized Regression Weights</th>
<th>S.E.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work environment --&gt; Personal growth</td>
<td>0.621</td>
<td>0.048</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>Work environment --&gt; Positive work relationships</td>
<td>0.606</td>
<td>0.045</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>Work environment --&gt; Meaningful work</td>
<td>0.558</td>
<td>0.042</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>Work environment --&gt; Worklife balance</td>
<td>0.309</td>
<td>0.033</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>Personal resources --&gt; Worklife balance</td>
<td>0.309</td>
<td>0.066</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>Personal resources --&gt; Personal growth</td>
<td>0.100</td>
<td>0.097</td>
<td>0.056</td>
<td></td>
</tr>
<tr>
<td>Positive work relationships --&gt; Happiness at work</td>
<td>0.183</td>
<td>0.025</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>Work environment --&gt; Happiness at work</td>
<td>0.125</td>
<td>0.028</td>
<td>***</td>
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</tr>
<tr>
<td>Personal growth --&gt; Happiness at work</td>
<td>0.198</td>
<td>0.024</td>
<td>***</td>
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</tr>
<tr>
<td>Personal resources --&gt; Happiness at work</td>
<td>0.122</td>
<td>0.037</td>
<td>***</td>
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<tr>
<td>Meaningful work --&gt; Happiness at work</td>
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<td>0.027</td>
<td>***</td>
<td></td>
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<tr>
<td>Worklife balance --&gt; Happiness at work</td>
<td>0.060</td>
<td>0.035</td>
<td>0.048</td>
<td></td>
</tr>
</tbody>
</table>

**Hypothesis**<br>**Indirect Effect (Mediation)**<br>**Estimate**<br>**Lower and Upper**<br>**P-value**

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Indirect Effec</th>
<th>Estimate</th>
<th>Lower and Upper</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>H3</td>
<td>Work environment --&gt; Personal growth --&gt; Happiness at work</td>
<td>0.078</td>
<td>0.045, 0.124</td>
<td>0.000</td>
</tr>
<tr>
<td>H4</td>
<td>Personal resources --&gt; Personal growth --&gt; Happiness at work</td>
<td>0.025</td>
<td>0.000, 0.059</td>
<td>0.053</td>
</tr>
<tr>
<td>H5</td>
<td>Work environment --&gt; Meaningful work --&gt; Happiness at work</td>
<td>0.130</td>
<td>0.093, 0.185</td>
<td>0.000</td>
</tr>
<tr>
<td>H6</td>
<td>Work environment --&gt; Positive work relationships --&gt; Happiness at work</td>
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<td>0.036, 0.109</td>
<td>0.001</td>
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<tr>
<td>H7</td>
<td>Work environment --&gt; Worklife balance --&gt; Happiness at work</td>
<td>0.012</td>
<td>-0.002, 0.031</td>
<td>0.092</td>
</tr>
<tr>
<td>H8</td>
<td>Personal resources --&gt; Worklife balance --&gt; Happiness at work</td>
<td>0.024</td>
<td>-0.005, 0.059</td>
<td>0.101</td>
</tr>
</tbody>
</table>

Remarks:<br>*** p < 0.001<br>Hypothesis was supported

The main insight gained from the study is that work environment affects happiness at work for project managers through the positive functioning variables: personal growth, meaningful work, and positive work relationships. This is a critical finding because many happiness studies place work environment as a direct antecedent to happiness at work without considering the effect of positive functioning variables. Thus, the theoretical
relationships developed in such studies may be incomplete, and the findings may be somewhat distorted because the causal relationship may actually be occurring through unaccounted for and unmeasured variables.

The main insight gained from the study is that work environment affects happiness at work for project managers through the positive functioning variables: personal growth, meaningful work, and positive work relationships. This is a critical finding because many happiness studies place work environment as a direct antecedent to happiness at work without considering the effect of positive functioning variables. Thus, the theoretical relationships developed in such studies may be incomplete, and the findings may be somewhat distorted because the causal relationship may actually be occurring through unaccounted for and unmeasured variables.

Additionally, there are some unexpected insights gained from this study. First, despite logical intuition and literature supporting that work-life balance mediates the effect of work environment on happiness at work, the mediation effect was not statistically significant. This insignificant effect may be due to the weak effect of work-life balance on happiness at work (standardised regression weights = 0.06). As project management is a profession that always requires delivering projects within time, cost, and budget, project managers tend to be target-oriented. To achieve their targets, they are more willing to put in extra effort whenever it is necessary. That could explain why work-life balance does not serve as a mediator for project managers’ happiness.

Second, the mediation effects of personal growth on the relationship between personal resources and happiness at work was insignificant. The reason is that personal resources have no significant effect on personal growth. As this study only includes vitality and resilience as personal resources, we suspect that other personal resources that were not included such as self-efficacy, optimum, and hope, could generate a different result.

Finally, work-life balance has an insignificant mediation effect on the relationship between personal resources and happiness at work. This insignificant effect is likely due to the weak effect of work-life balance on happiness at work, which is the same as what we discussed previously.

From a practical perspective, the insights from this study suggest that organisations should invest more on building a positive work environment and creating a positive meaning at work because these two factors supply a stronger effect on happiness at work than other factors. The standard regression weights of work environment and meaningful work is 0.325 and 0.367 respectively.

This study was limited in many common ways. First, as project managers were surveyed using self-reporting measures rather than conducting an experiment, observation or measuring happiness for a specific event. Thus the measures of the study are subject to self-reporting bias. Second, we only obtained a usable sample size of 227. While it is not small, it is also not large given the complexity of the model. With a larger sample size, more reliable estimates could be obtained and tested. Lastly, we did not control for any potentially confounding variables, such as age and gender.

Beyond overcoming these limitations, future research are recommended to further explore the effect of personal resources, which have been widely studied in positive psychology, for the relationships in the model. Psychological capital could be one of the resources at the top of the list due to its linkage with various positive outcomes. Moreover, future research could also look into the interaction effect between work environment and
personal resources on happiness at work, an interaction that more closely corresponds to dynamics at play in real-world situations.

**CONCLUSIONS**

In this study we aim to get a better understanding of the antecedents and their relationships as they contribute to project manager happiness at work. We found that work environment and personal resources, personal growth, meaningful work, positive work relationships, and work-life balance have significant positive effects on project managers' happiness at work. In addition, personal growth, meaningful work, and positive work relationships mediate the effect of work environment on happiness at work. Although limited in scope, the findings from this study enable construction researchers to conduct studies on happiness based on a more well-defined measurement suggested in the model. It thus shines light on several new opportunities to better understand what leads to happiness at work for project managers, and provide a foundation upon which other may build as they seek to find ways to better understand and improve happiness at work.

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GETTING HIGH ON THE SCAFFOLDING? CONSTRUCTION SAFETY, LEGALISED MARIJUANA AND WORKER IMPAIRMENT

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Recreational drug use in construction is an area of concern as workers have a higher prevalence of such behaviours than those in other industries. The legalisation of marijuana in several US states has led to suggestions that this will result in increased use among workers. With problems around existing methods of drug testing for marijuana (its longevity in the body outlasts actual intoxication) and a lack of scientific agreement of quantifiable long-term effects on work performance, experimental approaches to this phenomenon are not straightforward. Here, a social constructionist methodology has been adopted, able to acknowledge the shift in cultural context caused by legalisation, and through discourse analysis a 'non-event' of legalisation was revealed. Although legalisation has had no impact on use amongst construction workers and impairment whilst at work remains unacceptable, a conflict now exists around personal freedoms and drug testing, leading to both resignation and dissatisfaction amongst workers. This could negatively influence the development of a 'just culture' on sites, and hinder worker engagement overall. It is recommended that companies and unions recognise that blanket testing policies are problematic in practice, and support the development of accurate testing for immediate impairment from marijuana use, where it has been legalised.

Keywords: legalisation, marijuana, safety, worker impairment

INTRODUCTION

Construction workers take drugs. Amongst global industries, construction comes at or near the top for worker drug consumption (e.g. Gerber and Yacoubian 2002; French et al., 2004; Minchin et al., 2006; Schofield et al., 2013; Bush and Lipar 2015 cited in Fardhosseini and Esmaeili 2016), with significantly higher use than that found in other high-hazard industries (Tan and Lloyd 2016). Concern is growing around this trend, not least because of the potential impacts to worker safety from either the long-term consequences of such use, or from immediate impairment that affects not only the worker concerned, but also their colleagues on site.

Although there is no definitive data yet available, it has been suggested that the shift towards decriminalisation and even legalisation of marijuana for recreational use, as has recently occurred in several states of the USA, will lead to an increase in its use overall (Englund et al., 2017). For construction companies operating in such states, the

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legalisation of recreational marijuana has raised not only similar concerns of increased use, but also several more complex ethical, legal, and technical considerations.

To better understand the realities of marijuana use amongst construction workers, research was carried out in a setting where it has been legalised for recreational use, the State of Colorado, USA. The goal of such inquiry is to better understand ethical and legal issues that have arisen. Using a social constructionist methodology, conversations with site workers and supervisors revealed shared understandings around the use of marijuana and other substances, both legal and illegal. The conversations also highlight areas where the impact of drug use to safety and safety management is most significant. The findings suggest that legalisation has itself been a 'non-event' for the vast majority of construction workers and getting high whilst on site remains something that is simply not tolerated. However, the results highlight that there are fundamental problems with current drug testing programmes and technologies that detect marijuana use. These problems manifest in negative impacts on worker engagement, the development of a just culture (Dekker 2007) within the site workplace, and the safety culture of construction sites overall.

**CONTEXT**

**Marijuana and Construction Work**

At present, the impacts of marijuana use on construction safety and worker well-being are unknown. In contrast, there is a considerable body of research examining marijuana itself and its effects on users (Fernandes and Moreira 2011). This research exists in part because of the benefits that marijuana provides (Hill 2015). Positive consequences include, among many, short-term increases in relaxation and decreases in stress, and increase in appetite.

When marijuana use and safety is considered, particularly within high-hazard contexts, it becomes much more problematic and divisive. As marijuana is a natural product, its potency varies with both the type of marijuana, as the active cannabinoids within the plant can vary in concentration from 0.3-30% (Fernandes and de Campos Moreira 2011), and how it is ingested by the user (Huestis 2007), resulting in no scientific agreement of any quantifiable effects. Despite this, research has demonstrated that use can result in various symptoms including: dizziness, tachycardia (accelerated heart rate), psychomotor retardation, alterations to perceptual and motor speeds and coordination (Fernandes and de Campos Moreira 2011). Marijuana has also been found to cause cognitive impairment (Caulkins et al., 2015:35) with long-term users potentially developing problems around intelligence quotient (IQ), reaction time, attention, loss of memory and becoming prone to knee-jerk reactions (Fernandes and de Campos Moreira 2011). However, the impacts on such cognitive functions are often difficult to quantify, due to the difficulties of segregating marijuana use from the user's natural functionality (Caulkins et al., 2015:33).

Within the construction site environment, it is clear why impairment is highly undesirable. Indeed, it has often been suggested that any substance use creates a safety risk to the user and those around them (Miller et al., 2007). However, this viewpoint is equivocal and there is no empirical research that has demonstrated causality between drug use outside of work and occupational injuries and illnesses. Caulkins et al., (2015:xii) state that current literature 'is insufficient to determine the extent to which marijuana use is casually linked to any of these outcomes', whilst some researchers have suggested there is no correlation at all (e.g. Pidd and Roche 2014). Frone (2013) goes further and argues that the correlation of drug use, cognitive and psychomotor performance to work safety is
not only unconvincing, it is also to some extent prejudiced. Clearly, further research is needed to contribute to this discussion.

**Marijuana and Drug Testing**

Given the high prevalence of drug use amongst construction workers, and the potential problems of impairment within such a high-hazard context, it is perhaps unsurprising that many construction companies and worker unions are increasingly operating Drug Free Workplace Programmes (DFW). These programmes often involve worker education, assistance such as detox programmes, and drug and alcohol testing of the workforce. Testing can be carried out pre-employment, post-accident, randomly, because of reasonable suspicion, or some combination of all four (Schofield *et al.*, 2013), with the goal of deterring substance abuse amongst workers, and avoiding hiring drug-using applicants in the first instance (Minchin *et al.*, 2006).

Yet, the considerable longevity of marijuana in the human body represents an additional confounding factor that is unique to the substance and different from others on typical drug testing panels. This causes an issue because users may test positive long after the effects of marijuana subside. From initial consumption, either through smoking or ingestion (i.e., edibles), it has been established that the effects last for about 3-5 hours, after which the influences on physiology wear off, and the user gradually returns to normal (National Highway Traffic Administration 2015). However, although the active ingredient in marijuana (tetrahydrocannabinol known as THC) creates the impairment, testing methods do not test for THC and instead they test for one of the cannabinoid metabolites. This chemical, called C-THC, is actually generated as the impairing effects of THC are wearing off, and has a much longer life in the body than THC itself, yet does not itself cause any impairment. The duration of this process varies from person to person, depending again on the marijuana strength, frequency of use and the individual's physiology, and can take over 30 days. Therefore, a positive test for marijuana (e.g., through a urine test) only indicates that drug exposure has historically occurred, and is not confirmation of current impairment (Huestis 2007). There is not yet a set of accepted quantitative metrics that correlate a level of THC or its metabolites to the more familiar measure of blood-alcohol.

**Problems and Conflicts**

Marijuana is arguably the most complicated drug for the construction industry to manage, and perhaps as a direct consequence of this many US employers and unions have simply adopted blanket policies where no marijuana use is acceptable, citing Federal law under which it remains illegal (Halverson 2013).

However, the dissonance between DFW testing programmes, the way marijuana use is determined by current testing technologies, and its legalisation in some states for recreational use has the potential to cause inconsistencies and problems on sites. For example, there is a clear conflict between DFW programmes seeking to prevent immediate worker impairment on site, and the way marijuana remains within the body long after use and impairment. It could even be suggested that workers, well aware of how testing currently works, may actually seek out other illegal and more potentially harmful substances over the weekend, simply to avoid returning a positive test from marijuana on Monday morning. There are also further ethical considerations. Any physical testing of workers is arguably a violation of privacy and autonomy (Sherratt 2015), and particularly relevant when the findings relate to a substance which has been deemed socially acceptable for public use and legalised. Yet, testing is likely to continue,
as companies with established testing programmes often receive discounts on their worker compensation insurances, and commercial drug testing itself is a multi-million dollar industry (Wickizer et al., 2004).

Perhaps of greater concern is the potential for a positive marijuana test to provide a simple 'root cause' for any worker accident, despite the fact that a positive test is not confirmation of impairment at the time of the accident, only of historical use. Although worker impairment must be recognised as a potential factor in site accidents, and should not be tolerated by managers or peers, testing can create a simple 'blame the worker' situation whilst more complex problems of poor management remain hidden. This also has the potential to lead to an avoidance of reporting and concealment of incidents for fear of the consequences (Miller et al., 2007; Schofield et al., 2013), including the negation of any compensation payments should a worker test positive after an accident. Such simplistic accident reporting is also likely to limit accident investigation to the superficial, curtailing organisational learning opportunities (Hale and Borys 2013). Indeed, such a dissonance does not support the development and evolution of organisational safety, creating barriers to worker engagement, limiting the establishment of a just culture (Dekker 2007) and ultimately the contributions both elements can make to improvements to safety in practice.

METHODOLOGY

As shown, there are several complex and interrelated factors related to marijuana use and construction safety that yield ethical, moral, and scientific questions. For example, a debate is still ongoing as to whether accident causality can ever be truly proven (Hollnagel 2014). Thus, the proposition that drug testing is a preventative tool (Schofield et al., 2013:99; Gerber and Yacoubian 2002:67) may never be validated, which yields the argument that there is no way to ever know if marijuana use or drug testing causes an increase or a decrease in safety performance.

Whilst overcoming the technological problems around testing for the chemicals that actually cause impairment is perhaps best left to science, it must be acknowledged that this is also a construction safety management problem, one that has the potential to influence worker engagement and safety culture on sites. But it is also a messy and complicated phenomenon, and so a research approach that allows for complexities, inconsistencies, and incoherence in its findings is therefore proposed.

A Social Constructionist Approach

A social constructionist approach grounds itself in a relativist ontology, accepting that the world we experience is socially constructed by the people within it through their interactions, systems and practices (Gergen and Gergen 2004). This results in shared versions of 'knowledge' within particular communities and the 'truth' simply as the currently accepted way of understanding that particular world (Burr 2003). Such an approach inevitably challenges traditional positivistic conceptions such as validity, replaced here by credibility (Lincoln and Guba 1985) as demonstrated through persuasive coherence and robust argument (Taylor 2001), and reliability, here demonstrated through standardisation in the data collection, transcription and constant comparison during analysis (Gibbs 2007). What is therefore revealed are the ways in which marijuana, legalisation and impairment are understood within the context of a construction site. This is achieved by illuminating the dominant discourses (Taylor 2001; Burr 2003) associated with the phenomena, by exploring and unpacking how people are talking about and so creating shared understandings of how marijuana currently 'works' on sites.
Method and Sample

Previous work exploring drug use and the construction industry has focused on the opinions or attitudes of employers, human resource or safety managers (e.g. Gerber and Yacoubian 2002; Fardhosseini and Esmaeili 2016) yet as Miller et al., (2007:570) state, informal norms take precedence over formal policies, and so any real insights are likely to come from the site workforce rather than the corporate offices. The data presented here was collected in one day on a site in Denver, Colorado, USA, where marijuana is legalised for recreational use. Two researchers spoke with eighteen native-English speaking workers and supervisors, employed by a number of different subcontractors, on the site about marijuana and construction work. These semi-structured interviews were digitally recorded in the field, and later transcribed using Jefferson Transcription (2004) to enable subsequent discourse analysis of the data (Taylor 2001). The researchers were able to discuss the data during its collection, and were therefore aware of the growing prominence of certain discourses over time. This enabled a rough consideration of 'saturation' to be made during data collection (Kumar 2005), the state at which no new insights were being revealed from the empirical data, and this was also confirmed during the subsequent transcription and analysis.

The findings of this research are presented through the dominant discourses as revealed by the data as a whole. In instances where extracts are used they are representational and have been re-transcribed to illustrate rather than replace any analysis. These findings are here interwoven with discussion, enabling consideration of the theoretical alongside the empirical, as the 'truths' about marijuana, legalisation and impairment within the construction site context are explored.

FINDINGS AND DISCUSSION

Who Cares? The Non-Event of Marijuana Legalisation

Construction workers take drugs - whether they are legal or not. The dominant discourse associated with the impacts of marijuana legalisation for construction is one of inconsequence, there has been no increase in use. In fact, for these construction workers, the legalisation of marijuana has made no difference at all; as one worker explained: 'people that have used it have always used it, whether it's legal or illegal they still use it'. A ready association was made between this use and the principles of individual choice and privacy. This suggests support for, conformity with, or at the very least acceptance of, the wider changes in social and cultural attitudes that have culminated in legalisation. If construction workers do use outside of work, it's not really anyone else's business.

The ready acceptance of use was not prominently positioned in any negative way with regards to construction work, other construction workers or themselves, nor did the dominant discourse make any immediate associations to safety within these contexts. Although some workers associated safety with marijuana legalisation, the consequences were constructed as minimal, for example as one worker noted: 'I've been more careful myself just because of the thought that it could possibly have somebody high out here …it's not really that much, just stay an extra few feet back from the piece of equipment'. Such minimisation of any realisable danger is common within all worker discourses around safety (Sherratt 2016), and such associations were not prominent within the data as a whole.

Instead, the more common development of the discourse was one of positivity around legalisation, with medical use and benefits in terms of generated tax revenue for the state drawn upon to support the acceptance of the legal change. One unexpected finding was
the frequently shared understanding that the construction industry in the State of Colorado had, as a whole, actually benefited considerably from marijuana legalisation. Workers were keen to associate increases in the volume of local construction work with the change in legislation and something that was attracting more people to come and live in the state. As one worker put it: 'you've got more people coming here, you need more houses, you need more hospitals you need more schools'. This pragmatic and positive consideration of marijuana legalisation by the workers from a workload perspective was more prominent in the data than any associations with increases in risk or unsafety on sites.

**Impairment, Construction Work and Drug Use**

Despite the lack of immediate associations between marijuana legalisation and impairment at work, the overriding discourse around worker impairment and construction was one of intolerance and unacceptability. As one worker said: 'if you’re not one hundred percent here at the job site there’s a risk, especially on construction sites there’s a risk for danger’. This was perhaps unsurprising given the location of the interviews out on the site with machinery working around them, which may have reinforced the immediacy of such hazards, yet the site environment remained a constant presence in the data. Construction workers are well aware of the potential for injury on site, and this is reflected in an intolerance to immediate impairment. In addition, there was an aspect of collegiality and social concern that supplemented that of individual safe practice as noted earlier. As one worker stated: 'everyone wants to go home to their family safe without having some jackwagon come in all high and jeopardise everyone'. In their considerations of danger, the workers referenced both themselves and their co-workers, readily able to consider the site workforce as one team, of which they were an active member. This finding suggests there would be a ready acceptance of peer-based workplace drug prevention programmes within the construction workforce, such as the bespoke PeerCare programme developed for the transportation industry, analysed by Miller *et al.*, (2007) and found to be cost-effective in practice.

Yet, as noted above, this discourse of impairment intolerance was not closely associated with marijuana, legal or not, and instead was more frequently mobilised in discussions of other drug use amongst construction workers. Indeed, most dominant was the positioning of alcohol as far worse than recreational marijuana. Contextualised through either its immediate effects, next-day consequences or long term health problems, recreational marijuana is considered by the construction workforce as a far 'lesser evil' than alcohol. This discourse rapidly developed beyond construction work with reference to wider social aspects, for example as one worker said: 'I’ve never met anybody that went and smoked a bowl and went home and beat their family'. Furthermore, the benefits of recreational marijuana were also often juxtaposed with the understanding that there are no such benefits for alcohol use as compared to the known medical uses of marijuana.

**Drug Testing: Practicalities, Resignation and Conflict**

Yet it must be recognised that to some extent these shared understandings of impairment as associated with recreational marijuana and the acceptance of its use in general are influenced by the inevitabilities of drug testing. All the workers on the case study site could be subjected to drug testing at any time from a number of sources; random testing from the main contractor, their own company, their union, or post-incident testing should an accident occur on the site, and would likely be immediately dismissed for a positive test result.
There was notable variation amongst the workers as to their representations of how drug testing for marijuana works, with specific regard to the ability of the technology to make the distinction between impairment and historical use. There was even a hope that there was some way for this to be determined, but that it just wasn’t being used on sites, which is unfortunately not the case in practice. Two distinct voices eventually emerged around testing that essentially grew from these variations in understandings, constructing areas of overlap and inconsistency in the discourse.

Firstly, there was the voice of ‘compliance’, which positioned testing as a valid management tool and did not acknowledge, or even wish to acknowledge the problematic nature of marijuana testing. As one worker said: ‘if you test hot, you’re fired, the longevity, either thirty days or forty days it stays in your system - that means you shouldn’t’ve been doing it’. This voice did not mobilise any positivity around marijuana use, and whilst the discourse of intolerance to impairment was often built upon and developed here, this was often done in a way that contradicted the practicalities of the testing system and its consequences for workers. There was no collegiality here amongst the workforce team, which itself creates inconsistencies within the wider discourse. Yet this understanding must also be placed within the context of employment law in the US, whereby worker rights vary from state to state and for some workers company policy simply is the law, as employees can be fired ‘at-will’ with no notice or cause required. As this voice was heard within the data, it could also, perhaps unsurprisingly, be associated with an emerging discourse of resignation, grounded in the legalities of such employment practices. As one supervisor noted: ‘apparently it’s not against civil rights here, and I think if that’s the company’s policy, as long as the employees know going in to it, then that should just be an accepted fact’.

The second dominant voice found within the data was that of testing as ‘problematic’. Workers of this voice were well aware of the technical issues with testing for marijuana, familiar with the longevity of marijuana in the system and so the potential to test ‘hot’ a considerable time after use and when impairment had ‘worn off’. It is perhaps worthy of note here that this second voice was the most prominent, and testing for marijuana was positioned as problematic, divisive and unfair by the majority of the workers. The conflicts between marijuana legalisation and drug testing were frequently constructed through scenarios, as one worker said: ‘you could have a couple beers, you could have a smoke, and then on Monday you wouldn’t fail an alcohol test but you would fail a marijuana test’. Although perhaps not as dominant within the site’s shared understandings as theory might suggest, this was subsequently associated by some supervisors with accidents and problems around their investigation: ‘some guy could’ve gotten high two weeks ago and then just had an accident, but it’s still going to show up in his UA-his urine analysis, it makes it difficult.’ Indeed, associations with the consequences of accidents and testing were even more limited amongst the front line workers, with only two workers drawing on such a scenario to develop their considerations towards the workers compensation system and how a positive test could negate any payment. This could be a manifestation of the reluctance of construction workers to ever consider themselves vulnerable to an accident, as revealed in other safety discourse work (Sherratt 2016), or simply acceptance of the inevitabilities of the system; as one worker asked: 'what are you gonna do? Insurance is insurance, you know, not much you can do about it'.

Resignation emerged as one of the dominant discourses associated with drug testing and legalised marijuana amongst the workers, whether with US employment law, the inaccuracies of the test, or with the need for compliance in case of an accident. A frequently mobilised scenario was that, should any testing occur people would get caught
and inevitably fired, itself reflective of both the realities of consumption amongst the workforce and site life. As one supervisor said: 'any time we could have a random UA [Urine Analysis] and people would lose their jobs'.

Indeed, such dissonance between the way legalised marijuana and construction work are currently 'working' can readily develop into conflict, a management issue closely associated with constraints to the development of any kind of 'just' workplace culture (Dekker 2007). For example, one scenario that was developed by several workers is that inadequacies in testing can actually bring greater harm to the workforce. For example, as one worker said, 'it kinda pushes people to do more hard drugs like cocaine and things like that', with the potential for more serious consequences both for site safety and long-term worker health. That construction companies and unions may be directly influencing such behaviours is likely to only enhance worker dissatisfaction with the current testing system. Furthermore, such rigidity in testing may also cause stress to workers, a form of impairment itself, as to use recreational marijuana outside of work becomes a significant risk. As one supervisor noted: 'if one was to choose to use marijuana and were to work for a company that did random testing, I think that’d be the chance you’d take'. That there may be workers, even those with medical marijuana certification, coming to work afraid that today may be the day they are drug tested and fired, is also unlikely to facilitate the creation of a happy and harmonious workforce.

Analysis also reveals several fundamental discords between the dominant discourses around marijuana legalisation and construction work. Notably, the acceptance of this change in law by the construction workforce and the fact that this is supported by a shared understanding of individual privacy and freedom of choice, supplemented by the agreement that it is less dangerous than alcohol as a drug, are inevitably at loggerheads with the way testing currently penalises workers who use. As one worker noted: 'it's hypocritical that somebody can go home and drink eighteen beers and come to work the next morning at five o’clock and run a crane, but can’t smoke dope once a month'. For the autonomous construction worker, it could be suggested that the former will come to dominate the latter, drawing as it does on wider social implications than the construction site itself. Despite the current temperance of resignation, this may well lead to increased dissatisfaction amongst the workforce in the future. As one worker noted: 'if they’re gonna legalise it, you know it’s gonna be like alcohol or anything else, as long as they’re using it on their own time'. The problem is of course that you can't use marijuana 'on your own time' and still pass a drug test. The need for accurate testing for immediate marijuana impairment is a key finding of this study. Indeed, the blanket policy and flawed testing system has been shown here as a cause of dissatisfaction amongst the workforce. Consequently there is the potential for this to negatively influence worker engagement, impair the development of a 'just culture' and so hinder the contribution both elements can make to improved safety in practice (Hollnagel 2014).

CONCLUSIONS

Construction workers don't really care about marijuana use, nor do they care particularly whether it is legal or not; what they do care about is worker impairment through any substance use, which is simply not tolerated on sites. Although for some the blanket policies proscribing any marijuana use are an acceptable aspect of their employment, for many they are not, and the inherent problems with current testing for marijuana have manifested in several ways. There is currently something of a balance between resolution and dissatisfaction, grounded in shared understandings of personal freedoms, current testing technologies and job security. That company policy could be encouraging
workers to take harder drugs or become stressed by the possibility of testing is also worthy of consideration.

Yet this balance may well shift in future, and even now is likely to limit the development of a just culture on sites, and hinder worker engagement overall. Indeed, the repeated loss of skilled workers to a flawed test should perhaps catalyse construction companies and unions to support the development of more robust testing technologies. It cannot be to the benefit of companies to lose trained and skilled workers for a test that does not prove immediate impairment or, in this context, anything even illegal.

Although these findings are from a social context in which marijuana is legal for recreational use, they are also able to inform practice and policy in countries where it remains illegal, as it is highly likely that construction workers there are also partaking. Although they are most definitely not getting high on the scaffolding, construction workers are vulnerable to the phenomena illuminated here, and given societal trends towards legalisation of marijuana for recreational use, these findings should be considered by the global construction industry in the future development of their drug-management programmes.

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Sherratt, Welfare, Hallowell and Tania


The style of induction presentation and other processes, irrespective of duration, immediately establishes the context and attitude of the construction site team and is where initial behavioural standards are established. A case study within a large contractor investigates site induction activities in practice to better understand the operational demands on time for those involved in managing site inductions and the impact of this activity on safety behaviour on site. The research method adopted was a desk-based review of company policy through document analysis, observations of site induction practice, operations and semi-structured interviews. Trade-offs between time losses/benefits, safety in practice, technology implementation and their impact on administrative processes are examined. It is argued that the use of observations has allowed the identification of the actual time commitment in practice. The principal contractor's allocated time for providing and undertaking site induction activities was underestimated by 16% to 20%. There is potential to save time through exploitation of existing and new technology solutions more fully. However, those with an H&S leadership role have indicated difficulties in keeping up with the pace of change in technology development for this purpose.

Keywords: practice, leadership, lost time, safety, site induction

INTRODUCTION

Konstantin et al., (2010) identified that the most frequently measured safety issues in the US were management commitment to safety followed by supervisor competence, priority of safety over production and time pressure, considerably less is known about other constructs that contribute to effective safety on sites. There are similarities with the UK context (Sawacha et al., 1999) where the top five important issues found to be associated with site safety were: (1) management talk on safety; (2) provision of safety booklets; (3) provision of safety equipment; (4) providing safety environment and (5) appointing a trained safety representative on site.

The safety principle of prevention, evident in the research findings indicates the importance of pre-project planning, role of leadership, inductions/orientations and training (Hinze and Wilson, 2000; Nga et al., 2005). The literature acknowledges the importance of site inductions, however, the investigations to date have not focused on the key area of site induction practice and tend to focus more on in-principle rather than in-practice. This paper investigates site induction activities in practice to better understand the operational issues for those involved in managing site inductions and the impact of this activity on safety behaviour on site. The issues surrounding trade-offs between task...
priorities, the role for leaders in safety practice, and opportunities to make more use of existing and developing technology (e.g. CSCS and PAS 1192-6) and their impact on administrative processes are examined. Findings of the case study are then presented and discussed comparing practice with theory.

**SAFETY PRACTICES ON CONSTRUCTION SITES**

**Trade-off between priorities**

Previous studies confirm that there is evidence that site inductions have an impact on site safety behaviour (Tam and Fung, 1998; Peckitt et al., 2004; Spillane and Oyedele, 2013) but none of the studies examine the factors influencing the effectiveness of site inductions and emphasise mainly the principles rather than practices. Site inductions are one of several methods construction companies undertake to reduce fatality statistics and maintain their commitment to keeping their track record in health & safety. Usually on-site inductions are split into two parts; the first part contains a general introduction to the health & safety protocol implemented by the company whilst the latter part of the induction incorporates the site-specific elements with regards to the company’s current project.

Whilst there is no denying the importance and significance of the site induction carried out by a construction company, the efficiency and effective implementation in practice contain major obstacles. Managing time and cost effectively provide simple indicators for measuring project success. The replication of site inductions can result in substantial lost time. “Willmott Dixon has estimated that each person working on its sites was inducted between four and 20 times per year. The time lost by site managers giving duplicate inductions, across all the contractor’s sites, added up to over £1.2m of unnecessary costs” (O’Neile, 2016). Koehn and Wilson (2000) identify safety management is a method of manipulating on-site safety policies, procedures, and practices relating to a construction project, there is no investigative data on effectiveness of safety management on these factors.

**Attitudes and behaviour**

Attitude and behaviour, are set by policies in place but also the practice of implementation (Kinesa et al., 2005). Seeing the policy being carried out in practice from the very start, through showing concern for others, leads to trust in the alignment between site practice and organisational policy statements on health and safety (Sarkus, 1996). Setting the appropriate values and expected behaviours is an essential factor in establishing improved safety performance (Wamuziri, 2015).

In addition, Walumbwa et al., (2010), Cooper (2015) identified that leaders creating a supportive environment could exert strong influence on employee engagement, safety behaviour and incident reduction. However, leadership needs to avoid becoming too informal to avoid lapses in safety standards (Zhou and Jiang, 2015). Edwards and Edwards (2013) identify that word of mouth feedback of participants (site induction practice) leads to other sub-contractors coming to site with a pre disposed attitude and expectations. Therefore, the impact of the time spent on induction can reach beyond the immediate site behaviour.

When reviewing transformational leadership Donovan et al., (2016) state that the reason that transformational leadership has a positive influence on health and safety is due to the added trust and their safety participation which adds to the employee’s safety compliance. Lekka and Healey (2012) have concluded that a positive safety culture combined with a
strong trust between managers and employees results in better practices. A characteristic of both transactional and transformative leadership is the strength and values as a leader to “not turn a blind eye” to unacceptable practices. Given the complexities of leadership in practice and the abilities of individuals to adopt and apply a leadership model that describes their approach, it is possible to deduce that whilst leadership style has a bearing on site practice and behaviour it is important for all of those with a leadership, management or supervisory role to take responsibility in active and positive promotion of safe working practices, commencing with the first point of contact at the site induction.

**Technology implementation (e.g. CSCS)**

Even with advancements in the Health and Safety sector in recent years, it is still frequently found that construction companies/projects are typically using paper-based site induction methods to record the inspection results of site-workers’ certificates of training. Currently 6% of contractors are using smart technology and 69% still reliant on paper-based system entirely (O’Neile, 2016). ‘CSCS SmartCards’ (Construction Skills Certification Scheme) system promotes itself as an alternative approach to accessing key data confirming the identity of the person, attained qualifications or training certifying they are fit to carry out that certain job/task and the expiration date of the card affirming the qualifications or training that has been passed. The ‘SmartCards’ system digitally checks the same criteria as a paper-based system. The information recorded is accessible and can be revised in ‘real time’, limiting the possibility of out-of-date information being displayed or checked enabling, for example, previous inductions undertaken and toolbox talks to be readily added.

The introduction of BIM - PAS 1192-6 Specification for collaborative sharing and use of structured hazard and risk information for Health and Safety also provides greater opportunities to use technology as an embedded part of safety education and training on sites as more organisations engage with BIM. Whilst PAS 1192-6 is still a draft and available for consultation, the process suggested is expected to address the variable quality of health and safety systems and deal with ‘foreseeable risk’ at all stages of the project. In particular a visualisation model of the project can be used to review, assess and communicate construction options, hazards and risks in a more easily understood method. Whilst the tools and capability are available for increased use of technology in practice that can also support productivity increases (Hammad *et al*., 2012) the uptake can be described as slow for a number of reasons (Armstrong and Gilge, 2016).

Studies mainly emphasise the principles rather than practices. Therefore, there is a requirement to study through observation and evaluation site induction in practice to understand issues around trade-offs, attitudes and technology application.

**METHODOLOGY/DATA COLLECTION**

The case study involves a privately-owned group of companies working in infrastructure, support services and construction throughout the UK that employs over 1450 people. A mixed method approach was used, incorporating quantitative observational methods of data collection and analysis and qualitative literature review and individual interviews, to establish a breadth and depth of understanding and corroboration (Creswell and Clark 2011). The study was framed around understanding the execution of organisation policy in practice in relation to Health and Safety. The first stage of data collection was focused on a community campus project of just under £40 million. This project was one of a series of PFI projects with the same principal contractor of a similar type within a five year period. At the time of the study, 3 projects led by the principal contractor were...
running concurrently in the same geographical location. There were many sub-contractors working on the case study project, all of whom had to be inducted by a staff member from the principal contractor. Many of these subcontractors were working across other sites for this principal contractor. These inductions were observed over a 5 week period to examine the context, content and duration of the induction processes. This was followed by five Semi Structured interviews undertaken with construction professionals working across the principal contractor. These interviews were undertaken with employees serving different functions e.g. General Manager, Site Manager, H&S Manager. Document examples and templates of on-site induction paperwork and health and safety documents such as risk assessments, method statements and permits were also analysed.

**RESULTS**

*Stage 1 Observation on community campus project site*

The principal contractor currently operates what they believe is an effective site induction, typically lasting 30 - 45 minutes. Site inductions take place every morning at 8.30 AM and are conducted by one of the Site Managers, either the Senior Site Manager or the Assistant Site Manager. The induction covers the following: general health and safety aspects of construction such as the use of PPE and working at height; aspects of the company and health and safety relevant to every site they operate such as their environmental policy and commitment to the Considerate Constructor Scheme. Site specific issues such as site layout, specific health and safety concerns for the site and the first aiders currently working on the site. Time taken to deliver inductions by the principal contractor was recorded for 5 weeks. An example of 1 week's observation is shown in Table 1.

*Table 1: Recorded time for site manager induction activities*

<table>
<thead>
<tr>
<th>Day</th>
<th>Task</th>
<th>Time Spent (mins)</th>
<th>Total (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>Preparation for week’s Inductions</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Induction</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Tuesday</td>
<td>Induction</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Wednesday</td>
<td>Update of Induction PowerPoint</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Induction</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Late Comer Induction</td>
<td>30</td>
<td>95</td>
</tr>
<tr>
<td>Thursday</td>
<td>Induction</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Late Comer Induction</td>
<td>30</td>
<td>65</td>
</tr>
<tr>
<td>Friday</td>
<td>Induction</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Record Week’s Inductees</td>
<td>50</td>
<td>95</td>
</tr>
<tr>
<td>Total (hours)</td>
<td></td>
<td></td>
<td>5.83</td>
</tr>
</tbody>
</table>

The principal contractors’ allocation for this specific induction activity was 5 hrs a week. Over 5 weeks of observations the time spent on induction was between 5.83 - 6hrs. This is a variation of between 16% and 20% between allocated and observed time. The observations indicate that there was 1 hour of ‘lost’ time in one week for late arrivals. Based on this indication, this amount of lost time scaled up over 10 sites over a year lead to a substantial sum of lost time and associated costs. A second observation is that the
shortest time for induction was 35 minutes, with longest 45 minutes. It is not clear whether this extended time is because of lost time or long Q&A. There is a consequence to repeating or delayed inductions for late arrivals. However, if the principal contractor does not repeat the induction, the contractor is unable to start work until the next scheduled induction. The principal contractor has to accept the fact that there will be lost time. The main issue becomes the awareness of how much time is really lost in practice and by whom.

Stage 2 Semi Structured interviews across the company
The purpose of the semi structured interviews was to establish views on the current approach to induction, problems and areas for improvement.

The semi structured interviews focused on addressing the following questions:

- What is the current site induction procedure is undertaken by the company?
- What is your opinion of the current site induction procedure carried out by your company?
- What improvements do you feel that should be made to improve this site induction process?
- What impact would an electronic database as a checklist for general site inductions have for your role?
- What do you think would improve the efficiency of the currently implemented site induction method?

The responses were transcribed and analysed by thematic analysis (Braun and Clarke 2006) into 3 themes:

- Adapting to technology - collection of statements covering video clips, DVDs, use of internet for pre-site induction and the SmartCard system
- Improvements to existing systems - various areas where practical suggestions made or observations on current practice based on experience of existing systems for site induction
- Problems - areas where existing problems as well as those for improvements can be foreseen, recognising the need to maintain flexibility yet achieve health and safety objectives

A selection of illustrative quotes are presented within the themes in Table 2 for Senior Roles and Table 3 for Operational Roles and discussed in the next section.

DISCUSSION
The findings of the interviews reflects the Senior Roles and their focus on managing systems in practice. The ability to identify and articulate the problems and potential improvements indicates an overview of the project and organisational context, typically recognising the complexity of the problem. There is also recognition between the need for policy and system control to be balanced with the needs for operational commitment, “What do you do when guys turn up onto your site who don’t have CSCS? Do you turn them away? How do you deal with that because that’s what happens in the real world”. The overview also indicates an appreciation for the benefits of technology combined with a critical evaluation of the limitations. A desire to use the tried and tested methods that work indicates a similar outcome to the study of Armstrong and Gilge (2016) into the adoption of technology within construction. One option to reduce lost time is to make site inductions more proportionate to the needs of the person being inducted. For example, a sub-contractor working for the same principal contractor across 3 sites where electronic records are shared, only requires a full general introduction to the health & safety
protocol implemented by the company once for the first site they work on, with two further inductions requiring only site specific information.

Table 2: Senior Role Theme Comments

<table>
<thead>
<tr>
<th>Theme</th>
<th>Improvements to existing systems</th>
<th>Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Manager</td>
<td>There are obviously improvements that can be made... along with the DVD make a recording of the project manager or site manager of that specific site going through the site specifics. There should be a system where information is provided before they even turn up on site, so that we can then verify it, have it logged...know who’s got a card and if they have been to any of our inductions before</td>
<td>You end up getting into a process of inducting everybody all the time, which can take up quite a lot of time in your day. There is the monotony of constantly having to do these inductions. You kind of lose the emphasis of what’s important in it sometimes because you do it so often and it just rolls of your tongue and there’s always the opportunity to miss sections.</td>
</tr>
<tr>
<td>General Manager</td>
<td>In an ideal world... before anyone comes to the site they have been online and logged in their tickets, their CSCS, CPCS or their NPORC or whatever they’ve got and they are checked automatically. As part of that process, they could also receive the general part of the induction online before they come to my site to save some time, but whether that works or not I don’t know, I know it’s something that we are looking at. ...what I would like to see is a pre-registration system but with more controls on it ... but it’s hard enough to get the method statements and risk assessments off of companies before they arrive on-site. We have to have a system that works for everybody and is flexible ... or we have to be strong enough to turn people away but that impacts on us. It’s about making sure they know the values and the behaviours that we are trying to put in place.</td>
<td>The downside to [on-line induction] is that you don’t know, who watched the video, was that actually the person that is coming to site? It’s hard to control that and I don’t know what controls we could put in place to do that. Companies will say only CSCS or we’re going to use a CSCS database. What do you do when guys turn up onto your site who don’t have CSCS? Do you turn them away? How do you deal with that because that’s what happens in the real world</td>
</tr>
<tr>
<td>Project Manager</td>
<td>I have seen a card system where guys who have been inducted within a company, they are then valid to go work on other same-company sites and only require the site-specific induction. If you are sat with a bunch of slides and it’s just somebody reading through them, it can be fairly boring and monotonous. A video version which was eye-catching ... makes it more interesting. 9 times out of 10, they’ve lost their CPC/CSCS card and you have to go on Card checker online and maybe there is a way of centralising the database within the company</td>
<td>It is a standard induction used across all projects ... if you are somebody that comes and goes through a lot of projects and inductions, you hear the same thing and probably tend to switch off</td>
</tr>
</tbody>
</table>

There is recognition that repetition in of induction can lead to monotony and switch off for all involved. There is evidence that discussions, comments and feedback between
participants in learning experiences (such as site inductions) leads to different levels of engagement and behaviour for subsequent participants (Edwards and Edwards, 2013).

**Table 3: Operational Role Theme Comments**

<table>
<thead>
<tr>
<th>Theme</th>
<th>Adapting to technology</th>
<th>Improvements to existing systems</th>
<th>Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>H&amp;S Manager</td>
<td>I would perhaps, go down the lines of a safety passport … quite a lot of companies have a safety passport which lasts for a year and an electronic system to track that.</td>
<td>The previous DVD was from about 9-10 years ago and was quite dated in some of the methodology and the ethos behind health and safety was different those days so the message wasn’t quite up-to-date. The safety passport is being explored currently, because one of the aims is that we would like to be able to track people so they don’t have to sit through the 15 minute group message every time.</td>
<td>Because there are a number of foreign tradesmen… online induction material has also been converted so we cover most of the people on site. We are so close to [specific location] there is also a separate environmental induction because we are in such a sensitive area.</td>
</tr>
<tr>
<td>Site Engineer</td>
<td>There’s an induction prior to anybody going out on site and is delivered via a video followed by site-specific verbal induction.</td>
<td>I think inductions should be site-specific to your job role rather than other things that sometimes lose their attention. I think it [centralised electronic database] would be beneficial and a better format to keep track of the guy’s records and to go on and check their training and competency.</td>
<td></td>
</tr>
</tbody>
</table>

The impact of prioritising safety and taking the appropriate time has an impact beyond the site, as ‘word-of-mouth’ reinforces the expected health and safety standards. The Senior Roles not only recognise this problem in themselves and for others but have a genuine desire to ensure the appropriate values and behaviours towards health and safety are evident. “We don’t spend enough time … the culture of safety is …it really is about them. It’s about making sure they know the values and the behaviours that we are trying to put in place”. The main issue here is recognition that while the CSCS Smartcard system is being publicised as a solution it clearly does not address the reality of complex problems, “Companies will say only CSCS or we’re going to use a CSCS database. What do you do on when guys turn up onto your site who don’t have CSCS? are we making the industry only for the people who can afford the CSCS? That is a concern”. Some of the claims indicate administrative time-saving opportunities (O’Neile 2016) are indicative of the information being presented but don’t address the operational issues identified by these managers in practice.

The responses from the Operational Roles clearly identify with operational improvements. Issues with a greater response focus on where the practical application of
technology or system improvement can be seen (Safety Passport and CSCS Scanner). Whilst these options appear useful, the appreciation shown by Senior Roles of system failures in the technology is not evident in relation to, for example, card systems other than CSCS. Operational Roles indicate the need for information capture and recording, but unlike the more Senior Roles there is no indication that the function is about behaviours and attitudes, which may be because of the job role and focus being on productive work and meeting system needs for recording activity in induction. The lack of consideration of problems also reflects the typical requirements of the roles of the site engineer and section manager as ‘can do’ people that solve problems. These roles deal with problems as they come along and getting on with the existing systems in place to make them work as best they can.

The length of induction may be a result of the needs of the person(s) being inducted but also dependent on a number of factors influencing the deliverer's time and ability to provide the induction. There are operatives and professionals with varying degrees of site experience and knowledge and visitors that will be exposed to fewer risks. One option is to make site inductions more proportionate to the needs of the person(s) being inducted.

Technology has been presented as an opportunity to reduce the amount of lost time in the induction process by targeting the right level of induction. Senior Roles are aware of potential opportunities to spend less time on this activity but each solution has limitations as discussed above.

CONCLUSION

This paper investigated site induction activities in practice to better understand the operational demands on time for those involved in managing site inductions and the impact of this activity on safety behaviour on site. The observational data examined the trade-offs and weightings between time losses/benefits, safety in practice, and technology implementation.

Trade-offs and weightings between time losses/benefits
The mandatory nature of site inductions means that those with a leadership role responsible for delivery recognise them as a priority. This is without a full appreciation of the time involved. There is clear evidence that there is more principal contractor time spent in relation to the induction process for health and safety arising from the actual induction itself and the associated administrative processes than planned. The cumulative impact of this 1 hr of "lost time" per week multiplied across the year over a number of sites can be described as ‘substantial’. However, both the principal contractor and sub-contractors recognise the value and benefits of effective site safety induction, which leads to associated appropriate site behaviour. The impact of prioritising safety and taking the appropriate time has an impact beyond the site as 'word-of-mouth' reinforces the expected health and safety standards.

Technology implementation and administrative processes
Technology has been presented as an opportunity to reduce the amount of lost time in the induction process by targeting the right level of induction. Our study revealed that the site induction deliverers are aware of potential opportunities to spend less time on this activity but each solution has limitations. For example, opportunities for savings through technology include, pre-registration, off-site videos and sharing of existing site inductions across sites but the data still needs to be created, current and have a reliable authentication process. Those with a leadership role have indicated that there are difficulties in keeping up with the pace of change in technology development for this purpose. The issue of
keeping pace with changes in technology is recognised as an industry-wide problem, in particular, for implementing BIM.

*Safety practices on construction sites and attitudes and behaviours.*
The principal contractor as an organisation expects their managers to lead by example, which is why they prioritise site induction so that people understand it is valued, creating a solid reputation for appropriate site behaviour. Putting into practice the claims of the company policy leads to trust between site staff and managers. Senior Roles demonstrated a genuine desire to ensure the appropriate values and behaviours towards health and safety are evident. This recognises that if leaders do not exhibit the expected leadership example, this will undermine the attitudes and behaviour on site on the basis that the leadership supports a less than rigorous approach. Operational Roles indicated the need for information capture and recording however there was less recognition that the function of induction was about behaviours and attitudes.

The application of observations has allowed us to identify the actual time commitment of leadership in practice. The principal contractor's allocated time for providing and undertaking site induction activities was underestimated by 16% to 20%. The interviews identified the potential to save time through fuller exploitation of existing and new technology solutions. However, those with a leadership role indicated difficulties in keeping up with the pace of change in technology development for health and safety induction and there were also operational issues in practice.

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HUMAN RESOURCE MANAGEMENT
WOMEN IN QUANTITY SURVEYING: A NEW CAREER APPROACH

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Most research concerning women’s experiences in the construction industry focuses on barriers to women’s career progression and success, where progression is based on the upward movement of an individual through an organisation and success is measured by extrinsic factors such as hierarchical status or salary levels. Most women do not follow this pattern, leading to the conclusion that they are not progressing or succeeding in the industry. The focus of this paper is women’s careers in Quantity Surveying, an area currently under researched. It discusses the literature discussing career theories relating to the construction industry, and presents an alternative career model highlighting intrinsic measures of success. The paper concludes with a proposed theoretical framework discussing how Sen’s Capabilities Approach and Bourdieu's Theory of Practice can be used to demonstrate that women in Quantity Surveying can achieve a 'boundaryless' career.

Keywords: women, quantity surveying, career success, gender

INTRODUCTION

This paper focuses on the careers of female Quantity Surveyors - a profession in which women have been recognised for fewer than 100 years. From undertaking the measurement and costing of construction works for private practices, QSs now have a variety of job titles (North, 2010), including cost manager, project manager, estimator, cost planner and dispute resolution advisor (Ashworth et al., 2013). In addition to professional practices, QSs in all roles now work for a variety of organisations, including national and local government bodies; contracting and subcontracting organisations; developers; and financial and legal companies (Ashworth et al., 2013).

The diversity of job roles and range of employing organisations should enable women to develop successful careers in QS, and yet they remain underrepresented in the profession. There are several reasons given for the limited numbers of women in construction, including poor recruitment of women in the first instance, and women leaving the industry and not returning - known as the 'leaky pipeline'.

Women seeking careers in the industry do not achieve the same levels of career success as men (Dainty, 1996) and there has been a great deal of research regarding barriers to women’s career development i.e. the ways in which women have been excluded or controlled (Wright, 2016). Barriers include: the attitudes or behaviours of men towards

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2 The abbreviation QS is used to denote either Quantity Surveyor or Quantity Surveying, depending on context.

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women (Greed, 2006; Chan, 2013); male-dominated institutions (Powell et al., 2005; Watts, 2007); and lack of role models or mentors (Sealy and Singh, 2008).

Research regarding women's perceived lack of career progression and career success in the industry is based on traditional, hierarchical career patterns where the measures of success are extrinsic (e.g. salary level or hierarchical status); these career patterns and measures of success disfavour women.

This paper suggests that the traditional, hierarchical career pattern is the standard applicable to all when, for many women, this pattern is the exception rather than the norm (Inkson et al., 2012). Alternative career patterns, such as the boundaryless (Arthur and Rousseau, 1996) or protean career (Hall, 1976) or, what Lips-Wiersma and Hall (2007: 772) term, a "new career", that base success and progression on intrinsic values (such as work: life balance, or variety of work roles), are a more appropriate mechanism by which to analyse the careers of women in the industry. This research, therefore, applies Sen's Capabilities Approach and Bourdieu's Theory of Practice to propose a theoretical framework discussing how social and cultural capital acquired by women, through qualifying and working as a QS, once converted into capability sets upon which the women can draw, can lead them to career development based on the boundaryless, or protean, pattern. Constraints to this process are given in the form of barriers to women's career development in the construction industry.

Theories of women’s careers have been developed, although most have been multidisciplinary. One example is Hakim’s (2000) Preference Theory, which proposes that women have a choice to be home-centred, work-centred or adaptive (a balance of the two); the adaptive group is the largest. Criticisms of Hakim's theory centre on the fact that preferences cannot be considered in isolation (Leahy and Doughney, 2006), that she does not consider either the various constraints women face, or that preferences change over time. Leahy and Doughney (2006) suggest that Sen’s approach is better able to demonstrate women’s preferences.

This paper positions the role of female QSs in relation to women in the wider industry and by proposing an alternative pattern regarding career success and development.

**WOMEN IN THE CONSTRUCTION INDUSTRY**

A great deal of research regarding women’s experiences in the construction focusses on barriers to career success and career progression, based on the upwards movement of an individual in an organisation. It finds that these barriers include unfair working practices; bullying and discrimination; lack of training; poor site facilities and inappropriate equipment; socialisation issues; the structure, and male-domination, of the industry; lack of role models; and the assumption that women will leave to have children, or will have other caring responsibilities (Fielden et al., 2000; Greed, 2000; Agapiou, 2002; Bagilhole et al., 2008; Powell and Bagilhole, 2009).

More recent research has found that women find ways of managing interactions with men by drawing on “gendered power resources” such as wit, character and experience (Wright, 2016: 132), yet it remains apparent that women are still having to manage their male colleagues.

**Women in quantity surveying**

There has been very little research into women in QS. Greed (1991), investigated the experiences of women in surveying, but gave little mention of QSs, and only then in a very generalised way. She acknowledged that there have been few studies of surveyors at
all, citing Thompson's (1968) history of surveying as an exception, although women were 'scarcelly mentioned' (Greed, 1991: 7).

The 2011 census shows that there are 3,821 women QSs, out of a total of 40,786 (equalling 9.4%) (ONS, 2011). There are also an additional 4,427 female construction managers (or related professionals), out of a total of 63,885 (6.9%), some of which may have qualifications in QS (ONS, 2011). The census also shows that 9,533 women identify as chartered surveyors (out of a total of 89,623 – 10.6%) some of whom also may be qualified as QSs. Overall women represent 10.3% of construction managers and professionals (ONS, 2011) a figure that has remained quite consistent in recent years. The census also demonstrates that it is difficult to ascertain exact numbers of people who would describe themselves as a QS. Nevertheless, despite the increased range of QS roles over recent years, and the greater diversity of people attracted into the industry, the percentage of women remains constant at around 10% - a figure that Greed (1991) had also quoted.

**WHAT IS A CAREER?**

**Definition of career**

The term ‘career’ is often used synonymously with 'job', 'occupation' and 'vocation' (Patton and McMahon, 2014). There is consensus that while a job is a paid work experience, a career involves a series of employments over time (Arthur et al., 1989) and could be extended to include whole-life factors (Patton and McMahon, 2014).

Psychological career theories have existed for over 100 years, focusing on career choice and best-fit models of people with occupations. Sociological career theories did not emerge until the mid-twentieth century; initially based on the traditional, hierarchical career, these later expanded to include non-organisational career theories.

**Traditional careers**

Career theories were "developed by white males of European descent” (Brown and Associates, 2002: 10) and so favour the career patterns of white men. The traditional career pattern is based on the upward progression of an individual through an organisation or occupational hierarchy (Kanter, 1977; Arthur and Rousseau, 1996). This pattern is said to favour men's careers as, historically, men are more likely than women to remain within one institution for their entire working lives (Kanter, 1977; Acker, 2006). Individuals are now less likely to remain in one organisation but this pattern, which measures success based on extrinsic factors such as upwards progression, salary level and managerial responsibility, is still common. This is particularly true of the construction industry, where career success “almost inevitably seems to equal management” (Watts, 2007: 238) and it has contributed to the view that women are not progressing or succeeding in the industry (Dainty et al., 2000).

An early sociological career theorist, Hughes (1958), argued that vertical progression, as a prerequisite of a meaningful career, means that most people would be denied career success as many occupations give participants meaningful careers without hierarchical movement. Schein (1978: 128) concurred, developing the concept of career anchors, by which he meant “concerns or values which the person will not give up if a choice is to be made”. The anchors demonstrate that, for some, creativity or autonomy may be more important than responsibility and hierarchy and so the traditional career pattern would not apply. Additionally, since the 1980s, lifelong careers "bounded" in a single organisation were no longer assured and, as careers became more individual, new career patterns emerged (Arthur and Rousseau, 1996:3; Lips-Wiersma, 2007).
Protean and Boundaryless careers

Defillippi and Arthur (1994) and Arthur and Rousseau (1996), critiques of the traditional career pattern, proposed an alternative in which consideration is given to -on-work factors and their influence on careers within an individual's life span. Their work built on the earlier work of Hall (1976), who suggested that a protean career “is driven by the person, not the organisation, and [it] will be reinvented from time to time as the person and the environment changes” (Hall, 1996: 8). Arthur and Rousseau (1996) called this the ‘boundaryless’ career and it is based on individuals pursuing independent goals regardless of for whom they work; success is judged on personal, intrinsic factors, such as work: life balance or flexibility (Hall, 2002).

In these new career patterns, which have had increased application in recent years (Baruch, 2014), individuals work for many employers, or organisations, throughout their working life. Validation can be gained from outside the employer - such as in publishing academic papers; belonging to a professional body; or having personal or family reasons to pursue an alternative career path.

New career patterns also include nonstandard work relationships, such as temporary and part time work or job sharing. They include those individuals taking a career break; or those who work as independent contractors; as well as those in pre-retirement, retirement and post retirement. It means that individuals make choices and compromises between themselves, their families and the organisations with which they are involved (Valcour et al., 2007).

New careers are usually seen as being heavily gendered towards women, although taking a career break, or working part time, is considered a legitimate need of women but not of men (Klein et al., 2000). Thus, Maniero and Sullivan (2005) found that men scorn other men who work this type of career pattern, more than they scorn women.

For an organisation, employing those whose identities are centred on non-work roles is an issue for consideration and negotiation as these employees tend to work shorter hours (Major et al., 2002). Arrangements are a question of negotiation in each situation (Kalleberg et al., 2003) and the ability to follow this career pattern can depend on organizational policies; supervisor and co-worker supportiveness; an organisational culture accepting of diversity; the ability of the organisation to work flexibly; and adequate staffing levels (Valcour and Tolbert, 2003). Although new career patterns do not necessarily have a negative effect on organisations, as those who make transitions between employers bring new skills and enterprise into the new organisation (Defillippi and Arthur, 1994; Higgins and Dillon, 2007).

Measures of career success

If the "goal of a career is psychological success, the feeling of pride and personal accomplishment” (Hall, 1976: 8), then there are many ways to achieve psychological success, whereas there is only one way to achieve vertical success. The length of someone's career, their hierarchical position or professional standing, become less important than the meaning individuals ascribe to what they do (Van Maanen, 2014).

However, the construction industry interprets career progression and success as individual advancement within an organisation or between organisations (Cuzzocrea and Lyon, 2011) as well as other extrinsic factors such as salary or car (Dainty et al., 2000). New career patterns, such as the boundaryless or protean career concentrate on intrinsic measures such as work: life balance; variety in work roles or tasks; or the ability to
publish academic papers and, whilst it is possible to have both types of success, there is only moderate correlation between the two (Judge and Bretz, 1994).

**Career theory and gender**

Gender issues are woven into the structure, functions, and social meaning of career (Young et al., 2002) because, as a male-orientated concept, it does not reflect the reality of many women’s lives (Gherardi and Poggio, 2007) and, so career and career success may have different meanings for men and women.

Attempts to view women in the workplace as equal to men, have remained on men’s terms, because successful women usually adopt masculine traits to progress (Young et al., 2002; Watts, 2007). Although it is more likely to be women who will pursue the boundaryless career pattern (Young et al., 2002), increasing desire amongst men for greater work: life balance, means that this approach can benefit men too. Lately, organization structures present fewer opportunities for hierarchical advancement, and this could be a catalyst for change (Lips-Wiersma, 2007).

**TOWARDS A NEW CAREER FRAMEWORK**

The concept of the boundaryless career has been used in many different contexts (Arthur, 2014), including women’s careers in construction (Dainty et al., 2000).

Developing theory alleges that it is too simplistic to divide careers into 'bounded' or 'boundaryless' and that a boundaryless career depends only on individuals’ choices (Dany et al., 2011). People are not free to have whichever career pattern they desire, as there are constraints and events that will be beyond their control, such as an organisation going out of business (Dany et al., 2011). Nevertheless, the "boundaryless career is an umbrella term under which to look for more specific research agendas" (Arthur, 2014: 632) and, as such, can be utilised as an overarching concept in researching women’s careers in QS. In boundaryless and protean careers, "personal development and the ability to follow one's own dreams" are "the most important career success factor" (Hall and Chandler, 2005: 2705). As such, Sen's capabilities approach is an ideal theoretical basis to conceptualise this career pattern.

**Sen's capabilities approach**

The premise of the capability approach is that an individual should be able to do and be whatever they want to be (Sen, 1992). Individuals' goals (or 'functionings) may differ (Sen 1985; 1992), but even if their goals are the same, people will have different freedoms (or 'capabilities') to pursue their desired goals (Sen, 1992).

The approach thus acknowledges the structure-agency debate. Sen (1992) places much emphasis on agency, and Robertson (2014) acknowledges all structural factors affecting agency need to be considered. To be realised, functionings (the ‘beings and doings’ of an individual), need capabilities (“the genuine opportunities or freedoms a person has”) (Sen, 1992: 40). Resources are required to develop capabilities and convert them into functionings (Sen, 1992). It is the ability to convert resources into capabilities and functionings that governs well-being (Sen, 1999; Nussbaum, 2000).

Sen (1990) also asserts that extrinsic measures of success do not encapsulate people’s well-being; non-economic factors such as family relationships, friends, beliefs, health and purposeful activity are also important (Gasper, 1997; Robertson, 2014).

Sen’s approach is not a theory as such, it is designed to be used in combination with other theoretical approaches to suit the context in which it is being adopted (Robeyns, 2005).
Whilst its main application has been in economic development, it has also been applied within education (Robeyns, 2005; Hart, 2012), health (Abel and Frohlich, 2012), and career choice (Robertson, 2014). Its focus on the goals of individuals, acknowledging the constraints in achieving those goals, and measuring success by intrinsic factors, make it an ideal approach to use in careers research.

In career development, resources are converted into capability sets; notwithstanding the barriers that must be managed or overcome in this process. Once acquired, capability sets can be traded off against one another to suit current goals (Sen, 1992). For example, a female QS could trade hierarchical status or salary level for flexibility, if she is bringing up a young family, or for job variety if that is her goal. Resources required by QSs (male or female) include educational qualifications, and social connections and networks; these can be represented by social and cultural capital as given in Bourdieu's theory of practice (Bourdieu, 1972). Similarly, the structures of the industry that both constrain and enable the agents within it can be represented by Bourdieu's concept of habitus.

**Bourdieu's theory of practice**

Bourdieu’s theory of practice utilises the elements of field, habitus, and capital to examine the dichotomy between structure and agency (Bourdieu, 1972). Structures, for Bourdieu, are represented by habitus which is the embodied history of a practice as well as its active present (Bourdieu, 1990). Regular practices can be explained by calling them habitus; practices that adjust to their context, and are reinforced or modified by the actions of agents, but are seemingly unchanging.

Habitus and field are linked whereby the field shapes the habitus which then shapes actions that reproduce the field (Crossley, 2001). Fields are the social context in which individuals operate (Bourdieu, 1972; 1986), and so, while careers themselves are not a field, they take place in one or more fields - such as the work environment, company, and / or professional body. Individuals use capital to enter the field, and then to advance and / or consolidate their position in it. Bourdieu (1972) identifies three forms of capital: economic, social and cultural. By working, a person transforms cultural and social capital into economic capital, but they also add to their cultural and social capital (Iellatchitch et al., 2003).

For QSs, cultural capital usually comprises the qualifications acquired to enter the profession and gain employment. Social capital, such as networks and connections also helps this process. This paper proposes that a career is built by the individual acquiring cultural and social capital. To build a career these need to be converted into capability sets as the more capital an individual has, then the greater number of capability sets they acquire. This gives them greater freedom to choose the lifestyle - or career pattern - they desire. However, in construction, both the process in acquiring capital and the ability to convert capital into capabilities, are gendered (Benschop, 2009). Women are more likely than men to concentrate on gaining cultural capital to compensate for their lack of social capital (Dainty, 1996). However social capital is most often acquired through networking, a process that favours men over women, and which is deemed more valuable than cultural capital. Additionally, the ability to convert resources into capabilities is easier for men than women, due to the barriers, or constraints, women face. While ownership of resources enhances the freedom to achieve, it does not follow that people will achieve because of "significant variations in the conversion of resources and primary goods into freedoms” (Sen, 1992:33).
CONCLUSION

The careers of female QSs are under researched. Women in construction are said to face many barriers to their career progression leading to the view that they lack career success, compared with men. However, career success in construction is often measured using extrinsic values such as salary level or hierarchical status. This paper proposes that intrinsic measures of career success, such as work: life balance, flexibility or job variety, may be better constructs by which to measure the career development of female QSs. Therefore, a boundaryless career pattern is suggested for female QSs based on the ability to convert capitals into capabilities. Further research will be to ascertain the capability sets of female QSs as well as identify the constraints and enablers regarding the conversion of capitals into capabilities.

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POPULATING THE SOCIAL REALM: EXAMINING NEW PROFESSIONAL ACTORS RELATED TO EMPLOYMENT REQUIREMENTS

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Employment requirements are increasingly used in construction procurement in Sweden. The aim is to investigate how increased use of employment requirements give rise to new type of actor in the construction industry. This includes investigating how these actors define and populate a new professional role and knowledge domain within the construction industry, how they shape their identities and work practices, as well as how they redefine boundaries of the field. Semi-structured interviews with 21 built environment professionals working with employment requirement showed that that the increased use of employment requirements creates both opportunities and complexities for the construction industry. Due to an unclear knowledge domain, uncertain allocation of responsibilities, and iterative role development, “employment requirement professionals” are not a cohesive group, even though the role seems to be undergoing a professionalization process. The paper contributes to an understanding of the implications employment requirements have on roles and identities of built environment professionals, and how a new professional domain, new social identities and driving forces, and new collaborative work practices are established.

Keywords: employment requirements, professionalization, roles, Sweden

INTRODUCTION

Sweden is struggling with increasing social exclusion (for definition see Brännström 2004: 2516), where poor urban areas are characterized by unemployed or low-income immigrants, rundown housing in need of refurbishment, tenants that cannot afford extensive refurbishment investments, and socio-economic development lagging behind the national average (Jonsson et al., 2017). Simultaneously in the construction industry, there is a growing lack of construction workers, making it difficult for contractors to provide tenders, e.g. for the needed refurbishment projects (Bennewitz 2017). In an attempt to mitigate issues related to the above-mentioned challenges, municipal and private organizations in the construction industry, e.g. housing companies, see possibilities to implement employment requirements. This means to combine construction projects with employment opportunities, such as internships or (temporary) employment in the projects for people that stand outside the job market (Lind and Mjörnell 2016). Consequently, employment requirements are high on the political and business agenda in Sweden. However, use of employment requirements in procurement comes with its own set of organizational difficulties. When employment requirements are introduced, new competencies and responsibilities are needed, forcing actors in the construction industry, like clients, contractors as well as consultants, to revise and adapt their practices (Barraket et al., 2016, Petersen and Kadefors 2017). This also leads to the

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establishment of new roles in the construction industry, i.e. a new set of actors that populate the social realm of construction.

To better support the development of employment requirements in procurement, as means to increase social sustainability, studies of these new roles and practices were identified as important. However, even if social procurement, meaning measures related to e.g. health and safety, buying from women- and minority owned businesses, and employment creation for disadvantaged groups, are emphasised as important in research, business, and on the political agenda (Walker and Brammer 2012; Barraket et al., 2016; Loosemore 2016) this field suffers from weak theorization, conceptualization and empirical investigation. In addition, few studies focus on roles and professionalization processes related to the development of employment requirements. One exception is Barraket et al., (2016) who argue that social procurement has become a “distinct domain of practice” (p. 51), likely to become an institutional field of its own. Because social procurement is emergent rather than fully institutionalized, roles and relationships between actors become important elements in the process of legitimizing social procurement. Roles are prescribed with values and norms, which in procurement include attributing certain tasks and purposes to a role, such as disseminating information, providing services, pursuing profits and/or social outcomes, and creating networks. In the case of social procurement, a variety of actors such as commercial firms, non-profit organizations, governments, social enterprises, and support functions inhabit these roles. When multiple actors work towards a common goal, like creating social value through procurement, this collective work can become normative. This means that in a yet-to-be-fixed institutional field of social procurement, traditional roles might become contested, negotiated or reified, leading to new roles being created, or new aspects overlaying traditional roles. In that case actors might have to navigate between conflicting roles. Barraket et al., (2016) claim that individuals have an important role in the adoption of new practices, and that close relationships between individuals facilitates the dissemination of practices. By developing practice frameworks, templates, etc. for e.g. implementing employment requirements, practices can become established despite the absence of institutional norms and rules that the emergent field of social procurement lacks.

Sutherland et al., (2015) found that both construction clients and contractors in Scotland have begun to create new roles solely dedicated to working with employment requirements. To build competences for better processes related to employment requirements, clients have for example assigned specific procurers responsibility for employment requirements, contractors have established new employment requirement coordinators in their organizations, and many existing professional roles have got extended responsibilities related to employment requirements. Thus, there are examples of how roles in the construction industry is changing due to the increased use of social procurement and employment requirements, but little detail into how this process is unfolding. Creating an increased understanding on how new roles are shaped follows a vein of research that emphasise the role of professionals as agents for sustainability (e.g. Cole et al., 2010, Daudigeos 2013, Gluch and Bosch-Sijtsema 2016). These studies have in common that they emphasise the importance of a strong professional status, purposeful use of influence tactics, as well as catching enthusiasm in order to create space to manoeuvre strategic directions for sustainability.

This paper aims to investigate how increased use of employment requirements give rise to new type of actor in the construction industry, i.e. “the employment requirement professional”. This includes investigating how these actors define and populate a new
professional role and knowledge domain within the construction industry, how they shape their identities and work practices, as well as how they redefine boundaries of the field.

METHOD

To investigate how increased use of employment requirements gives rise to a new type of actor and how this role is framed in terms of knowledge domain, professional identity and interrelations to others, 17 semi-structured interviews with 21 individuals were conducted. Interviews were carried out by one of the authors between May 2016 and February 2017. Although explorative in character, the interview questions were derived from previous research and covered issues such as: work experiences related to employment requirements, views on one’s own role, relationships with other actors, values and characteristics prescribed to their role, and future prospects on the role.

Through snowballing, the interviewees were chosen due to their experience with working with employment requirements. In addition, they were reputed as influential on the future development of employment requirement practices within the Swedish construction industry. The interviewees have diverse backgrounds in terms of education and previous work experiences. A majority are either engineers or business administrators; others are former teachers, social workers, construction workers, and legal counsellors. Looking to current professional roles of the interviewees, three main categories can be identified: coordinators, sustainability specialists/managers, and procurement specialists/managers. Within these three role categories the interviewees represent many different types of organizations in the construction industry, including public and private client organizations, contractors, architects, and other organizations such as the Employment Agency. Henceforth the interviewees will be referred to with their work title and personal code, see table 1.

Table 1: Information on interviewees’ roles and positions

<table>
<thead>
<tr>
<th>Professional role</th>
<th>Examples of work title/position</th>
<th>Individual codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinator (C)</td>
<td>employment officer, CEO, business developer, project leader, project manager, head of development</td>
<td>C1-8</td>
</tr>
<tr>
<td>Sustainability expert/manager (S)</td>
<td>sustainability manager, process leader for employment requirements, CSR manager, development strategist for social issues</td>
<td>S1-8</td>
</tr>
<tr>
<td>Procurement specialist/manager (P)</td>
<td>procurement manager, head of procurement, strategic procurement officer, purchasing officer</td>
<td>P1-5</td>
</tr>
</tbody>
</table>

The interviews lasted between 45 minutes and 3 hours, were recorded and transcribed in verbatim, and then coded in NVivo in order to enable a systematic review of the data. First the data was coded according to the interview questions. After this initial, rather inductive coding, the empirical excerpts were thematically analysed guided by the analytical framework in order to identify emerging patterns and specific areas of interest. Coding was conducted by both authors jointly.

ANALYTICAL FRAMEWORK

In this paper, roles are associated with identified social positions in which normative expectations generate roles, where these may vary among individuals as they reflect formal demands and/or pressure from informal groups (Kabiri et al., 2012). The ability to have exclusive control of work tasks, depends on inter-professional competition, bound up in performativity and constructed in the intersection of resources (Styhre 2011) and in interrelation with other actors (Brown and Phua 2011). In understanding roles and
identities of professionals it is therefore important to investigate what they do in terms of their professional behaviour and work tasks, and also to identify possible alignments and tensions in this doing in relation to other occupations. The work tasks of professionals are also in a continuous and iterative process simultaneously affected by the professionals themselves and/or formed through proxies such as various professional institutions (Brown and Phua 2011).

Previous research suggest that professional actors’ actions include knowledge-based problem-solving skills, a high degree of independence and judgment skills, conformance to codes of ethics, and that they occupy a specific knowledge domain or expertise area (Styhre 2011). Characteristics of professionals are also their emotional engagement in their work and an increased sense of responsibility. Their professional roles are thus strongly shaped by their work tasks and how they conduct these in a ‘professional’ way. Consequently, activities and tools associated with a ‘competence’ centred discourse related to that professional practice are closely related to professional identity (Brown and Phua 2011). Styhre (2012: 634) describes professional identity as the “totality of images of the self and norms and beliefs related to such images that guide and structure everyday practices and behaviours [at work], helping the actor to cope with both demands and expectations articulated by others in a domain of professional practice”. The idea is that professional identities are social constructs shaped in practice through on-going social processes of interactions between individuals, artefacts and the institutional context in which they are embedded (cf. Muzio et al., 2013). This approach challenges the traditional view that roles are presumed as relatively stable and settled in contractual agreements and/or dictated in cultural relations (Georg and Tryggestad 2009).

Individuals actively strive for making sense of their work life (Gioia et al., 2010) where practice influences identity creation and vice versa. Here the construct of role has been suggested as a meaning creating device (Simpson and Carroll 2008), where role identification in the development of professional roles endures over time but also across organizational boundaries (cf. Löwstedt and Räisänen, 2014). However, self-identifications among managers within the construction industry, regardless of their functions and responsibilities, often relate to an idealized role of someone that knows ‘how to build’ (Löwstedt and Räisänen 2014; Styhre 2012).

FINDINGS

After a thematic, foremost empirically-driven and iterative analysis guided by the analytical framework, three main areas emerged that relate to a new group of actors within the construction industry working with employment requirements in procurement, hereafter named “employment requirement professionals (ERP)”. These themes relate to (1) how these professionals define their organizational space in terms of organisational belonging, responsibility allocation, role identification, and knowledge domain, (2) how they frame their social identity, and (3) what work practices they adopt.

Defining a professional space and knowledge domain - organisational belonging, responsibility and role identification

The number of people who works with employment requirements within the construction industry in Sweden is quite few, and most of the ERPs work alone or as members of small internal networks. Even though the interviewees have quite diverse backgrounds in terms of education and previous professional experiences, the interviewees’ role could be divided into three different types. First there is the coordinator role, who creates space for and manages coordinating activities within and across organizational boundaries. The
Coordinators work with employment requirements either full time or part time, sharing this task with other duties like administrative tasks, business development, or working with recruitment. Second, there is the internal sustainability manager/expert, where employment requirements, as part of a social sustainability frame, are a targeted focus, sometimes together with other sustainability areas, e.g. ecological sustainability. Third, there is the procurement manager/specialist who mainly work with procurement, but that has been assigned responsibilities related to employment requirements as part of this area.

For the interviewees, many of their roles are new, and often instigated and designed by the interviewees themselves. Many have proposed the need for their role or got it as an extension of another role, as a sustainability manager (S4) puts it: “I have created this role as a sustainability manager, [the need for a role] was my suggestion and a seed I planted within the organization”. As such they are also involved with continuously developing their own roles as new areas of responsibilities becomes needed. In many ways, the role maintenance and development is an ad hoc process, largely influenced by sudden events that need immediate care, e.g. the large inflow of refugees in 2015. Also, many feel as they need to go beyond their formal role description and collaborate with others in order to fulfil their responsibilities: “it’s about finding other channels than the ones we might have, to provide opportunities for the contractors (...) to thereby establish new contacts which I can use (...) We take that extra responsibility when it comes to employment requirements so we can support the contractor as far as we can (...), just because it is employment requirements we want to help a bit more” (employment officer, C7). This act of stepping outside the normal working routines, includes contacting local football clubs in order to find potential employees, spending off-duty hours reading about social procurement initiatives, and initiating discussions with stakeholders to exchange knowledge.

Because implementation of employment requirements is a multi-party activity, there is no unified view regarding where the responsibility of employment requirements should be. The interviewees propose that the responsibility could lie either within a specific sustainability function, within HR, within each individual construction project, within the purchasing department, or at the Employment Agency. However, even though employment issues are generally related to HR activities, none of the organizations the interviewees represent have placed responsibility for employment requirements within the HR function. Instead, some of the organizations have deliberately placed it within a business development function to be integrated into the organization’s core business: “it was a strategic choice not to label [employment requirements] CSR. We have instead chosen to place it within a business development [frame] (...) because we [the Company] should offer sustainable solutions to all our clients, in every business deal” (development strategist, S2). Similarly, a sustainability manager (S4) said: “it’s not only about pulling your weight, it’s also about business development. There is commercial value in this, that is why we do it”.

There is also uncertainty regarding to what extent the interviewees, who mainly work on a strategic level, should work operatively with employment requirements, where a development strategist (S2) said that: “we try to find a balance, to find a suitable level for engagement, and then find other ways in which we can help the projects to realize what they want in practice”. Although they get ‘involved’ in operative tasks they currently feel they lack time and resources to do both. A sustainability manager (S8) says that: “there has to be a competent person here [in the Company] who actually asks the question ‘how do you (contractor) plan to solve this? What are your difficulties? Why aren’t we meeting you (contractor) halfway? Can we help?’.”
Much like the diverse roles and background of the ERPs, and due to ambiguous organizing of employment requirements, the knowledge domain connected to employment requirements is undeveloped. There is no national “government sanctioned” definition of what employment requirements should entail, and many of the interviewees feel that this makes their work problematic: “it’s incomprehensible that there is a non-existent national support, when the government in the next moment says it’s such a gigantic issue” (sustainability manager, S7). The interviewees also explain that it can be difficult to pin-point social sustainability activities: “many [employees] are very experienced in building sustainable concepts, but they haven’t even realized that it is sustainability” (sustainability manager, S7). The interviewees explain how learning is often informal, ad hoc and difficult to transfer: “every new procurement is like a new mountain to climb. Sometimes it’s very difficult to learn from one project to another” (business developer, C5). In absence of commonly shared practices and routines, one project manager (C3) referred to this type of learning as “walking in the moccasins to understand the process”.

Social Identity and the Value of Personal Engagement

Considering the diverse background of the interviewees and the sometimes lonely and difficult role they have within their own organizations, the interviewees’ need for a personal driving force is frequently emphasized. Their own personal commitment and engagement is often stated as crucially important for their work: “80% is about people who are personally committed and who believe in what you do, and then the strategic elements are 20%.” (Process leader, S3). Connected to their personal driving force for working with employment requirements, there are different types of social roles that the interviewees identify themselves with, related to their driving forces. First there is the ideologist, who choose to describe themselves as the good and caring society builder, who contribute to a larger social system of public welfare, seek to help individuals, by offering ‘meaningful’ employment opportunities so they can create a better life for themselves, which would benefit to society as a whole. Second, there is the problem solver, who are triggered by the complexity of and uncertainty involved in implementing employment requirements. They are driven by the idea of finding a “recipe” that makes employment requirements commercially profitable. Third, there is the bureaucrat, who is the least represented type among the interviewees. The bureaucrat is committed to employment requirements due to political or company policy. There are little sentimental values in his or her work, but rather a drive to perform work in a good and directive-abiding manner.

The interviewees thus explain that this engagement is driven from their own personal interests and virtue of being a problem solver: “we are problem solvers, and that’s good, because we are never afraid to get involved with things that are difficult” (sustainability manager, S7), and “I’m damn curious (...) I see myself as a problem solver and someone who drives development” (sustainability manager, S4). The interviewees are also interested in the extraordinary work tasks related to employment requirements, “we are ordinary employment officials who thought it would be a fun thing to do something besides the [ordinary] work tasks we have in the office” (employment officer, C4), and “it’s a fantastic mission to try to find a model where those coming as refugees could join the labour market” (process leader, S3). The engagement is often based on the self-identity as a good society builder but also on the perception of filling an important space within the organization: “suddenly I am the only one among 11 000 employees who knows something about something” (development strategist, S2).
Collaborative and Communicative Work Practices

The interviewees describe their daily work in a quite similar manner even though they have different professional roles and backgrounds. The interviewees indicate a processual nature of their actual work tasks as they use a lot of active verbs, which roughly fall under three interrelated categories, operational, educational and co-creating activities. Even though the interviewees work mainly on a strategic level, the first category concerns operational activities where they in a rather hands-on manner ensure that employment requirements can be practically implemented by solving problems etc.: “I’ve tried to make it as easy as possible, by coming with suggestions, and templates they can simply cut and paste” (project leader, C1).

Secondly, educational activities mainly concern agenda setting and convincing people of the importance of employment requirements. One of the main issues ERPs must deal with is to communicate knowledge about employment requirements to other employees in their organization and other stakeholders: “one task that is important for me is to make sustainability understandable and tangible, both externally for our stakeholders, and internally” (sustainability manager S7). As such, they are extensively engaged in educating colleagues, management, construction workers, partner organizations, and other external actors like clients and suppliers. When the interviewees talk about their role as informants, they use words as ‘teacher’ or ‘gardener’ to emphasise their work mission. Teacher is used to describe themselves as messengers of top-down information, stating that they “are out [there] educating construction workers (...) I meet so many people in the Company because I teach so much, many, many thousands of people every year” (sustainability manager, S7).

The gardener metaphor also relates to a third category of tasks, co-creating activities. One sustainability manager (S7) states: “you have to grow people, and it takes time to grow competence”, and another “It’s so important that [employment requirements] are promoted in the right way, that a seed is planted” (sustainability manager, S4). In co-creational activities, collaborative space across organizational boundaries is created to develop competences and practices together, partly in an effort to overcome some of the complexities created by employment requirements. One sustainability manager (S7) explained that: “I believe in knowledge, to give people tools, because you own what you’ve been part of creating, and what you own you take responsibility for. You will never let go of what you feel responsible for”. Co-creation is thus highlighted as important daily work, “we do this together, we hold hands and we have done this [employment requirement initiative] together with ‘Organization X’ (...) and we do this jointly because together we can reach out” (development strategist, S6), and “if this is going to be social sustainability, ergo over time, then we must have everyone on the train and they must sit in the same carriage” (process leader, S3).

DISCUSSION

Similar to previous research (e.g. Sutherland et al., 2015), a creation of new professional roles in relation to employment requirements can be seen also in the Swedish construction industry. These were often sold to the company and filled with ‘substance’ by the role holders themselves. Much like theory states (Brown and Phua 2011), existing roles seems to be developed in an iterative process where new issues and sudden changes to the area of employment requirements influence the role, like for example the refugee crisis. Even though the roles often were self-created and iteratively developed, the interviewees described their role as ambiguous due to a discrepancy between personal expectations and expectations from others. Kabiri et al., (2012) states that expectations generate roles,
which in turn reflect demands and pressure from others, and in the case of employment requirements this was particularly clear. Due to unclear responsibility allocation, they had to navigate between sometimes conflicting roles, e.g. between their formal strategic role and informal supporting, operative role prescribed to them by others (cf. Barraket et al., 2016). As a consequence, they on the one hand were torn between their long-term focus and strong personal engagement in the subject, and giving practical advice to a vast amount of people on the other, which led to undue pressure on them to fulfil perceived expectations. Moreover, the interviewees talk much about the unclear knowledge domain in which they work. If a knowledge domain is still developing and competencies among professionals is missing, if learning is ad hoc, and if knowledge is difficult to transfer, then it might also be difficult establish a professional role.

As professional practice is closely tied with professional identity (Brown and Phua 2011), this would then suggest that ERPs are influenced by how they see themselves and their role, and vice versa. The findings indicate three main identities among the interviewees: the ideologist, the problem-solver and the bureaucrat. Looking to what the interviewees describe that they do in their work, similar patterns can be seen. They inspire courage for change, they plant seeds and grow people, educate, and convince others of the potential of employment requirements, actions that could be associated with the ideologist. They also ensure things gets done, concretizes employment requirements and break barriers, which could be associated with the problem-solver. Finally, they also serve, provide support and comprehensive solutions, which could be associated with the bureaucrat. Therefore, the results correspond with theory which states that identity guides everyday practices and behaviour (Styhre 2012).

However, just like identities influence what professionals do, work practices also influence who the professionals identify as (Gioia et al., 2010). The findings suggest that employment requirements lead to increased complexities and collaboration needs, much like described in previous literature (Barraket et al., 2016). The knowledge domain is also unclear, and much of the work is ad hoc. This means that the work of ERPs poses demands on their identity as well. For example, because the work entails problem solving, they are problem solvers, or because the work entails helping people inside and outside of the organization, they are ideal society builders, or because they create templates and guides to facilitate implementation of employment requirements and dissemination of practices, like also suggested by Barraket et al., (2016), they are bureaucrats. In this sense, the ERPs’ role might function as a meaning creating device (Simpson and Carroll 2008) to understand their complex work tasks.

This mutual reinforcement of self, identity, and work practices may be further influenced by the interviewees’ personal driving forces. The interviewees spoke in length about their reasons for conducting their work, where many of them referred to their personal characteristics such as liking to solve problems, helping others, educating and communicating. This is similar to what has been found in professionalization literature, where professionals’ “doing” includes problem solving, adherence to codes of ethics, and having expertise (Styhre 2011). These main activities suggested by professionalization theory corresponds well to the operational, educational and co-creating activities described by the interviewees, who solves problems, are ethical builders, and who are experts supporting their organization.

The emphasis the interviewees place on these identities, work practices and characteristics is perhaps because they come from such diverse backgrounds, some of which is not typically related to the idealized role of someone that knows ‘how to build’
Therefore, relying on an adopted identity and role might be easier than relying on one’s previous educational or professional background and affiliation, especially as the interviewees collaborate and co-create extensively across organizational boundaries. These identities, work practices, and driving forces can therefore perhaps unite a profession which is still under development in an unclear knowledge domain.

CONCLUSIONS

Increased use of employment requirements creates both opportunities and complexities for the construction industry and its actors, their identities, roles and work practices. Due to the unclear knowledge domain, uncertain allocation of responsibilities, and iterative role development, actors working with employment requirements are perhaps not a cohesive profession, even though the actors may be undergoing a professionalization process. For practitioners, this insight may create an understanding for what their future professional space might be, potentially making collaboration and co-creation processes across organizational boundaries clearer. This could subsequently enable a dissemination of practices (Barraket et al., 2016), and facilitate an establishment of a specific knowledge domain. For theory, this means that the quite scarcely investigated concept of employment requirements becomes more transparent. The findings may also enable a better understanding of how a single concept, which in this case mainly belongs within procurement activities, can affect many areas of an organization and an industry, and how professionalization processes might be hindered due to issues with knowledge domains, conflicting demands on responsibilities, and ad hoc, iterative development of roles and work practices.

Future research could further investigate employment requirements and its organizational implications by studying emerging work practices. This study on role implications could also be extended by including actors working on a more operative level, like the newly employed and the more traditional construction workers. Such an extension could provide a more comprehensive picture of how employment requirements affects specific actors in the construction industry.

REFERENCES


PLANNING AND PERFORMANCE MANAGEMENT
LESS VISIBLE INNOVATION AND THEIR IMPACTS: A QUANTITATIVE ANALYSIS OF NON-CONFORMANCE

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In the construction industry, there is often little budget and motivation to innovate. Reasons include fear of disruption, perception that it does not add value and clients do not demand or reward innovation. This paper argues that lessons from project non-conformances (NCs) can instigate innovation in order to either mitigate identified issues or improve performance. Whilst the total cost of NCs has been alleged to be 10% of total project cost, little is known about the actual cost of recurring NCs to inform learning and innovation. The objective of this paper is to identify recurring trends in project NCs, their root causes and associated costs. Quantitative analysis of over 3000 NC data from 3 large projects in Australia was carried out. Findings identified 3 types of NCs accounted for approximately 75% of the total number of NCs across these projects. They were (i) Inadequate planning (ii) Process not followed and (iii) Inappropriate resourcing. The root causes of these NC types were: lack of expertise (e.g. skills), insufficient communication and limitations posed by other project constraints. Drawing on Social Cognitive Theory (SCT), a case for using NCs for driving organisational learning and innovation is presented.

Keywords: knowledge management, non-conformance, organisational learning

INTRODUCTION

Innovation is a very complex and multi-dimensional concept, heavily influenced by perception depending on whom you speak with (Goswami and Mathew, 2005). It is broadly categorised into technical and administrative innovations (Damanpour and Evan, 1984). One of the most popular perceptions however links innovation to novelty. By implication, you have to do something that hasn’t been seen or done before in order to innovate; be it technical or administrative. This perception may have limited most organisations’ ability to innovate. For clarity, this paper has adopted one of the most concise interpretations of innovation which states that “invention implies bringing something into being while innovation implies bringing something into use” (Mohr, 1969). It is an idea, process or technology that is new to the organisation, which may be an existing knowledge borrowed from elsewhere (Rogers, 1998). This type of innovation is non aggressive and hence termed “conservative” (Miller and Friesen, 1982).

Construction companies generally face many constraints, including limited number of projects and short-termism. Consequently, they are risk averse and conservative in terms of innovation (Gann and Salter, 2000). This research presents an assured way to innovate without being excessively exposed to risks. It focuses on ways to improve efficiencies (process innovation) in order to gain financial or competitive advantage in the market.

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Although most tier-one companies are ISO certified, the frequency of recurring NCs and their similarities across projects is concerning (Love and Edwards, 2004). This suggests lack of attention to this trend. The non-standardisation of classifications of NCs also makes identification of trends and subsequently control of NCs difficult (Jamaludin, 2008).

NCs have received a lot of attention from researchers in recent years. The majority of their works have focused on the costs of NCs (Love and Edwards, 2005, Love and Irani, 2003, Love and Li, 2000, Love, 2000). Others have looked at how to capture NCs and even proposed a number of tools to be used (Maheswari et al., 2016, De, 2009). However, little or no research has considered NCs as a driver for innovation. Similarly, construction organisations appear to be insensitive to this opportunity to invest time and resources into innovating solutions to these pressing needs (Love and Li, 2000). The reality is not in doubt; costs of rectifying NCs are high and deplete the profit margin of construction companies whilst also making them less competitive (Abdul Rahman et al., 1996).

In order to justify the investment in innovation, this research proposes to link top recurring NCs to the overall project performance, including its relationship with the total project cost. Hence, the objectives are to (1) Demonstrate the impact of non-conformances on contractor performance, and (2) Propose a theoretical framework that will inform how non-conformance data can drive innovation with a view to improving both competitiveness and profit margin of the organisation.

Consequently, a quantitative analysis of NC data from 3 large projects in Australia was conducted. The process included codification of NCs to ensure a like-for-like comparison. The findings of this study presents project NCs on a platform that makes it assessable and relevant to the users. The ranking of the recurring NCs will facilitate either the introduction of new processes or refining of existing ones to deliver on better goals by eliminating identified issues. This paper is structured as follows: A review of the body of work already done in this domain is presented. This includes establishing what is obtainable in practice and thereby identifying any gap/s that may exist between research and practice. This is followed by the theoretical framework that underpins this study as well as all related concepts. The research method adopted for this paper is then discussed followed by the findings. In the final section, a conclusion is drawn, addressing the top root causes of NCs identified by the study.

**INNOVATION, NON-CONFORMANCE AND PROJECT PERFORMANCE TRILOGY AND DEFINITIONS**

Some projects record every non-conformance in order to learn from them. However, anecdotal evidence suggests that most projects either do not report them at all or under report the occurrence or the associated costs and that they tend to suffer time or cost (or both) overruns. NCs, innovation and project performance are interrelated concepts. NCs and project performance are however on the opposite sides of the spectrum in that an increase in one sometimes suggests a decrease in the other. Whilst NCs are not desirable because of the resulting rework and its associated cost to the project (Love, 2000, Love, 2010), we view capturing NCs as a great opportunity to improve project performance by focusing innovation on eliminating recurring NCs. These may be new ideas adopted from other places or simply refining existing processes to eradicate the cause(s) which will in turn improve project performance.
Innovation

Despite being one of the most debated concepts, researchers agree that the value of innovation is to deliver profit or economic value to parties involved (Goswami and Mathew, 2005). However, not all innovations successfully deliver value to the proponent, despite their good intentions (Kimberly, 1981). Innovation is often seen as novel, hence the mix up with invention. Some of its definitions include inventing something new, a new idea or concept, introduction of a new product etc. (Evans, 1991). In this study, innovation is defined as the introduction of a new or refined way of doing things, which although may be new to the organisation, has been implemented successfully elsewhere. This aligns with Rogers' position that innovation may be in the form of completely new method or a transfer of knowledge from other fields or organisation (Rogers, 1998). Innovation ultimately results in improved performance and competitive edge through increased efficiency (Tatum, 1988).

Non-conformance

NC is arguably one of the most controversial concepts in quality management. It is heavily influenced by perception, hence the challenge faced by organisations in effectively implementing it. An indicator to its divergent perspectives is captured in the various terminologies used in referencing it and the different interpretations given to it, both in practice and research (Love, 2002b). ISO 9000:2005 defines a defect as “nonconformity with specified requirement” whilst ISO 9001 defines non-conformance as “deviation from agreed specifications or requirements”. As a result of this divergent views, majority of construction organisations either do not capture non-conformances at all or fail to capture its true cost and impact on their business (Love, 2000). The logic behind this is simple, when people don’t see value in a process; they will not invest their resources into it. This simply negates the "Plan, Do, Check, Act" (PCDA) philosophy as postulated by Edward Deming (Meiling et al., 2014). A quality outcome is premised on adequate planning and execution of processes. The purpose of capturing NCs and its associated costs on projects is basically to identify areas where improvements can be focused for increased efficiency and competitive edge (Love and Smith, 2003). The success of this exercise is dependent on access to good data.

Project Performance

In the literature there is no convergence on the definition of project performance (McCoy, 1986, Liu and Walker, 1998). Whilst there are divergent perceptions and definitions, all parties tend to agree that some requirements have to be met for a project to be deemed to have performed very well; be it internal (i.e. participating construction companies), active stakeholders (i.e. asset owners) or passive stakeholders (those impacted by the project). The needs can be grouped to include cost, time, quality, functionality, durability, etc. For the purpose of this paper, project performance is defined as an outcome that meets the goals and objectives of all participants and stakeholders involved on a project.

Relationship between Innovation, Non-Conformances and Performance

Often, the common indicator of the quality of a product or service adopted in practice is rework. Rework on the other hand has been linked to quality; being measured as rework occurring from non-conformances (Roundtable, 2005). (Harris and McCaffer, 2013) defined quality as the combination of all attributes (goals and objectives) of a project that ensures it meets the requirements of all stakeholders. The definitions above clearly chart the impact of non-conformances on project performance; non-conformances lead to
Adio and Aibinu

Rework, rework impacts project quality and project quality is one of the key metrics upon which project performance is measured.

As shown in figure 1, the ability to identify the root causes of recurring NCs will ensure innovative efforts (e.g. new strategies for preventing recurrence in the future) are concentrated on the area of need which in turn leads to improved project performance. Whilst novel innovations are great, they should not be confused for invention; it may present in form of simple improvements or even adoption of processes previously used in other organisations or industries e.g. cross pollinating ideas between, for example, aviation and construction industries. Imagine a hypothetical project of $100M. The cost of rectifying NCs will be approximately 10% of the project cost, i.e. $10M (Ison., 1995).

![Figure 1 Relationship between NCs, Innovation (I) and Project Performance (PP)](Image)

If the project can identify the most recurring NCs or those responsible for the highest percentage of the cost of rework, then the project can innovate specifically to solve this problem. The implication of this is a potential savings of all or most of the cost of rework; $10M. Whilst the scope of this paper is limited to the three interrelated concepts discussed above, there are other concepts that have influence on them. For instance, proper documentation and analysis of NCs ensures organisations can learn from their errors. In order to convert NCs to genuine lessons learned, they have to go through the process of codification, storage and ultimately made easily assessable to the organisation. The concepts of NCs, Lessons Learned (LL) and Knowledge Management (KM) are clearly inseparable and they are the bedrock of genuine innovation. Previous works had put forward this argument that without a body of knowledge, properly managed and disseminated, there would be nothing to drive innovation (Du Plessis, 2007).

Underpinning the interdependences illustrated above is the Social Cognitive Theory (SCT). The human mind is generative, creative, proactive, and reflective, not just reactive (Bandura, 2001). “Through the exercise of forethought, people motivate themselves and guide their actions in anticipation of future events. When projected over a long time course on matters of value, a forethoughtful perspective provides direction, coherence, and meaning to one’s life” (Bandura, 2001)

Accordingly, when people know the consequence of their actions or inactions, they make better decisions to attain their desired outcome. The analyses of the root causes of NCs can provide organisations with key issues to eliminate in order to make significant savings on projects. This gives them the motivation to innovate solutions.

**Method**

This paper adopted the quantitative research method for identifying and analysing the most recurring NCs and their correlation with cost of rework. The selection of the 3 projects (P1, P2 and P3) under review was informed by the size and complexity of the projects. Large projects typically take between 3 to 4 years to complete; hence the selected projects were among the most relevant in that decade. As one of the key approaches of this paper is to identify trends, it is necessary to compare data from multiple projects of similar size and nature. This requirement fit perfectly into the definition of a quantitative research method; the evaluation of pre-existing or newly
obtained data through numerical, mathematical or statistical analysis with a view to identifying similarities, disparities and trends in data from multiple sources in order to answer specific research questions. (Wolf, 1986, Creswell and Clark, 2007). Essentially, the projects entail key aspects of civil works which includes earthworks, structural works, structural steel, services relocation and or installation. The 3 projects adopted a collaboration system platform for handling Correspondences, Contract Administration, Safety, Environment, Human Resources and Quality Management. NCs, Request for Information (RFI), Design Change Management and Lot Management were all hosted under the quality management module of the respective collaboration systems. Because of the size and complexity of these projects, they were either executed via alliancing or joint ventures involving 2 or more of the top five construction firms in Australia. These data were therefore representative of a complex and large projects.

Having gained access to an excel export of NCs from these collaboration systems, the first activity required was to import each file into a standard template ready for analysis. On the three projects, the 3,092 NC data entries were not classified the same way. Consequently, entries were reclassified where necessary and in some cases the primary causal factor (root cause) were identified and noted on the spreadsheet. The entries were then statistically analysed to identify the number of recurrence of each of the NCs and subsequently the root causes. The costs of rectifying each of the NCs were also graded in order to identify the root causes associated with the highest cost of rework. As was the case with the disparities noted in the categorisation of NCs, costing of rework was also not consistently captured. Hence, systematic format for costing NCs was developed and applied across the three projects. This included a minimum cost of NCs which was derived by taking into account the standard cost of labour per hour for engineers, designers, materials and other forms of resources involved in the processing and rectification of the NC. A typical processing entails identifying the nonconformity, isolating the product or process, analysing the root cause, determining the remedial action and lastly executing a corrective action. This average cost was set at $500. NCs with the “use-as-is” disposition would generally belong in this category. This category includes minor NCs like achieving a concrete strength of 39Mpa instead of 40Mpa. Although the result was less than specified, it may be left as is due to it having little or no impact on the durability and functionality of the product. This category of NCs however does take time to close out due to the need to convince the client to accept as is. By setting this minimum value, it was then possible to establish a benchmark against which the impact of NCs could be measured across different projects. The top five most recurring NCs were then tabulated and presented in tables 2 and 3 alongside the root causes and associated costs.

FINDINGS AND DISCUSSION

As discussed in the methodology, the magnitude of disparities in the classifications of these NCs does not allow for easy comparison (Jamaludin, 2008, Love, 2002a). The classification grouping adopted is presented in Table 1. Table 2 summarises findings from the three projects analysed respectively. Though Peter Love (2002a) submitted a novel taxonomy for classifying NCs, it was targeted at indirect consequences of NCs and hence not suitable for a complex project.

The analysis found a high level of underreporting or lack thereof, of the cost of non-conformances. In Project 1 (P1) for instance, 645 NCs were not classified whilst another 991 had no cost assigned to them. Out of the 991 not costed, 900 of them had the use-as-is disposition; meaning they had to seek the consent of the client in order to adopt a
finished product different from the specified (in quality, functionality, durability etc.). This highlights the need to standardise the classification of NCs in order to be able set benchmarks for future projects.

Consequently, a decision was made to apply a minimum cost of $500 to all NCs that were not costed across the 3 projects and also to classify NCs into 6 group types for easy and meaningful comparison. Firstly, a normalised classification table and that of recorded costs versus the adjusted costs are presented below.

**Table 1 Classification Template**

<table>
<thead>
<tr>
<th>NCR Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process not followed</td>
<td>Methodology, procedures and/or instructions were appropriate, but not followed</td>
</tr>
<tr>
<td>Design</td>
<td>Design deficient and/or late</td>
</tr>
<tr>
<td>Defective materials</td>
<td>Damaged/non-conforming purchased goods</td>
</tr>
<tr>
<td>Damage to the Works</td>
<td>Completed conforming works have been damaged</td>
</tr>
<tr>
<td>Inappropriate resourcing</td>
<td>Includes insufficient and/or incorrect plant/equipment/personnel</td>
</tr>
<tr>
<td>Inadequate planning</td>
<td>Methodology incorrect either through error or insufficient consideration, including insufficient communication</td>
</tr>
<tr>
<td>Requirements not met</td>
<td>If not other root cause applies but specified tolerances have still been exceeded</td>
</tr>
</tbody>
</table>

**Table 2 Analysis and comparison of NCs across the three projects sampled**

<table>
<thead>
<tr>
<th>NC Type</th>
<th>No of occurrence</th>
<th>Percentage</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P 1</td>
<td>P 2</td>
<td>P 3</td>
</tr>
<tr>
<td>Inappropriate resourcing</td>
<td>715</td>
<td>373</td>
<td>719</td>
</tr>
<tr>
<td>Process not followed</td>
<td>230</td>
<td>168</td>
<td>89</td>
</tr>
<tr>
<td>Inadequate work planning</td>
<td>175</td>
<td>163</td>
<td>109</td>
</tr>
<tr>
<td>Design</td>
<td>13</td>
<td>44</td>
<td>4</td>
</tr>
<tr>
<td>Defective Materials</td>
<td>3</td>
<td>80</td>
<td>3</td>
</tr>
<tr>
<td>Damaged works</td>
<td>3</td>
<td>54</td>
<td>19</td>
</tr>
<tr>
<td>Requirements not met</td>
<td>2</td>
<td>37</td>
<td>89</td>
</tr>
<tr>
<td>Total</td>
<td>1141</td>
<td>919</td>
<td>1032</td>
</tr>
</tbody>
</table>

**Table 3 Disparity in NCs cost report and true costs, including adjusted values**

<table>
<thead>
<tr>
<th></th>
<th>Reported cost of NCs</th>
<th>No of NCs not costed</th>
<th>Total projected cost of NCs not costed (Admin cost only)</th>
<th>Adjusted cost of NCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project 1</td>
<td>$511,671.00</td>
<td>991</td>
<td>$495,500.00</td>
<td>$1,007,171.00</td>
</tr>
<tr>
<td>Project 2</td>
<td>$369,515.00</td>
<td>N/A</td>
<td>$1,535,940.00</td>
<td>$1,905,455.00</td>
</tr>
<tr>
<td>Project 3</td>
<td>$469,197.00</td>
<td>893</td>
<td>$446,500.00</td>
<td>$915,697.00</td>
</tr>
</tbody>
</table>

*These values have been factored to disguise the projects.

A major constraint encountered during this analysis was the lack of ability to re-calculate the actual costs of rectifying these NCs, due partly to the retrospective nature of the review. A rule of the thumb for the industry splits cost of material versus labour into a 30:70 ratio. Should this rule be applied, the cost of NCs will increase by a factor of 2.3, taking the costs to $231,6493, $438,2546 and $210,6103 respectively.
One of the key findings of this analysis is that projects don’t appear to prioritise capturing costs of NCs. This is demonstrated in the 3 projects analysed. In Project 1, 86% of NCs were not costed. In Project 2, cost of NCs was undervalued by over 65% and in Project 3, 85% of NCs were not costed. The Social Cognitive Theory suggests that organisations will prioritise capturing NCs and its associated costs when they know how much impact it has on their performance. Without capturing these NCs, there is no way to assess these impacts on the projects and consequently no motivation to innovate.

Similarly, where costs were recorded, they were significantly less than the benchmark minimum unit cost of NCs of $500. In each of the cases, 88%, 60% and 88% of the NCs were below the benchmark. This implies that projects will be unable to justify the cost of innovation due to their inability to capture the actual costs of NCs. The inability to capture NCs can also be attributed to the lack of proper ontology on the concept. Hence the approach of establishing a naming convention and standard categorisation of NCs, which is novel to this paper, will eliminate ambiguity and ensure NCs can be captured, monitored, costed and compared across projects.

It was revealed through the analysis that standardising NCs enables trends to be identified, which previous researches did not do. The top three most recurring NCs across the 3 projects were Inadequate Planning, Inappropriate Resourcing and Process not followed. The 3 combined, make up for approximately 80% or over, of all NCs on these projects. Failure to recognise these could mean that the issues continue to repeat whilst the projects have no basis to innovate and as a consequence, project performance is impeded (fig 1).

The most recurring NC classification was Inadequate Resourcing (62%, 41% and 68% respectively). The contributing root causes to inadequate resourcing was found to be the lack of expertise/training by field personnel, which led to poor decision making or outcomes. By not identifying areas of focus, trainings may be untailored and haphazard due lack of direction, coherence and purpose (Bandura 2001). The predominant discipline related to inappropriate resourcing was as-built survey tolerance (54% of total number of NCs).

The best innovations are driven by needs. Innovations could manifest in form of a novel idea or an enhanced or existing idea. Innovation is only a means to an end when it comes to construction. This explains why very little is often invested in Research and Development. The identification of lack of training or expertise as the root cause for inadequate planning and the resulting costs however provides the necessary motivation to innovate in one form or the other. It provides the justification to invest in tailored training, revised or simplified process and even technology to tackle the recurring NCs. The impact of the 3 most recurring NCs on project performance is also evident. Project performance is a collection of needs, requirements or expectations of stakeholders. These needs or expectations are impacted by NCs or lack thereof i.e. cost overrun (impacted by cost of NCs), duration (inflated by non-productive time spent on NCs) and subpar product.

Developing outstanding organisational intelligence is premised on informative data. Figure 2 identifies NCs as a potential ingredient upon which the SCT could be based by providing the information that triggers forethought (Bandura 2001).

CONCLUSION

Noting that construction companies are in the business to make money, the ability to see how much money is lost to NCs will definitely change their perspective and move them
into action. In line with SCT, given the opportunity to know the potential outcome of an action before its done will influence the action taken to ensure it is tailored to the desired goal i.e. to make profit.

This paper identified survey as-built tolerance which falls under the broad category of inadequate resourcing, as the most recurring issue across the three projects reviewed. Inadequate resourcing encompasses lack of required skills or training, human error or mistakes amongst others. This outcome highlighted how new knowledge can be found or developed by organisations (Love, 2002a) to facilitate innovation.

Figure 2 Evolution of data

On the other hand, innovation can address this root cause of issues in a number of ways, including:

1. Innovating through improved system and control: Develop procedures to address the recurring issues. This may include engaging an independent surveyor to assist the teams. In addition to these, the projects may also set up control gates to check and verify conformance before works are made permanent.

2. Training: Investing in training to educate all participants in the construction process is another approach with potential results. This will ensure all the field staff are trained on what to look for and to construct within tolerance.

3. Innovating through technology: depending on the existing approach, the construction companies may also engage “state of the earth” technologies that will facilitate consistent conformance to specified tolerances.

Some of these interventions are not new to the construction industry all over the world. It is however mostly done as a fulfilment of a requirement i.e. by compulsion, especially when it is a condition of their contract. This paper however highlights the benefits and savings that proper planning and execution of these interventions could bring thereby making it an area of focus rather than a “side attraction”.

REFERENCES


Adio and Aibinu


ENTERING, UNFOLDING, EMBEDDING AND REVERTING: IMPLEMENTABILITY DIMENSIONS MADE EXPLICIT

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Implementability is a concept that is getting used more widely but is still poorly defined. A survey of a sample of 23 papers from the ARCOM conferences of the last five years with the word ‘implementation’ in the title demonstrates the absence of explicit definitions of the term implementation and a variety of implicit meanings. This vagueness in the use and meaning of the term implementation continues in the term implementability, which, said shortly, is the ability to be implemented. This paper aims at making the dimensions of implementability explicit. Four dimensions are distinguished on the basis of the results of the survey and the findings from an interdisciplinary literature study. The paper elaborates on each of these dimensions and takes them to practices in the built environment. It is argued that the implementability of a plan or decision is the degree to which this plan or decision can be entered, unfolded, embedded and reverted in the aimed organisation as expected by the designers or decision makers.

Keywords: implementability, strategy, de-implementation, buildability, change

INTRODUCTION

Said shortly, implementability is the ability to be implemented; it is the property of a plan or a decision to be executed as conceived. The aim of this paper is to come closer to a definition and operationalisation of the term implementability. It is an essential concept in the author’s current investigation into a tool that assesses ex-ante whether a corporate accommodation strategy is implementable. It is a central concept in the sciences of the built environment in general, where it emerges under the flag of other terms like feasibility, buildability and usability.

The investigation to which this paper contributes is fully embedded within the sciences of the built environment and integrates concepts of corporate infrastructure development and management, sustainability in the built environment, construction design, case-based reasoning and strategic management. This paper copies this broad approach and, when suitable, surfs to other domains and disciplines to make its point clear.

PROBLEM DESCRIPTION

Implementation has become a common term in management research and practice (see e.g. Pressman and Wildavsky, 1984). But, although it is used by many, the term is seldom stated precisely, as is confirmed by the short survey reported hereafter. This shouldn’t be an issue when its meaning was clear and its use consistent, but these are not the case as will be demonstrated.

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What then about implementability, the term that is derived from implementation? Implementability is used in mathematics and computer programming since more than fifty years (see e.g. Chadam, 1965) and in the management sciences since the 1980’s at least (see e.g. Fforde, 1985). The term is less common than implementation. Google reports 177 thousand hits for it versus 466 million for implementation. In contrast to its ascendant, implementability is not explained in a dictionary. As a consequence, the understanding of implementability shows worse than the understanding of implementation: it endures the lack of clarity of the term implementation and seems to miss a grounded definition.

Survey Set Up

The lack of consistency and explicitness of the use of the term implementation within recent publications in the management sciences is clearly shown in a survey of the papers of the ARCOM conferences of the years 2012 till 2016. The sample consists of all papers that contain the word ‘implementation’ or one of its derivatives in the title. There are 23 of such papers in those five years. The subjects of these papers evidently relate to the construction sector and cover implementation issues about building information modelling (9 papers), supply chain management (2 papers), a particular project, an idea (general), inclusive design, innovation strategy, lean construction, off site production, public private partnership, procurement strategy, reverse logistics, risk assessment and management, social value, and sustainability.

The survey sought for answers on two questions: (1) Is there an explicit definition of implementation in this paper, and if yes, what is this definition? (2) What is the dimension of implementation that is addressed? The survey was supported by a qualitative data analysis and research software (Atlas TI). Hereafter the papers2 of the sample are called P1 till P23.

Findings

Just two papers of the sample contain an explicit definition of implementation, although implementation is a key concept in all selected papers and the term is used in the title of each of them. For paper 3 (P3) the implementation of an idea is “the introduction of the solution into the market, transforming of the tested idea into adoption of users”. P17 refers to literature and defines the implementation of information systems as “the process of reconfiguring a complex set of technologies, actors and activities within existing systems comprised of various existing organisational, cultural and social characteristics”.

What the papers understand by the term implementation can also be derived from the wording, such as the way the author’s position implementation against other terms. This delivered the following variety of dimensions. For P4 implementation comes after design. Following P3 it is the next step after idea generation and idea development. A common enumeration in the papers is ‘adoption and implementation’, which pops up.

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Implementability Dimensions

seven times in five different papers (P5, 7, 9, 13, 17). Other combinations are ‘awareness and implementation’ (P7), and ‘adoption, usage and implementation’ (P7). Enumerations where implementation goes first are ‘implementing and using’ (P17) and ‘implementation and operation’ (P23). These findings do not deliver a consistent meaning for the term.

Another way to detect the hidden dimensions of the term implementation is by analysing the paper as a whole. This results in three groups of papers. Within the largest group - 15 papers of the total of 23 - the term implementation is used for inserting something new in an organisation. Here implementation refers to changing the organisation by the deployment of a new technique or method. For the second group of papers the term implementation means using a certain technique or method (P6, 10, 11, 15, 16, 21). The term then refers to applying a method, to operating the organisation with the method embedded in it. In this second group of papers the aspect of change is absent. From two papers (P9 and 23) it couldn’t be settled whether the term was used in one of the two ways mentioned above or another way.

Table 1 - The results of the survey structured per implementation dimension. The arrows $$\Rightarrow$$ indicate that this dimension is included in the term of the previous column.

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<th>second dimension</th>
<th>third dimension</th>
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<td>introduction</td>
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<td>adoption, usage</td>
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<td>from the whole paper</td>
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Table 1 summarizes the findings of the survey. The term implementation is seldom made explicit, and the definitions that can be extracted from the papers are not consistent. Having integrated these findings and settled on the contradictions, the following can be concluded: implementation comes after design and consists of (1) the introduction of the plan or decision in the organisation, (2) its unfolding there, and (3) its use.

Structure of the Paper

The short survey sufficiently demonstrates the need to define the dimensions of implementation and its derivative implementability before the design of an implementability assessment tool can start and for better management research and

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3 These terms and also the terms ‘using’ and ‘operating’ on the next line do not come from the papers. They are used by the author to describe the dimension of implementation that is used in the paper.
practices. The aim of this paper is to unhide the dimensions of the term. The research methods used are an interdisciplinary literature study, the small survey reported above and a conceptual integration of the findings of both.

The explanation starts with a basic definition of implementability followed by a reflection on the complex relation between a plan or decision and its implementation. Thereafter the four dimensions of implementability are presented one after the other. Examples taken from the built environment are added for each. The paper concludes by positioning related concepts using these four dimensions.

A DEFINITION TO START WITH

As said already, implementability is not an uncommon term in management literature, but the word can’t be found in any English standard dictionary. Its primitive ‘implementation’ is described as ‘the process of putting a decision or plan into effect or execution: “she was responsible for the implementation of the plan”’ (Oxford Dictionary). Implementability should be defined in line with terms with a similar etymological structure like usability, scalability and profitability. These terms are compounds of ‘use’, ‘scale’ or ‘profit’ with ‘ability’. It is also correct to consider them as compounds of ‘usable’, ‘scalable’ or ‘profitable’ and ‘ity’ (Etymonline, 2017). Oxford Dictionary contains two slightly different meanings for such compounds. The dictionary defines scalability as “the capacity to be changed in size or scale”. Usability is defined as “the degree to which something is able or fit to be used”. In line with these definitions, implementability can be defined as the capacity to be put into effect, or the degree to which something is able to be executed.

Implementing is realising what is planned for. It is going from a little to a lot, and thrives on a divergent way of thinking. Implementing is about doing and acting rather than envisioning. Implementability is the property of the plan or decision to be treated this way, to undergo such process. It is the degree a plan or decision works out in the predicted way (Schumpeter 1976 by Orstavik, Dainty, and Abbott, 2015: 2). Related concepts in the sciences of the built environment are feasibility, executability, constructability, buildability (see also Table 2).

THE PLAN VERSUS ITS EXECUTION

In general, implementing is seen as the counterpart of designing and decision making, and comes after it. Designing is for the thinkers, implementing is the domain of the doers. But, the relation is far more complex.

Since Mintzberg indicated that a strategy can be a plan, a perspective, a position, a ploy and a pattern (Mintzberg, 1987), it became clear that strategies aren’t executed straightforward after they have been decided. Some are further elaborated or cancelled, some emerge during the implementation of others (Mintzberg, 1978). Mintzberg finished with the linear model where designing comes first, and executing thereafter and stressed the overlapping. His scholars Chakravarthy and White (2002) note that “strategy formation and implementation are closely intertwined. Decisions and actions together constitute the ongoing strategy process, and they influence each other” (Chakravarthy and White, 2002). Implementing is about pragmatic acting at the lower level in the organisation, but it is also about decision making at this level, which may entail a bottom-up process.

Gioia (2006: 1713), scholar of Weick, goes further than Mintzberg. He observed that people think by acting and that organisations in fact formulate strategies after they have
implemented them (Weick, 1977). For Weick a strategy is making the past consistent to allow for further action. Strategic management then is the process of sense-making, and organising is “creating stable interpretations of equivocal displays” (Chakravarthy and White, 2002: 191).

Within construction management the overlap of the plan and implementation stages and the blurring of the decision making levels is less present. Project management concepts and tools come in when a plan is clear, its chance of realisation is high and the lines of command aren’t contested. When these conditions are not sufficiently met, process management concepts and tools are more appropriate (De Bruijn, Ten Heuvelhof, and In ’t Veld, 2002).

FOUR DIMENSIONS

The small survey has demonstrated that the term implementation is used with naivety. It appeared also that scholars unknowingly give it at least three different dimensions. This impedes the work of designers and decision makers. When developing a plan or making a decision, they not only define the goals of the plan or decisions and the means to execute these. Explicitly or implicitly they also define the implementability of the plan. And this is done now with poorer precision than suitable. Plan and decision failures are the consequence (Gadiesh and Olivet, 1997).

Figure 1 - The four dimensions of implementability of a plan or decision in an organisation

It is argued in this paper that designers and decision makers consider four dimensions for the implementation of their plan or decision (see Figure 1). Three of these have been covered in the survey: entering the plan or decision in the organisation, unfolding it there and using it. Recent literature (see hereafter) refers to a fourth dimension: reverting the plan or decision from the organisation when this plan or decision malfunctions or is no longer needed. These four dimensions are explained hereafter.

ENTERING

The first sort of implementability designers and decision makers may consider, is whether the plan is able to enter the target organisation. The survey of the sample of 23 papers reported about this dimension through wordings as introduction, adoption and awareness (second column of Table 1). The plan or decision should pass the perimeter of the organisation first. It is not implementable when it doesn’t meet this criterion.

This dimension of implementability is not opposed by the knowledge that design and execution may overlap (Chakravarthy and White, 2002) or that their traditional order may even be reversed (Gioia, 2006: 1713). Not only wide plans and decisions, but also incremental acting may be rejected by an organisation.

The case of Ignaz Philipp Semmelweis (1818-1865), a Hungarian physician now known as an early pioneer of antiseptic procedures, is a good example of the difficulties that may...
arise to enter an established practice (Semmelweis University, 2017; Wikipedia, 2017). The doctors' wards in Vienna, where he was working, had three times the mortality of the midwives' wards. Semmelweis discovered that the incidence of the often fatal childbed fever could be drastically cut by the use of hand disinfection. In 1847 he proposed the practice of doctors washing hands with chlorinated lime solutions when moving from the mortuary to the wards, and showed that hand washing reduced mortality to below 1%. Semmelweis’ observations however conflicted with the established scientific and medical opinions of the time and his ideas were rejected by the medical community. Since, the Semmelweis reflex is given to human behaviour characterized by reflex-like rejection of new knowledge and practices because they contradict entrenched norms, beliefs, or paradigms (Nissani, 1995).

Within the built environment, this first dimension of implementability can be observed at several instances. It is present in the reluctance of the construction sector to innovate, of which “the suspicion has lingered that the industry is in the grips of particular stakeholder interests that uphold the status quo” (Orstavik et al., 2015: 3). The entering dimension is also present in the approval procedures for new building designs, which should be accepted by the commissioner and the stakeholders entitled with its approval. Here the organisation into which the plan should be able to enter is the firm of the commissioner and the committees with approving power.

**UNFOLDING**

The second dimension of implementability is unfolding the plan or decision in the organisation and make the organisation evolve from its current state into the state aimed by the plan or decision (Loorbach, 2010). A plan that can enter an organisation, is not necessary a plan that can be unfolded in it, and vice versa. And an organisation with unfolding potential may be averse to entrants, and vice versa.

The unfolding dimension is the most common dimension of implementation. Along this dimension, implementation is considered as a process of change. In the ARCOM sample, 15 papers of 23 use the term implementation in this way. Other terms used in the papers for this dimension are ‘transforming’ and ‘reconfiguring’ (see the third column of Table 1).

Unfolding affects the plan or decision to be implemented as well as the organisation wherein the plan or decision is unfolded. The plan needs to be translated and worked out in more detail, which transforms the plan into reality (Huber, 2011). On the other hand the local organisation activities should be reworked so that they align to the newly set goals of the plan or decision (Arnaud, Mills, Legrand, and Maton, 2016: 46). Arnaud et al., (2016: 40), adepts of the ‘strategy as practice’ school, describe the role of multimodal materialisation of a strategy in mundane tools to couple the plan or decision with the local practices. This facilitates workers engagement in a coherent way and embodies the strategy in their ‘sayings and doings’. The match of these translations with the strategy influences the implementation success of the strategy, here called the implementability (Huber, 2011).

Within the built environment, the unfolding dimension corresponds to practices of change management within the construction firms, which is covered in dedicated management literature, as well as to the concrete realisation of an approved design through on-site construction works. In the latter practice unfolding is analogous to buildability and constructability. Buildability is defined as “the extent to which the design of the building facilitates ease of construction” (McGeorge and Palmer, 1997: 54). This definition may
Implementability Dimensions

be interpreted as if only the design and not the implementation context nor implementation process affect the buildability of the design, but this is not the point these authors want to make.

**EMBEDDING**

Beneath entering and unfolding, designers and decision makers may want the plan or decision to be used in the organisation. They may want the organisation to start operating in its adapted state and to continue operating in this way for a defined period of time. Within the survey this was called “adoption of users” and “operation”. This dimension was found in the second largest group of papers. Here change is absent and implementation refers to operating the organisation with the plan or decision embedded in it. At first sight, it may be strange to consider embedding a dimension of implementability. It is not, however. Countless are the examples of plans or decisions that entered the organisation, were unfolded in it, but could never be used in operations.

In the built environment, the embedding corresponds to the use of the built environment after construction works have been carried out. A plan or decision should be acceptable for the stakeholders and technically fit for making - these are the entering and unfolding dimensions. Designers and decision makers most probably will want the object to be usable as well, and this as close as possible to the expectations of the users - this is the dimension of embedding. The definition of constructability of McGeorge and Palmer (1997: 56) corresponds with the three dimensions of implementability explained so far. For these authors attention to constructability doesn’t cease with the completion of the building (this is the unfolding dimension). The constructability of maintenance activities, such as the removal and replacement of materials, finishes and equipment, should be included as well (this is the embedding dimension). And even the procurement procedures should be part of it (1997: 56) (this is the entering dimension of implementation).

It is hard to believe that it is not in the tradition of all designers and decision makers to aim for embedding of their plans or decisions. In the 1960’s the General Bank in Brussels launched the replacement of its headquarters in the Warandeberg/Mont des Arts (Vande Putte, 2015). Architects Van Kuyck c.s. designed a brutalist building that matched a modernist urban concept for the city centre that was not yet in place then. The commissioning committee was fully convinced about the design of this building and approved its construction. Recent research disclosed an initial misfit between its brutalist design on one hand, and on the other hand the expectations of the users and several members of the board of the bank, who opposed fiercely. During its use, the building never got appreciated. The personnel disliked the dark office floors, the citizens its aggressive pose towards the 18th century fabric and the surrounding buildings. In the 2010’s, when the building was in need of its first in depth maintenance, it was decided to demolish it notwithstanding is unquestioned importance as a Belgian example of brutalist architecture.

**REVERTING**

Designers and decision makers may conceive one more dimension of implementability, which is the de-implementation of ineffective or superfluous plans and decisions. They may want their plan or decision to be undoable at a reasonable effort. This raises two questions. The first question is whether reverting a plan or decision is part of the implementation of this plan or should be seen as the entering and unfolding dimensions of a new plan that contains reverting of (parts of) the former plan. Second, the concept of
reversibility can be questioned in general, as it is quite an illusion that a system on which the plan or decision is implemented can ever return to its previous state.

Reversibility is common practice in law of obligations. Exit clauses are present in almost all agreements. Also in healthcare the concept of practice reversibility is gaining strength. The Journal of Implementation Sciences calls for studies on the de-implementation of ineffective practices (Implementation Science, 2016). In governance many decision makers refuse to design de-implementation possibilities. When in 2002 the local currencies of 12 European countries were replaced by the Euro, no strategies were developed to undo the change in case of a failure. The same applied for the membership of the EU, where not earlier than in 2009 the article 50 of the Treaty of Lisbon provided the procedures for leaving the EU (Poptcheva, 2016).

In the built environment the concept of reversibility got strength under influence of the sustainability discourse. The ‘do not harm’ concept pushes designers to take the dismantling of the product and the reuse of the materials into account as an initial design constraint. The design - the decision to construct - should be reversible.

Reversibility is a fundamental and long standing issue in physical heritage care. The monument, forming part of the archive of a civilization’s history, is subjected to a number of natural and man-made hazards inducing degradation. The measures taken to ensure conservation inevitably modify the status quo of the artefact and potentially obstruct future historical research. Reason for archaeologists and historians to target total reversibility of any conservation measure, for which exists consensus in methodological terms, but proved almost impossible in practice (D’Agostino and Bellomo, 2003).

CONCLUSION

Implementability is a relative measure. It is the degree to which a plan or decision can be executed along the designers’ or decision makers’ expectations, which consists of the degree of entering, unfolding, embedding and reverting of the plan or decision. When the implementability of a plan or decision is evaluated higher than the implementability of another plan or decision, the execution of the first plan better meets the designers’ and decision makers’ expectations on entering, unfolding, embedding and reverting the plan and decision in the aimed organisation.

The four dimensions of implementability allow for a more precise positioning of related concepts (see Table 2). The sustainability of a plan or decision, in its meaning of a plan or decision that lasts long, relates to the embedding dimension of implementability. The derived meaning of sustainability, whether the organisation (i.e. the ecosystem) wherein the plan or decision is implemented can sustain, is covered by the reverting dimension (see Table 2).

Understanding the dimensions of implementability is a necessary step for the design of an implementability appraisal tool, as is envisaged by the author. The more precise definition of implementation and implementability, and the operationalisation using four dimensions, will make scholars aware of the scope of the implementability concept. It will encourage and support them for being more explicit on the dimensions of implementation their research targets. For designers and decision makers the four dimensions of implementability function as a checklist to specify the dimensions they aim for. This will allow them to more easily design for implementability (Gadiesh and Olivet, 1997).
Within the built environment the four dimensions of implementability are omnipresent, in the daily practices of organisation management as well as in the concrete and physical interventions in the built environment. But these dimensions stay non-articulated, as is shown in this paper. This paper distinguishes four dimensions of implementability and lays a basis for improved practice in organisation management, and in design and construction management.

REFERENCES


SOFT INTERVENTIONS IN A HARD WORLD OF LEAN

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There are continual calls for improvement in construction but these are often seen critically both by industry and academia. Lean and the Last Planner System (LPS) are promoted as technical improvements but often the social and cultural impacts of the change are not acknowledged. This paper discusses this problematic gap through the ideas of hard and soft interventions in projects. It reports on an action research project which explored a soft approach to LPS involving working with an M&E sub-contractor and a main contractor on site with the aim of delivering practical improvements as well as research on interventions. Early work on the engagement included field non-participant observation and semi structured interviews and participant observation which revealed the practical, organizational and individual barriers to LPS. This allowed a soft intervention approach to be devised based on open discussion of problems with the LPS serving as an assistance to working together not a technique to be implemented. The agreed intervention facilitated positive outcomes which were analysed through final semi-structured interviews. The analysis shows how such improvements need: to address the different meanings of LPS to different participants and to handle differences in experience of risk and uncertainty. Improvement was aided by the soft intervention by creating trust and a positive organizational climate. This approach also saw the participants challenging assumption from past projects thus enabling future learning.

Keywords: uncertainty, planning, situations, improvement, last planner, lean

INTRODUCTION

Construction is seen as an industry that is unable to deliver to time, cost and quality and is being continually asked to improve (Fernie et al., 2006). Although the generality of this statement can be argued against, it is also the case that there are many examples of poor delivery. That it is possible to improve is not in question but the nature and real purpose of improvement is extremely contentious (Green 2011). Often other industries are used as exemplars of good practice and construction is goaded into adopting this because of their apparent success and ease. One such technique of improvement that has been heavily promoted is Lean Construction which is derived from the Toyota Production system (Womack and Jones 1996). This was reformed for construction by Koskela (1992) into a new theory of production that involved connected concepts of Transformation, Flow and Value (TFV).

These allowed the explanation of how construction transformed materials using organisation and management, how this should be seen as optimising flow, not task, to enable certainty and that the outputs should give value to the customer everything else being seen as waste. This was a significant achievement and much lauded by Egan (1998) although heavily criticised by Green and May (2005) and has not being adopted comprehensively by the industry (Mossman 2009). There have been documented successes and the logic of lean is useful for challenging the industry; however, what is

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required is a much more practical analysis of difficulties and an exploration of reasons for non-adoption. One particular aspect of lean construction is the technique of Last Planner (LPS) (Ballard and Howell, 2003). This identifies the organisation or individual who is accountable for managing and undertaking a task at the point of its delivery. It emphasises the importance of these individuals for delivery and for coordination between others undertaking connected tasks.

The paper makes use of the metaphors of soft and hard to describe interventions and approaches. Softness encompasses aspects that cannot be codified and measured plus goals that are not agreed or involve conflict (Rosenhead 1989). The idea that construction is a hard world being about technology, materials and goal focussed production is common place. However, many also see its softer aspects; its systemic nature (Fernandez-Solis, 2009), its flexible and negotiated operation (Dubois and Gadde, 2002) and its complex operation through people (Boyd and Bentley, 2012).

Lean is fundamentally a hard technique as demonstrated by Howell and Ballard (1999) in their defence of lean when they stated that 'production management is first about how things are made and not about how people are treated'. This hardness is the ability to plan and deliver to the plan thus this is key to Lean. However, the possibilities of this happening and the realities of it working have been challenged in particular by Winch (2011), who took up a challenge set by Koskela et al., (2004) against his Information Processing view of construction. This information processing view focuses on projects and the transaction economics of accomplishing them rather than lean view of materials flows and activity completion. This paper will take up and explore this challenge through the ideas of soft and hard interventions using lean: LPS within a real project. It was constituted as an action research project as the organisations and people were engaged in a learning way to address questions of what can be done to improve coordination and when is it worthwhile to plan and in what detail, and what are the uncertainties that each organisation is managing.

CONSTRUCTION MANAGEMENT AND LEAN

Hard and Soft Worlds

The metaphors of hard and soft have been used most extensively within the systems field (Checkland and Scholes 2009). The distinction has been used in project management (Daniel 1990) and in operations research (Rosenhead 1989) and value management (Green, 1999). Hardness describes worlds in which there can be certainty, agreed meaning and measurability (Rosenhead 1989). The hard worlds are where operations research can be effective in delivering efficiency and efficacy against a previously defined set of objectives and optimising these operations further. This aligns with the machine metaphor of Morgan (1986) who emphasises that the usefulness of this requires stability and controllability. This has its roots in Taylorism which is often criticised for totally disregarding people against objectives of production.

The soft metaphor has as one of its key aspects an acknowledgement of people as having their own purposes for being involved in an organisation which can disturb the machine (Rosenhead, 1989). However, soft approaches also refer to: the ways that the world cannot be reduced into such a mechanistic parts, the inadequacy of the thinking behind this and the unintended outcomes that result (Rosenhead 1989). This was explored by Green (1999) in relation to value management and involved the way people handle what is not known. In these instances, Rosenhead (1989) argues that it is problem structuring that is crucial, rather than problem solving in the hard arena. Soft does involve the
problems of people interacting but it is much more about how people hold different views and emotional positions about the same situation and how this needs to be acknowledged for people to work together. Daniel (1990) inter-relates hard and soft approaches within an R&D project management context. He considers that hard approaches have a tendency to be an 'over-concentration on pursuing technique for technique's sake, confusing means and end' (p79). Thus, the implementation of techniques (such as lean) is a hard systems approach giving problems associated with different individual needs in projects; this in itself induces soft outcomes which need managing.

**Lean and Projects**

As a hard systems approach, lean assumes a stable context in which a structured view and planning can be implemented as in logistics or the car industry (Womack and Jones 1996). Koskela (1992, 1999) developed this for the construction industry through his “new production philosophy” and later, postulated the TFV model of production (transformation, flow and value generation). Lean construction then needed a method to improve quality control of weekly planned operations and also increase work plan predictability (Ballard, 1993). This system Ballard and Howell (2003) named the Last Planner System (LPS). The LPS consists of five integrated elements: master plan, pull planning, look-ahead planning, weekly work plan (WWP), percent plan complete (PPC) and analysis of reasons for incomplete assignments. LPS uses the measure of achievement of this predictability as Percentage Plan Complete (PPC) and works towards making this 100%. It is the systematic implementation of LPS that is stated to improve planning practices and deliver productivity improvements (Ballard and Howell, 2003; Johansen *et al.*, 2003, Alarcon *et al.*, 2008 and AlSehaimi *et al.*, 2014); but this is from within an uncritical literature.

Winch (2011) critiques lean as being inadequate for real projects in four ways: it focuses only on materials processing, it has no acknowledgment of the organisational context, it cannot accommodate risk and uncertainty and it has a unitary concept of value. Thus, in Winch's (2011) view of projects, there are many transformations other than materials, in particular information, services and symbols. Similarly, real projects involve an interdependence of the processes which requires organisations to work on seeking to minimise uncertainty in the way they plan for action. This is explained in Winch's (2011) assertion that projects are fundamentally about managing risk and uncertainty, in other words, accommodating changes and problems as events unfold.

Thus, he asserts that a hard system can operate only when there is the likelihood of no uncertain events and he draws on Thomson (1967) who analysed coordination in different organisational arrangements. This challenge to lean about the management of risk and uncertainty needs further investigation. Indeed, LPS is partly a response to making planned decisions as close to the point of implementation as possible with the actors who are involved so that the knowledge of the future is better anticipated and so apparently viewing a more stable world. LPS however dictates that no work should start until all conditions are in place for this to be complete i.e. there should be no 'making do'; that is the world needs to be stabilised to the planned conditions.

**Towards a Soft Interventions**

There is very little discussion in the lean literature about the implementation of lean. Indeed, most research work is on more complete and sophisticated planning of the system of operation (e.g. Hamzeh, 2009) and indeed automating this (e.g. Dave, 2016). Those studies of practice focus on the lean measurement of PPC (percentage plan complete)
(e.g. AlSehaimi et al., 2014) This measures how close to the ideal that the plan, devised by the supervisors, manages to achieve. The supervisors are then meant to address why the plan has not been achieved and learn to operate the plan better. At the lean delivery side, implementation is regarded as training of actors to work with lean (e.g. CLIP at UK BRE, https://www.bre.co.uk/page.jsp?id=355). There is the assumption here that the problems of lean are due to people not understanding it or not implementing it properly; rather than having to manage the problems and unfolding events associated with real practice.

Thus, it is important to consider not just the structure of lean but its implementation. Lean is used in situations that are seeking improvement, particularly productivity improvements; however, the role of social changes is left underestimated (Green, 1999). The few studies that have a softer viewpoint on lean do emphasize the cultural and behavioural improvements during the organizational change even seeing benefits from an incomplete implementation of the methodology (Hamzéh, 2009; Viana et al., 2010; Priven and Sacks, 2015. Thus, what implementation involves can be seen as an intervention in a current way of undertaking construction in context, not just a technique to be implemented. This softer view of interventions was promoted by Svensson-Dalgren and Gard (2009) who highlighted the factors of successful interventions as effective participation and employee’s empowerment; communication and social support; action research to work with changing values, skills, control, politics and rewards; and integration between research and implementation in practice. This informed the current research approach towards seeing improvement as intervening in the multi-organisation on site rather than merely implementing LPS.

**METHODOLOGY**

This study aimed to explore the process of intervention to implement a lean: last planner system to improve actual construction practices. It followed Williams (2002) who emphasised that better results could be achieved when hard and soft interventions are implemented simultaneously during organizational change. Thus, it acknowledged LPS hard system problems and determined to support these with soft approaches. LPS does idealistically conceiving of a future perfect world and tries to manage its realisation. However, a soft intervention starts from seeing the people with their uncertainty and variability of circumstances as part of the real world and LPS as an assistance to help everyone to work better together. In this spirit, an action research (AR) approach was adopted to make the results practically relevant to individuals and to give something back to the project that agreed to support the research. The AR model was first introduced by Lewin (1951) to obtain knowledge about a social system while at the same time trying to change it. This model involves an iterative cycle of: problem diagnosis, planning of action and its implementation, and the evaluation of outcomes (Elden and Chisholm 1993).

Participatory action research (PAR) encourages participants to play an active role in the problem-identification and decision-making processes and, therefore, to achieve viable results (Baskerville et al., 1998). Implementation of the LPS through a soft intervention was conceived through Lewin’s (1951) three step model. The unfreezing stage was undertaken during non-participant observations of the current planning practices in both companies. The interventions were designed in partnership with participants to get better results of the LPS soft interventions, acknowledging different views and perceptions (Harden et al., 1999). The changing stage included participant observations of collaborative meetings and weekly planning sessions to collect data of the LPS soft
interventions. The freezing stage included semi-structured interviews to evaluate the results of the AR.

The case study project was of a university new Science & Health building. The research part of the AR examined interventions and the complexity of organisational and social relationships between the main contractor and the M&E subcontractor. Observations were carried out at the construction site as part of the action research. Both companies had a long-term relationship that had proved effective in previous projects. The main contractor’s team included a project manager (MCPM), site managers (MCSM), and a planner (MCPL) who had an understanding of Lean, but had not applied it practically on live projects. The M&E subcontractor team included M&E engineers, a project manager (MEPM), a planner (MEPL) as well as a logistics controller. The M&E team members had completed a short Lean course and this University building became their pilot project.

**FINDINGS**

**Introduction**

In an action research project the research and practical-change occur simultaneously. This makes the research partly a presentation of what happened; however, the added meaning of this is more complex as the situation is unique, the circumstances change and opportunities for generalisations are limited. The findings are reported here chronologically but theoretical issues are picked up in the discussion.

**Stage 1 Entry to Situation**

The initial engagement of the AR facilitator involved non-participant observation designed to understand the situation and the people. Both companies had some previous experience of introducing lean and LPS but had very different experiences and so different expectations of the AR project. There was a negativness both about lean and about meetings. The main contractor had a particular negativness:

*In our company the education was started from the top and then distributed to the lower levels. However, the top level have different goals …… So when the information actually came to the site it was presented very weakly and we didn’t see the impact that it should have.* (MCPM)

*Lean is more production or manufacturing orientated where there are a lot of repetitive operations. On site … there are everyday changes and less repetitive operations. I don’t think that Lean could be applied fully in our project.* (MCPM)

*If we use the word Lean they wouldn’t understand. When you say the word Lean they are in doubt that they can do something better than they did for the last 10 years.* (MCSM)

The M&E subcontractor did see lean differently and in a more mixed way:

*In the beginning, there was negative and positive attitudes towards LPS implementation. The younger employees and those employees who knew about Lean Construction had a positive attitude towards LPS. However, the older employees are less happy to be involved* (MEPM)

This initial study determined that the arrangements and subject of meetings were important. The main contractor’s site manager mostly focused on Health and Safety (H&S) issues which took around 35 minutes to detail and increased the meeting minutes by up to four pages. The meeting then involved filling the weekly plan report that clarified the works, identifying resources along with any possible problems in the weekly plan, and highlighting on the drawings where jobs had started. However, after one and a half hours of the meeting there were just a few participants left to ask questions about job overlap’ problems with many staying quiet while the projects delays had already started
to form. At the same time the main contractor’s site manager who carried out the meeting wasn’t aware that each subcontractor had their own programme for providing updates of jobs towards their aims which did not relate to the main-contractor’s programme which remained unchanged from its initial conception. These meetings also showed a resistance to maintain the handover practice in the collaborative meetings which was initially requested by the M&E subcontractor.

This shows how important past experiences and real time issues are for people, and with the different perceptions of LPS, this overshadows the positive aspects of lean and it is this that needed to be balanced by the soft aspects in this implementation.

**Stage 2 Participation and Improvement**

The format of the soft intervention was discussed with participants and agreed, with the aim to try to achieve better planning. This is configured in LPS as look ahead meetings where blockers are identified and solutions found; it very much focuses on the constraints for completing the tasks. However, it was recognised that these meetings to be successful would expose the parties' different priorities for meetings and their personal positions in the project. In particular, some participants would find it difficult to share their issues due to a “blame culture” awareness.

The AR facilitator attended the planning meetings and promoted the soft approach. Being external (but involved) this was not regarded as threatening and did induce discussion and change i.e. the meeting were run with soft objectives so that the participants could modify its direction. For example; one change resulted from an unplanned event with the main contractor and the M&E subcontractor. The “six week look ahead plan” programme presented in the third collaborative meeting induced a discussion regarding the differences between the M&E programme and the main contractor’s version of the programme.

The M&E specialists found it difficult to track their works in the contractors' programme, while the main contactor planner rejected using an updated version of the programme. The unplanned event involved the realisation of the implications of delays in producing the M&E drawing to a particular levels of the building and this was a shock to the main contractor’s project manager and immediately produced defensiveness in all parties. The AR researcher managed to get the M&E subcontractor project manager and planner, the main contactor planner and the project manager into a productive meeting. This revealed the necessity to track the actual jobs progress through the programme planning and monitoring during the weekly collaborative meetings and highlighted the negative consequences of the previous practice.

**Stage 3: Reflection and learning**

Finally, the AR project was reviewed through a series of interviews and this focused on the success of soft interventions and how people and organisations learn from the project. There was a general very positive response to the AR project interventions and outcomes:

*These meetings improve problem-solving processes between subcontractors (MCPM)*

*I think sometimes we need an outsider who could give us a different opinion and give recommendations. As usually in our meetings everyone tried to be very defensive and didn’t want to share their ideas. So we started becoming more open (MCPM)*

In particular, they liked how the interventions enabled them to work together better:

*It is difficult to create a “no blame culture” among subcontractors, thus it is difficult for subcontractors to provide full information (MEPM)*
I think you need to try and convince the subcontractor that you wouldn’t use the stick approach. If someone comes to me and said that I can’t do an activity in time, we previously would have said that it will cause a delay and cost, so you now will be liable for x amount of money. So previously the subcontractor preferred to hide this from us as they don’t want to be beaten for this issue. Now we have a more relaxed approach and prefer to listen to them and take measures for how to improve the situation rather than apply the punishment approach. (MCPM)

After we brought fruit to the meeting, people became happy and more open in discussions which is really good to the collaborative process. (MCSM)

They all got something out of it even if this was quite different:

We, as the M&E subcontractor have more specified information regarding M&E works which therefore has different handover/acceptance forms whilst the main contractor have their own form which is standard to all subcontractors. Thus to ensure that all the handover/acceptance records have the same level of specification we add notes in the main contractor form which is a challenge. We are also trying to re-educate our main contractor in some specific aspects of M&E works that could be crucial to us as well as to the overall project. So a part of our handover/acceptance policy is a sharing our knowledge with the main contractor. (MEPL)

Currently I am working with a team on the 6 week look ahead community house programme where I also want to involve construction workers on site in planning (MCSM)

**DISCUSSION**

The research identified issues about the meaning of lean (Green and May, 2005), risk and uncertainty (Winch 2011) and soft interventions (Green and Liu 2007). Lean presents a solution to the problems of construction through reconceiving the activity as TFV, involving a strict regime of planning. As Winch (2011) argues it is an idealisation of what construction is and only works when it follows the plan rigidly. The reality of construction is that events do not occur as expected and the management of construction involves coping with this uncertainty and change. However, there are aspects of LPS that do seem to be beneficial to the reality of construction, however these need to be presented in a much softer way than the rigid bureaucratic approach of lean. This action research project, using a soft intervention, explored how implementation is the key to success and future development.

The realities of construction are that there are different perceptions of the LPS. Often a single perception is driven hard from a top down approach where implementation is dictated by training that presents an ideal against experiential reality. It was evident from the case study that even the more accepting M&E subcontractor had reservations about hard lean, never mind the main contractor who did not believe that such planning, for an ideal, was worthwhile.

The work of Winch (2011) focuses on the organisational requirements to manage risk and uncertainty which dictates how possible it is for plans to be met. The differences between the main contractor and M&E subcontractor reflect a difference in the complexity and linearity of their management tasks. The main contractor is working with a multiplicity of agents, tasks and path dependent outcome. These reduce the effectiveness of plans and make the effort of planning itself seem not worthwhile. To the main contractor, coordination requires iteration and dynamic capability, not planning. The M&E works in a much more structured environment and controllable sub sub-contractors that respond to planning. Their uncertainty arises from the main contractor and changes that need to require redesign of work. This finding concurs with Winch’s (2011) assertion about how the organisational context dictates the value of using LPS and the importance of transactions between the parties.
A soft intervention based on LPS then opens up this difference for discussion and collectively can find solutions for both the main contractor and sub-contractor. The fact that they both hate the bureaucracy and endless meetings that hard lean requires needs to be managed creatively so that the planning provides rewards not just agonies of planning and being blamed for failure. In this way, the main contractor PM enhanced their management approach and actually was more in control by better managing the uncertainty using LPS to help. The looser adoption overcame the problem of blame, as to be successful the LPS requires honesty (saying what is) and taking responsibility- (doing what say). Application of a “no-blame culture” is required in hard improvements like Lean and LPS, however, these promote “mistake free” outcomes; this creates a tension and a lack of trust because of commercial business relationships between organisations (Provera et al., 2010). A soft intervention helps here to draws people in through sharing their problems and gets the different perspectives to plan collectively with different people (as promoted by Trist, 1976) with the potential of exposing and sharing risks. LPS soft interventions in the demonstration project created a precedent to stimulate employees to re-evaluate their system of thinking and challenge their assumptions which represents a deeper learning process (Henderson et al., 2013). In this it is not just the current project that was improved, the parties learned to change the way they thought about their own tasks, the coordination task and how they work together in a positive way which they can be taken forward into the next project.

CONCLUSIONS
This action research project explored the role of LPS as a soft intervention in inter-organisational relationships rather than an implementation of a technique. The project itself had positive results by instigating a collaborative planning process between main and subcontractors which started to develop a “no-blame culture”. The research analysis showed how soft approaches explicitly handle the different meanings of LPS to different participants and also how the differences in risk and uncertainty experienced by parties need to be acknowledged in planning. This analysis and the project itself show that improvement is aided by soft interventions that seek open discussion of problems, over driving technical goals, thus creating trust and a positive organizational climate. It also enables the challenging of assumptions from past negative experiences and so learning for future projects.

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Boyd and Talliss (Drovosekova)


PRECAST PRODUCTION SCHEDULING USING HEURISTIC ALGORITHM

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Precast concrete comprises the basic components of modular buildings. The efficiency of precast concrete building component production directly impacts the construction time and cost. In the processes of precast component production, mold setting has a significant influence on the production time and cost. However, the development of mold setting plans is left to the experience of production staff, with outcomes dependent on the quality of human skill and experience available. This can result in sub-optimal production efficiencies and resource wastage. Accordingly, in order to improve the efficiency of precast component production, this paper proposes an optimization model able to maximize the average utilization rate of pallets used during the molding process. The constraints considered were the order demand, the size of the pallet, layout methods, and the positional relationship of components. A heuristic algorithm was used to identify optimization solutions provided by the model, based on a 'best-fit' (BF) strategy. Through empirical analysis, and as exemplified in the case study, this research is significant in offering a prefabrication production planning model which improves pallet utilization rates, shortens component production time, and reduces production costs. The results clearly demonstrate that the proposed method can facilitate the precast production plan providing strong practical implications for production planners.

Keywords: heuristic algorithm, optimization model, precast production

INTRODUCTION

Prefabrication is the practice of assembling components of a structure in a factory, or other manufacturing locations, and then transporting complete assemblies or sub-assemblies to the construction site where the structure is to be erected. Whereas, traditional building construction takes place on site, prefabrication has gained much interest in recent years, particularly with regard to industrial buildings, for its potential energy saving benefits, as well as improved efficiencies in the construction process. Consequently, the efficiencies gained in the production process of precast components directly enhance the construction time and cost of buildings.

It is well established that production schedule is the key element in the precast production process and it is closely related to the production time and cost. Scheduling involves the allocation of resources over a period of time to perform a series of jobs that are subjected to known constrains. However, the current practice of designing precast production schedules depends primarily on the scheduler’s experience, which has generally proven to be problematic for planners and schedulers (Chan and Hu 2002). Often, inefficient resource utilization and high production cost are common in the precast industry due to unsuitable and inaccurate planning methods (Dawood 1995, Ko and Wang 2011).

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Therefore, optimizing the production schedule is vital in the precast component production process.

Subsequently, this particular area has attracted the interest of many researchers who have proposed various computational techniques to manage scheduling issues. For example, Dawood (1995) developed a scheduling model for the precast industry using the heuristic job scheduling approach. Chan and Hu (2002) developed their Flow Shop Sequencing Model for the precast production scheduling by incorporating actual constraints. Benjaoran et al., (2005) studied the quantity of molds on shop floor schedules of precast production and proposed a Bespoke Precast Flow Shop Scheduling Model by using a flowshop sequencing model. Ko and Wang (2011) applied a Multiple-objective Genetic Algorithm to search for optimum solutions with minimum makespan and tardiness penalties. In their model, buffer size was considered for the first time.

Tharmmaphornphilas and Sareinpithak (2013) developed a scheduling model to select concrete formulas and schedule jobs and proposed a heuristic approach to solve the model. Hong and Lee (2014) developed algorithms that could promptly establish a production layout plan by considering in-situ production factors affecting composite precast concrete members. Prata et al., (2015) proposed a model based on integer linear programming to schedule the production of the beams so as to minimize the losses at a minimal time. Yang et al., (2016) proposed a Flowshop Scheduling Model of Multiple production lines for precast production and developed an optimization approach to facilitate optimized scheduling.

Examining the existing literature on precast production schedule, it is seen that generally there are two categories of researches. The first category focuses on optimizing the specific process for some distinct precast production methods, such as the roll-cutting process of the filigree wide-slab method (Prata et al., 2015) and the layout process of composite precast concrete members for precast concrete in-situ production (Hong and Lee 2014). The second category focuses on the traditional precast production methods for optimizing the production plan based on the job shop/flow shop scheduling problem (Dawood 1995, Chan and Hu 2002, Benjaoran et al., 2005; Ko and Wang 2011, Tharmmaphornphilas and Sareinpithak 2013, Yang et al., 2016), which mainly emphasize on the flow variability between processes under special constrains such as limited labor and mold (Ko 2011). However, the strategies for improving the specific production processes for traditional precast production methods are generally neglected in current literature.

This paper evaluates the molding process, a critical process closely related to the precast production efficiency, and proposes a layout optimization schedule of the components on pallets during the molding process that; 1) improves the utilization rate of the pallets, 2) shortens manufacturing time, and, 3) reduces the component manufacturing cost of the assembly line.

PROBLEM DESCRIPTION

There are two basic types of precast component production systems in a precast plant, namely fixed location production and flowshop production (Yang et al., 2016). Additionally, with the development of production technologies, traditional precast production methods have evolved and become more efficient. For example, in China, the traditional flowshop production has developed into 'circulation flow production' (CFP) where, all processes are now fully automated. All three production methods involve six main processes, which include: 1) pretreatment, 2) molding, 3) placing of rebars and embedded parts, 4) casting, 5) curing, and, 6) stripping.
It is worth noting that two of the processes, mold setting and curing, have a significant impact on the component production efficiency and cost. In regards to the CFP and the flowshop production, numerous pallets are cured in a curing kiln during their curing process. The curing kiln is limited by a fixed pallet capacity and it would cost a couple of hours to cure the precast components loaded on the pallets. Therefore, although, there are many pallets ready to be cured, there is a limit to the number of pallets that can go through the kiln due to the fixed pallet capacity. In other words, the pallet capacity is responsible for the production capacity of the assembly line. In the mold setting process, molds are placed onto the pallets according to the component production layout plan, which determines the number of components on each pallet. Obviously, the more components loaded on a pallet, the lower the average curing cost for each component and the larger the efficiency of component efficiency. Thus, cost and efficiency of component production is directly responsive to the configuration of the mold setting process. Similarly, for fixed location production, which normally uses steam curing method in its curing process, a much more efficient layout plan also helps to reduce the number of pallet cycles.

Figure 1 shows an example of a typical production layout plan of precast components. It includes a large area inside an unused pallet. Not only does this reduce the pallet utilization rate, but this also causes a waste of production capacity. Consequently, this results in extended production cycles and increased curing costs.

**Fig. 1: An example of a typical precast production layout, showing sources of wastage**

In summary, concrete components are laid out on pallets based on the existing practices and the judgment of the manager, which can be sub-optimal. This leads to lower utilization rate of the pallets and curing kiln, and consequently imposes higher costs and reduces production rates. If production efficiency is to be improved, a structured, scientific approach to the laying-out of the precast molds needs to be adopted. The aim of this study is to propose such a structured approach.

**PROPOSED MODEL**

Precast components are usually rectangular and the workers normally arrange the molds in an ordinary way (horizontal or vertical). These will be incorporated as assumptions that inform the model developed. There are three such assumptions: 1) the shape of the production component is to be contained within an envelope rectangle of the smallest possible size, 2) the edge of the component is to be arranged parallel or perpendicular to the edge of the model, regardless of the diagonal layout, and, 3) the amount of mold available is unlimited. Table 1 shows the notions used in the model.
Table 1: The notions used in the model

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
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<tbody>
<tr>
<td>$L$</td>
<td>the length of pallet</td>
</tr>
<tr>
<td>$W$</td>
<td>the width of pallet</td>
</tr>
<tr>
<td>$i$</td>
<td>the type of components</td>
</tr>
<tr>
<td>$N$</td>
<td>the number of pallet cycles</td>
</tr>
<tr>
<td>$j$</td>
<td>the $j$th layout of precast production on the pallet</td>
</tr>
<tr>
<td>$d_i$</td>
<td>the demand of component type $i$</td>
</tr>
<tr>
<td>$x_j$</td>
<td>the number of the $j$th layout</td>
</tr>
<tr>
<td>$a_{ij}$</td>
<td>the number of the $i$th component used in the $j$th layout</td>
</tr>
<tr>
<td>$l_p, l_q$</td>
<td>the length of component $P$ and $Q^*$</td>
</tr>
<tr>
<td>$w_p, w_q$</td>
<td>the width of the component $P$ and $Q^*$</td>
</tr>
<tr>
<td>$(x_{pq}, y_{pq})$</td>
<td>the lower-left coordinates of the component $P$ and $Q$</td>
</tr>
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Equations 1 to 7 - The layout optimization model is formulated using the following mathematical equations

$$\max_{i=1}^{m} \sum_{j=1}^{n} l_i \cdot w_i \cdot a_{ij}$$

$$\sum_{j=1}^{n} a_{ij} x_j = d_i, \quad i = 1, \ldots, m, \quad j = 1, \ldots, n. \quad (2)$$

$$0 \leq x_p \leq L - (1 - r_p)l_p - r_p w_p.$$  $\quad (3)$

$$0 \leq y_p \leq W - r_p l_p - (1 - r_p)w_p.$$  $\quad (4)$

$$x_p \geq x_q + (1 - r_q)l_q + r_q w_q.$$  $\quad (5)$

$$y_p \geq y_q + (1 - r_q)w_q + r_q l_q.$$  $\quad (5)$

$$r_p = 0 \text{ or } 1, \quad r_q = 0 \text{ or } 1.$$  $\quad (6)$

$$a_{ij} \geq 0, \quad x_j \geq 0, \quad i = 1, \ldots, m; \quad j = 1, \ldots, n.$$  $\quad (7)$

In the model, the objective function in Equation (1) represents the average utilization of the pallets. By computing this equation for the highest value, the highest utilization rate can be determined, with the number of pallet cycles consequently minimized.

The constraint introduced in Equation (2) ensures that the number of components required to meet the order agreement are achieved. The constraint in Equation (3) and (4) ensures that the component layout will be limited within the pallet size. In order for the components to be arranged within the pallet dimensions, the formulas in Equation (3) and (4) will need to be satisfied.

The constraint in Equation (5) assures that the component layouts do not overlap. There are four non-overlap situations in total, each formula in (5) represents a non-overlap situation of the $P, Q$ components. If the components layout does not overlap with each other, at least one of the formulas in (5) will be satisfied. Constraints in Equation (6) indicate the placement method for components, where $r=0$ means that the components are
laid in a transverse direction, and \( r=1 \) means that the members are placed in longitudinal direction. Constraints in equations (7) are constraints of decision variables.

The above discussed problem is concerned with a two-dimensional stock cutting problem, which was first proposed by Gilmore and Gomory (1965). The objective of the classical two-dimensional stock cutting problem is to determine a layout pattern to maximize the utilization rate of a single rectangle that is required to accommodate items. However, some practical problems of enterprises often involve with multi-items multi-sheets, not just a classical two-dimensional stock cutting problem, the original objectives and constraints shall be reconsidered (Jin et al., 2015). Thus, based on the actual situation of the precast production, this paper develops an optimization approach to maximize the average utilization rate of pallets with extra constraints, such as the size of molds and the order demand. A heuristic algorithm based on BF (best-fit) strategy is developed in this paper. The algorithm consists of two parts: the main heuristic algorithm and the subprocess of the heuristic algorithm. Table 2 shows the notions used in the heuristic algorithm.

Table 2: The notions used in the heuristic algorithm

<table>
<thead>
<tr>
<th>Notion</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T )</td>
<td>The sequence set of precast components to be arranged. ( T = {T_1, T_2, \ldots, T_k} ), where ( T_k ) is the ( k )-th sequence consisting of ( Z_1 ) to ( Z_i )</td>
</tr>
<tr>
<td>( Z_i )</td>
<td>The sequence of a ( i )-th type of component. ( Z_i = {z_1, z_2, \ldots, z_i} ), where ( z_2 ) is a matrix that contains the size information of component, and ( d_i ) is the demand.</td>
</tr>
<tr>
<td>( v )</td>
<td>The width of the lowest available space</td>
</tr>
<tr>
<td>( h_v )</td>
<td>The height of the lowest available space</td>
</tr>
<tr>
<td>( U_k )</td>
<td>The utilization rate of the layout patterns according to ( k )-th sequence</td>
</tr>
<tr>
<td>( N_k )</td>
<td>The number of pallet cycles according to ( k )-th sequence</td>
</tr>
<tr>
<td>( F_k )</td>
<td>The ( k )-th layout plan</td>
</tr>
<tr>
<td>( H )</td>
<td>The component layout height</td>
</tr>
</tbody>
</table>

The main heuristic algorithm is used to find the best precast component sequence among several sequences which are randomly created by computer. The specific approach is to compare the average utilization rates among the given the sequences, and find the sequence with the highest utilization rate. The specific algorithm flow chart is shown in Figure 2a and the procedural steps are outlined below.

Input: Pallet size \((L, W)\), component demand \((n_i)\) and component size \((l_i, w_i)\).

Output: The minimal cycles of pallets \( N \), the maximum average utilization rate \( U \), and the best layout plan \( F \).

**Step 1:** Initialize. Let \( F=\emptyset \), \( U=0 \), \( N=0 \), \( k=1 \).

**Step 2:** \( k=k+1 \). Run sub-process, save \( N_k \) and \( F_k \), calculate \( U_k \).

**Step 3:** Compare \( U_k \) with \( U \).

- If \( U_k > U \), then \( U=U_k \); otherwise, keep \( U, N, F \) unchanged.

**Step 4:** Check if all the sequences are already arranged.

- If \( T=\emptyset \), then go to step 5; otherwise, go to step 2.

**Step 5:** Output \( U, N, F \).
Fig. 2: Flow chart of the heuristic algorithm

In order to calculate the utilization rate of each sequence, a sub-process of the heuristic algorithm is developed. The specific algorithm flow chart is shown in Figure 2b and the procedural steps are outlined below.

**Input**: The $k^{\text{th}}$ sequence $T_k$.

**Output**: The number of pallet cycles according to $k^{\text{th}}$ sequence $N_k$, the average utilization rate according to $k^{\text{th}}$ sequence $U_k$, and the $k^{\text{th}}$ layout plan $F_k$.

**Step 1**: Initialize. Let $F_k=\emptyset$, $N_k=1$, $U_k=0$.

**Step 2**: Calculate $v$.

**Step 3**: Search available components by the order of the sequence. Define the placement strategy of components as $r$. $r=0$ means that the component is arranged horizontally, $r=1$ means that the component is arranged vertically.

- If $v$ is longer than the long side of the component then $r=0$;
- If $v$ is longer than the short side, but shorter than the long side then $r=1$;
- If $v$ is shorter than the short side then $r=-1$.

**Step 4**: Search for the value of $r$ in sequence $T_k$. Check whether there exist $r\geq 0$.

- If true then place the component with the first minimal value of $r$ to the left side, go to Step 5; otherwise update the lowest available space, go to Step 2; (The updating principle for the lowest available space is to raise its height to the penultimate lowest space when it’s compared to the current one.)

**Step 5**: Compare $H$ with $W$;
If $H < W$ then accept the component, add the component into $F_k$; and remove it from $T_k$, go to Step 6; otherwise, $N = N + 1$; go to Step 2;

**Step 6:** Check whether $T_k = \emptyset$.

If true, save $N$ and calculate $U_k$, go to Step 6; otherwise, go to Step 2.

**Step 7:** Return $F_k$, $N_k$, $U_k$.

**CASE STUDY**

As shown in Table 3, this study collected the actual production data from a precast component plant (Plant A) in Chongqing, and the method described here was used successfully to solve the component pallet layout. The optimization problem presented in this paper has general applicability, such that various sizes of precast components, as well as models with different indicators may be used.

As per an order received, the plant management set the production quantity to take a certain amount of time, during which eight kinds of precast components, such as outer wall panels, inner wall panels and superimposed floors, etc. would be produced. According to the specification of the precast production line, the length and width of the pallets were 9m and 4m, respectively. The curing kiln could simultaneously cure 21 pallets; the curing time required for the components is 8 hours; the running cost was 600 RMB per hour. In the original plan, the total number of cycles of the pallets was to be 261, using the curing kiln 13 times, for a total of 104 hours.

<table>
<thead>
<tr>
<th>Type</th>
<th>Components</th>
<th>Length</th>
<th>Width</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Outer wall panel 1</td>
<td>318</td>
<td>310</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>Outer wall panel 2</td>
<td>318</td>
<td>420</td>
<td>126</td>
</tr>
<tr>
<td>3</td>
<td>Inner wall panel</td>
<td>292</td>
<td>80</td>
<td>339</td>
</tr>
<tr>
<td>4</td>
<td>Superimposed floor slab 1</td>
<td>328</td>
<td>162</td>
<td>220</td>
</tr>
<tr>
<td>5</td>
<td>Superimposed floor slab 2</td>
<td>456</td>
<td>132</td>
<td>174</td>
</tr>
<tr>
<td>6</td>
<td>Concrete slab</td>
<td>106</td>
<td>84</td>
<td>120</td>
</tr>
<tr>
<td>7</td>
<td>Precast beam 1</td>
<td>408</td>
<td>34</td>
<td>132</td>
</tr>
<tr>
<td>8</td>
<td>Precast beam 2</td>
<td>502</td>
<td>38</td>
<td>86</td>
</tr>
</tbody>
</table>

In this case, Visual C++, on a Windows 7 platform, was used for programming the heuristic algorithm. The final result showed that only 203 cycles were needed to finish the production task, for which 5 different layout schemes were needed. Figure 3 shows the two types of the layout schemes. Table 4 shows the number of the pallet cycles and the utilization rate of each layout scheme. According to Table 4, the best layout plan needs five configurations, the average utilization rate is 90.6%. These five configurations reduce the original number of pallets used from 261 to 203, saving 58 pallet cycles and improving efficiency and shortening manufacturing time by 22.2%. Furthermore, the improved plan would only use the curing kiln 10 times, instead of actual 13 used, which saves $(13 - 10) \times 8 \times 600 = 14400$ RMB, represents a 23.1% curing cost saving.

In summary, the real-life case, where experienced managers having been operating 'Factory A' over a number of years, utilizing their experience in combination with current best practice, shows that this proposed model has genuine applicability to real-world
scenarios. The proposed model provides a scientific approach to generating optimized component schedules that are relatively simple to use, while offering significant gains in production efficiency, time saving, and overall cost reduction.

Table 4: Utilization analysis of various layout schemes

<table>
<thead>
<tr>
<th>Schemes</th>
<th>Quantity</th>
<th>Pallet area (m²)</th>
<th>The area used (m²)</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheme 1</td>
<td>43</td>
<td>36</td>
<td>32.86</td>
<td>91.3%</td>
</tr>
<tr>
<td>Scheme 2</td>
<td>58</td>
<td>36</td>
<td>33.48</td>
<td>93.4%</td>
</tr>
<tr>
<td>Scheme 3</td>
<td>40</td>
<td>36</td>
<td>32.64</td>
<td>90.6%</td>
</tr>
<tr>
<td>Scheme 4</td>
<td>26</td>
<td>36</td>
<td>32.72</td>
<td>90.9%</td>
</tr>
<tr>
<td>Scheme 5</td>
<td>36</td>
<td>36</td>
<td>29.79</td>
<td>82.8%</td>
</tr>
</tbody>
</table>

CONCLUSION

This paper establishes a layout optimization model for scheduling precast components on pallets during the mold setting process. The model was based on a two-dimensional stock cutting problem, considering the constraints inherent to the pallets (capacity/size), to the precast components (demand and size) and to the layout rules (layout methods and positional relationship of components). To the best of the authors’ knowledge, there is no other formulation in the literature for optimizing the mold layout plans of precast components production. The proposed model was solved using a heuristic algorithm based on a BF strategy. The empirical analysis illustrates that the model and the algorithm proposed in this paper are highly operable and can effectively improve the utilization rate of pallets. The model provides strong practical benefits for component manufacturers seeking to optimize their production plans, shorten production time, and reduce production costs. In turn, the model may be expected to enhance competitiveness in the industrial buildings sector.

However, this model has some limitations. Notably, the proposed plan requires various types of components to be loaded onto any single pallet, which may add complexity to the pallet preparation stage, as well as complicating the transport and storage of the various finished components products.

In future studies, the cost fluctuations arising from the above-mentioned problem should be explored, with the influence on the changes in costs under such increased multi-component production complexity evaluated. It is expected that while the model offers significant efficiency gains from limiting pallet and kiln usage, there may also be some increased inefficiencies in managing and transporting multiple components at one time. Certainly it is expected that the gains will far outweigh the costs, but that remains to be evaluated. Beyond that, the model should be extended to consider mold quantity...
constraint and time constrained related to the customers. Finally, a propriety 'user-friendly' software should be developed to assist factories achieve the promised efficiency gains, as well as reduce their production costs.

REFERENCES


POLICY AND MACRO PERSPECTIVES
FORGET THE RULES AND INNOVATE: CONTESTING A MYOPIC VIEW ON THE IMPACT OF RULES ON INNOVATION

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A persisting stance in practice is that obliteration of rules creates innovation paradise. Although it seems tempting, this view neglects that regulations may also constructively support innovation adoption processes. To stress these different roles that exist between regulation and innovation, scholars call for a careful empirical analysis of innovation contexts. Recent CM case studies, therefore, explore how standards emerge in new practices. Despite this, however, literature limitedly addresses the dynamic nature of the innovation context itself. This study, therefore, investigates how interactions between regulation contexts and innovation systems change during different innovation adoption phases. We explore this interaction by analysing two innovation trajectories: the Dutch Utility Information Exchange system and the Ground Penetrating Radar. During this desk study, we identified key innovation stages, standards and regulations; categorized these; and, allocated them to different product lifecycle phases. Outcomes reject the 'obliterate rules' stance and confirm the stabilizing role of rules in later innovation stages. To better understand the role and impact of rules on innovation we urge CM researchers to concentrate on the dynamic role that standards and rules have during innovation processes, rather focussing on their static impact only.

Keywords: regulations, rules, standards, innovation, coordination

INTRODUCTION

Promising construction technologies and methods entering the construction arena become embraced by early adopters (Rogers 2010) who aim to improve their work practices. To develop their sector further, these pioneers need to coordinate the behaviour of other stakeholders. Initially, their alignment of ambitions, requirements, and the innovation’s performance levels occurs through mutual adjustment (Mintzberg 1979). Stakeholders then directly engage with peers, clients, and end-users without making extensive use of standards and regulations. Such uncertainty reduction processes lose efficiency when innovations become implemented on a grander scale. Standards and regulations then partly replace the existing coordination through mutual adjustment and reshape the institutional context that innovations entered.

The standards and regulations that the institutional landscape comprises of are being contested frequently. Recently, for example, the US-president expressed a desire to 'slash regulations by 75\% or more'. This could save paperwork and time, and allow companies to hire more employees, which, in turn, could help spike innovations again. Further, it was argued recently that agencies 'use rules to just protect existing businesses from competition instead of stimulating innovation' (Black 2016). In a more subtle way, also the European Union and Dutch Infrastructure Ministry announced to 'address regulatory

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barriers’ to boost green building initiatives. The prevailing thought in these narratives is that rule abolishment creates an innovation paradise. This study challenges this view. We therefore explain, based on two cases, how the impact of standards and rules changed while innovations passed through different product lifecycle phases. Rather than supporting or contesting the positive impact of regulation on innovation, we identify the role of rules during the uptake of two systems: the ‘KLIC utility register’ and the ‘Ground Penetrating Radar’.

The remainder of this article first synthesizes seminal literature and elaborates how we used a product lifecycle perspective to study innovation and regulation. Next, we present results and conclude that the call to ‘reduce rules to stimulate innovation’ does not simply hold in any context. Finally, we propose hypotheses about what impact different rules and standards have during distinct product lifecycle stages.

**REGULATIONS, STANDARDS, AND INNOVATION**

Innovating involves the implementation of an idea or improvement into a new process, product, or system that is novel to the institution developing it (Slaughter 1998, Shilling 2010). Innovations land within an existing institutional setting where regulations and standards shape interactions between regulators, the market, and innovation systems (Lyytinen and King 2002). This interaction is very apparent in sectors that integrate multiple complex subsystems and technologies into specialized one-off products. In such regulated industries, authorities and companies dictate standards to shape collaborative innovation paths (Yoo et al. 2005, Dedehayir et al 2014).

Blayse and Manley (2004) found that regulations and standards are one of the six ‘main factors driving or hindering construction innovation’. Initially, innovation studies mostly focused on the restrictive influence that standards have (Gann, Wang, and Hawkins 1998). Such research stressed that regulations impose a cost burden on firms that reallocate spending away from investments in innovation (Stewart 2010). Consequently, the argument resulted that rules should be abolished to let innovations flourish. Later, this debate turned toward the enabling role of regulations with respect to stimulating innovations (e.g. Pries and Dorée 2005; Koch and Jacobsen 2014).

Rules may support innovation because they provide structure. They stabilize market situations, provide the technical infrastructure that facilitates diffusion (van Waarden 1996), and create competitive advantages for nations as a whole (Porter 1990). Furthermore, progressive rules create incentives to innovate (van Waarden 1996, Stewart 2010). Regulations about safety, competition, and sustainability, for example, triggered innovations in Formula 1 technology (Jenkins 2010), and automotive industry (Huber 2012). Similarly, innovations are stimulated through tight environmental regulations and green building standards (Porter and Van der Linde 1995, Monahan Coates and Clarke-Hagan 2014). These regulations shape conditions that re-allocate corporate investments toward environmental R&D (Brunnermeier and Cohen 2003, Kneller and Manderson 2012).

Overall, the structure and incentives that regulations provide create a minimum threshold for performance and may stimulate innovation. This needs to be balanced by ‘dangers of over-regulation’ (Loosemore and Holliday 2012).

Standards and innovation have a symbiotic relation: standards can be derived from an innovative technology, and alternatively, innovations can be spurred from standards too (Allen and Sriram 2000). Mainly three different ways for standards acceptance exist: industry accepts them de facto (such as a QWERTY-keyboard); authorities approve them...
Forget the Rules and Innovate

(regulatory standards) or professional associations reach consensus to use them (Allen and Sriram 2000). The effectiveness of rules on the adoption of an innovation depends both on the type of regulations as well as on the local external context in which innovations emerge (Hartmann 2006). Careful empirical studies of the social and material aspects that altogether define the non-linear relation between innovation and different standards are therefore needed (Timmermans and Epstein 2010, Koch and Chan 2013, Koch and Beemsterboer 2017, Yoo et al., 2005).

Despite this call for contextualized empirical studies, however, the different types and impacts that standards can have - depending on the innovation context - are often lumped together as if the standards-regulation-innovation relation is static and unambiguous. Although scholars often acknowledge that rules and innovations 'have a complex relation' it remains unclear how this relation should be conceptualized. Blind (2012) already distinguished between the short-term compliance costs and long-term positive effects that various rules can have on innovation. We contribute to this by hypothesizing that regulation, standards, and innovations interact differently during four stages of product adoption. These stages are called product lifecycle stages and include the following phases: introduction, growth, maturity, and decline. The aim of this study is to explore how the role of regulations and standards evolves during these distinctive stages.

**METHOD**

This study focused on the adoption of the KLIC system as well as the adoption of the ground penetrating radar device for utility mapping. Both systems were confronted with rules and standards. Besides choosing these innovations because they lie within the domain of expertise of the authors, we also selected them because they contributed significantly to the reliability of existing construction management practices. The KLIC system and ground penetrating radar enrich practice by providing information about underground project conditions. This helps project managers reducing the risk that excavation incidents occur. To analyze the uptake of both systems, we first conducted a desk study to backtrack the key activities during their adoption.

Moreover, the authors’ involvement in industry meetings and innovation initiatives allowed them to identify the main documents related to the adoption of KLIC and the GPR. We used these to identify the key events, standards, and rules that shaped the two innovation trajectories. As a next step, we used the taxonomy of Allen and Sriram (2000) to analyze what type of standards (de facto, regulatory or consensus) applied to each of the product lifecycle phases. Similarly, we used the terms from van Waarden (1998) to denote whether regulations were structural or used as an incentive. This finally allowed us to create an overview that categorizes the regulations, standards and their functional role during different product lifecycle stages.

**RESULTS: TWO INNOVATION NARRATIVES**

This section describes how regulations impacted two innovation trajectories. The first innovation trajectory we describe is the Dutch system for utility plan exchange - KLIC ('Kabels en Leiding Informatie Centrum'). KLIC stores and exchanges maps containing the geographical location of utility owners’ networks. The second trajectory focuses on the adoption of the ground penetrating radar as a technology for surveying buried infrastructure.
Trajectory 1 - The Adoption of the KLIC System

The utilities’ sector in the Netherlands became largely privatized in the 1990s. Back then, ownership and control over the utility networks migrated from a few government organizations to myriads of private and semi-private utility operators. The privatization involved a transfer of ownership over physical infrastructure. The new owners became responsible for the accurate registration of the location and status of their own assets. This information, in turn, supported construction planning and utility strike avoidance.

It became more crowded in the Dutch subsurface because more infrastructure - such as telecommunication lines, and fibre optic cables - entered public space since the nineties. The increase and fragmentation of utility information complicated street works. To reconstruct a street, for example, maps from the gas, water, electricity, sewage and telecommunication networks had to be collected from their respective owners. In the beginning, the government formulated no rules as to how the utility information had to be stored and exchanged. Each utility company used different approaches (syntax, symbols, and formats) to map and exchange their asset data. Stakeholders merged this data manually to create a comprehensive overview of all buried utilities on a construction project site. As a result, the integration of the different utility maps was cumbersome and time-consuming.

The Dutch utility sector responded to this information integration and exchange problem by founding the utility information centre, KLIC. Similar to the multiple dial-before-you-dig firms in the UK, project stakeholders contacted KLIC to receive utility plans for a particular area. The system was decentral. This means that utility owners maintained their asset information themselves, while the KLIC system handled the exchange of this information between utility companies and contractors. After implementation of the utility strike avoidance act WION (wet informatie-uitwisseling ondergrondse netten) in 2008, KLIC usage became mandatory for all infrastructure construction projects. The Cadastre became owner and operator of the system. Since that moment, utility owners had the obligation to make available the location data of their main utility lines, and to send this through the KLIC centre on request of a contractor. Together with WION, the national guideline utility strike avoidance (CROW 250) was launched. Nowadays CROW250 is used as a code of conduct that prescribes measures needed to perform careful excavation work.

Since 2010, the technology for digital mapping and exchange of utility plans progressed. The sector demanded from the KLIC system that utilities were mapped and exchanged digitally. These stricter rules become tightened even further in 2016-2018. During this period, the KLIC system will be adapted to the EU INSPIRE directive for public information exchange. This directive even prescribes the digital format and access requirements for public utility data. According to INSPIRE, network owners need to give the Cadastre access to the vector-based location information of their full network by 2017. This network information should not only include the main lines, but also the service lines that connect the main lines with facilities. In the next version of the KLIC system, the Cadastre expects to store all information centrally to provide near-ubiquitous access.

As of 2017, the Dutch KLIC systems is integrated as a public system for quick and low-cost information exchange between contractors and networks owners. In the UK, the regulatory support for this public systems seems not yet to exist. To identify utilities in the UK, private firms perform enquiries through traditional ‘dial before you dig’ services.
This trajectory shows that utility information exchange was first initiated voluntarily to support asset information exchange. While the sector gradually adopted it, the system passed introduction stages and rules structured behaviour. Later, the rules were sharpened again to provide an incentive for improving utility data exchange. As time passed, complementary standards were developed by the construction sector to elaborate how the rules needed to be applied in a context of excavation work. Incentive rules and consensus standards helped to let the innovation function effectively. Table 1 summarizes the innovation stages, regulations and standards, and regulation types from literature. In contrast with the 'abolish rules' motto, the table shows that rules and standards receive an important role during the innovation adoption.

Table 1: KLIC system product lifecycle, and the corresponding standards and regulations

<table>
<thead>
<tr>
<th>Period</th>
<th>Event</th>
<th>Related rule/ standard</th>
<th>Type</th>
<th>PLC stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-2008</td>
<td>Unregulated exchange of utilities plans through the KLIC system. Decentral storage of maps</td>
<td>Not applicable</td>
<td>Introduction</td>
<td></td>
</tr>
<tr>
<td>2008-2010</td>
<td>Mandatory use of KLIC system for the exchange of data about the location of cables and pipeline mains. Information stored at decentral location</td>
<td>KLIC incorporated in strike avoidance act (WION)</td>
<td>Incentive rule</td>
<td>Introduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industry standard CROW 250 on utility strike avoidance</td>
<td>Consensus standard</td>
<td></td>
</tr>
<tr>
<td>2010-2016</td>
<td>KLIC system exchanges information about the location of cables and pipeline mains digitally. Decentral storage</td>
<td>WION extended to facilitate digital exchange</td>
<td>Structural rule</td>
<td>Growth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industry standard CROW 250</td>
<td>Consensus standard</td>
<td></td>
</tr>
<tr>
<td>2016-present</td>
<td>KLIC system as a central system for storage exchange of utility information. Registration of the full network mandatory.</td>
<td>Extended WION (to facilitate digital exchange)</td>
<td>Structural rule</td>
<td>Maturity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New industry standard CROW 500</td>
<td>Consensus standard</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EU-INSPIRE directive</td>
<td>Incentive rules</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Information model IMKL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Trajectory 2 - The Adoption of the Ground Penetrating Radar of Utility Mapping

The ground penetrating radar (GPR) was developed in the late 1900s as a technique for geophysicists to explore soil characteristics and identify unknown objects in the subsurface. As antennas and processing software became more reliable, the technology also landed in the civil engineering domain. Array radars helped to sense the composition and the thickness of existing asphalt layers. Additionally, manufacturers and researchers started using the GPR to map buried infrastructure. In the UK, for example, researchers of the mapping the underworld and assessing the underworld programmes, tested and developed utility mapping techniques including the ground radar, electromagnetic locators, and acoustics. They concluded that each of the techniques had different uses and constraints. The ground penetrating radar, for example, could not function properly in wet soil and clay. In addition, the GPR was not able to detect all types of buried material. Although the UK projects terminated in 2015, the technology seemed mature enough for professional use. Industry hence started using GPR to map utilities.

In general, the first practical applications of GPR in utility mapping were disappointing. Either this became because of technology overselling (e.g. a supplier promised that a GPR detected more than it actually could), or because clients had unrealistic expectations.
of what output a GPR could produce. Dutch clients, for example, often expected that they would receive a map that visualized the locations of all buried infrastructure in the survey area. Surveyors could not live up to this expectation. The UK sector dealt with a similar problem and collectively developed the PAS-128 (entitled: Specification for underground utility detection, verification, and location) to define the different quality levels that utility detection technologies can achieve. Currently, the Dutch also start integrating the GPR-technology into a utility strike avoidance guideline Act (CROW 500) as well as in an equivalent to the PAS-128.

Table 2: GPR for utility detection product lifecycle, and corresponding standards

<table>
<thead>
<tr>
<th>Period</th>
<th>Event</th>
<th>Related standard</th>
<th>Type</th>
<th>PLC stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990s</td>
<td>Ground Penetrating Radar accepted term in science and technology</td>
<td>Not applicable</td>
<td>Introduction</td>
<td></td>
</tr>
<tr>
<td>2005-2016</td>
<td>MTU ATU programme</td>
<td>Not applicable</td>
<td>Introduction</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>Launch of guideline for surveying services launched</td>
<td>PAS128</td>
<td>Consensus standard</td>
<td>Growth</td>
</tr>
<tr>
<td>2016</td>
<td>GPR adopted as tool for surveying</td>
<td>CROW 500</td>
<td>Consensus standard</td>
<td>Growth</td>
</tr>
<tr>
<td>2015 - present</td>
<td>Dutch PAS-128-NL being explored</td>
<td>PAS128-NL</td>
<td>Consensus standard</td>
<td>Growth</td>
</tr>
</tbody>
</table>

Table 2 describes the adoption process of the GPR. It shows that the early adoption of GPR led to the development of standard processes that prescribe suitable steps and quality levels. These initiatives were industry driven and consensus-based. Standards provided clarity, reshaped the existing institutional environment and eventually contributed positively to the uptake of the innovation. The argument 'that rule abolition stimulates innovation' was not applicable here.

We allocated the identified regulation and standard types to the distinctive lifecycle stages in Figure 1 to compare the two innovation trajectories. With respect to trajectory 1, the figure shows that innovation growth relates to innovation incentive rules and consensus standards. In trajectory 2, co-ordination of the innovation process took place mainly through mutual adjustment between pioneering stakeholders. The growth and maturity stages of both trajectories were subject to structural rules. It is likely to assume that these rules come into play to stabilize the innovation within an institutional context.

DISCUSSION

All in all, this study shows that the claim that 'rules block innovation' is incomplete and myopic. It does not apply just everywhere and in any innovation context. We show that the regulations and standards have a different impact during each of the innovation stages. We use these findings to define two hypotheses: First, incentive rules, consensus standards, and mutual adjustment are mechanisms to coordinate behaviour in innovation introduction stages. The absence of structural rules and regulatory standards signifies that these rules may not have a positive impact during innovation introduction. Second, incentive rules seem to play no role during the successive stages. We hence hypothesize in relation to innovation growth and maturity stages, that structural rules and regulatory standards become increasingly important to stabilize innovation integration.
Previous studies (c.f. Van Waarden 1996, Gann et al., 1998, Allen and Sriram 2000, Timmermans and Epstein 2010, Koch and Beemsterboer 2017, Yoo et al., 2005) already highlighted the complex relationship between regulation and innovation. This study conceptualizes this further by using the product lifecycle to map the dynamic interplay between regulations, standards and the innovation system.

![Figure 1: allocation of the identified regulation and standard types and their relation to different product lifecycle phases](image)

Our findings fit within ongoing regulation-innovation debates. The changing role of regulations is, for example, also addressed by Blind (2012) who argues that the short-term impact of regulations may be negative, while on the longer term regulations encourage adoption, accelerate uptake, and create spillover benefits. Additionally, Shen et al., (2013) confirm our observation of a dynamic innovation context by claiming that hybrid standards may emerge from a combination of existing and new standards. Finally, our observation that mutual adjustment first coordinates innovation processes before structuring regulations come into play is in line with Van Waarden (1996). He argues that a pragmatic and flexible regulatory approach, where rules are implemented in close collaboration with industry, helps to shape a protective and innovative atmosphere where rules are challenged less frequently.

We suggest various steps for future research. First, this study contains only a first exploration of the innovation trajectories of the KLIC-system and GPR. Additional research could focus on mapping this interaction in greater detail. Such a study can then also take into account the various impacts that rules have on an innovation. Koch et al., (2014) give examples of such impacts by stating that standards: improve interoperability, enable efficient repetition in product development, stabilize volatile processes, and enable entry of products into new markets. Furthermore, additional studies of other innovation trajectories in different contexts would help explain whether cultural factors (such as regulator's flexibility and adversarial behaviour) also influence the emergence and effectivity of standards and regulations. Van Waarden (1998) advocated the point earlier but we did not yet consider it in our study.
CONCLUSIONS

This study explored the changing role of regulations and standards during the adoption of the Dutch KLIC-system and the utilities GPR. We outlined the key activities that influenced the adoption trajectory and used taxonomies of Allan Sriram (2000) and Van Waarden (1998) to categorize the relevant standards and regulations. Next, we developed an overview of the functional standards and rules during each of the adoption stages. Our comparison of the two cases from the utility construction domain demonstrates that the prevailing motto 'forget the rules and innovate' is unrealistic and short-sighted when considering the innovation lifecycle for analysis. We argue that, although freedom enhances design and innovation space, the reduction of rules is not the necessary solution for smoothening innovation adoption processes.

A closer look at the adoption of the KLIC system shows that different rules and standards influence distinctive phases of the product lifecycle. In this case, mutual adjustment first coordinated the behaviour of the stakeholders. Regulations and standards only emerged after the industry adopted the system on a larger scale. In both cases, the initiative to implement standards and rules originated from the sector itself, rather than from regulators.

This study contributes to practice by describing a more nuanced innovation context, and by explaining how the shape and impact of rules change along the product lifecycle stages. Furthermore, we refine the research concepts by adding the product lifecycle view to innovation-rules debates. This provides a more holistic and realistic frame of reference for future studies. Finally, we recommend practitioners to take into account the product lifecycle stage, as well as the regulation and standardization types before considering that construction industry should 'forget the rules and innovate'.

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INTERNAL REGULATIONS VS EXTERNAL BORDER CONTROLS: BREXIT AND ITS IMPLICATIONS FOR CONSTRUCTION LABOUR IN BRITAIN

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The paper explores the implications of Brexit for construction labour and argues for the continued free movement of labour with at the same time stronger internal regulation of the labour market. The construction industry is an important sector for migration, contributing to innovation and developing a qualified workforce. The large contractors are international, especially those constructing major infrastructure projects, and the industry is dependent on labour from across Europe. Without it, there are serious obstacles to meeting recruitment requirements, especially given the weakness of the British vocational education and training (VET) system for construction and the need for a more qualified construction workforce. Drawing on extensive research on labour in construction across Europe, the paper assesses the impact of Brexit on employment rights and working conditions in construction in the context of lack of regulation by successive British governments and reliance on European Union (EU) Directives, developed through the social dialogue. Brexit potentially entails significant losses for the workforce and the industry, including chronic skill shortages, low wages, deteriorating health and safety, and long hours, but this rests on the political strategy adopted. The question addressed is: How can the construction sector in Britain dependent on the European labour market, regulation, and know-how continue to thrive if external border controls instead of internal labour market regulation are imposed?

Keywords: BREXIT, labour, employment rights, European Union, UK

INTRODUCTION

With Brexit dominating the political and news agenda, it is important to consider what implications leaving the European Union (EU) might have for the construction industry, and in particular for construction labour, especially if the principle of free movement of labour is jeopardised. This is because the construction industry has always been an important sector for migration, which has contributed to innovation and the development of a highly qualified workforce. The large construction firms have also become increasingly international, in particular those constructing major infrastructure and engineering construction projects, including Vinci, Skanska, Holcim and Bouygues. Large infrastructure projects such as the London Underground Jubilee Line extension, Crossrail, the Gotthard Tunnel and Thames Tideway are inconceivable without the internationalisation of firms and the labour force.

However globalization and the financialisation of the industry have also gone together with greater and greater fragmentation, through extensive subcontracting chains, the use of agency labour and self-employment (Rafferty and Toner 2015). This has in turn contributed to employer disengagement from the vocational education and training (VET) of the workforce, which has led to the virtual collapse of the employer-based VET system.

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Clarke (CITB 2016a). Reliance on developing the construction labour force required through the VET system in Britain is therefore unrealistic given the very low levels of construction training (Chan et al., 2010). Ironically too the collapse in VET has occurred as the need for higher levels of knowledge, skills and competence is more and more evident as the labour process has become more abstract, especially through prefabrication, mechanisation, digitalisation and the demands of low energy construction (Clarke et al., 2016).

For the construction industry, the free movement of labour is especially important given the global nature of its labour process and the dependence on recruiting a workforce from all over Europe, thereby ‘poaching’ skilled labour from other countries. The consequences of Brexit are therefore potentially damaging, unless the VET system is transformed and free movement maintained. It is argued that the way in which free movement has been interpreted in the United Kingdom is distinct from elsewhere in Europe in being enacted within an increasingly deregulated labour market. In Scandinavian countries or in Germany, in contrast, freedom of movement exists within the context of regulated construction labour markets (Dølvik and Visser 2009).

The paper draws on extensive research on labour, VET and wages in the construction industry over many years, including research projects sponsored by the European Commission, Leverhulme Trust, and Nuffield Foundation. The author has also been in regular attendance as an expert at European Construction Social Dialogue meetings, works closely with the European Federation of Building and Woodworkers, and is a board member of the European Institute for Construction Labour Research.

Free movement of labour

By potentially presenting barriers to the deployment of workers from elsewhere in the EU, including those already working and living in Britain, Brexit raises the inevitable question of whether and how the free movement of labour is maintained. It is one of the four economic freedoms enshrined in the founding Treaty of the European Union (European Parliament 2017) and entails:

- the abolition of any discrimination based on nationality between workers of the Member States as regards employment, remuneration and other conditions of work and employment
- the right, subject to limitations:
  - to accept offers of employment;
  - to move freely within the territory of Member States for this purpose;
  - to stay in a Member State for the purpose of employment in accordance with the provisions governing the employment of nationals of that State;
  - to remain in the territory of a Member State after having been employed in that State, subject to conditions.

Perhaps one of the most important considerations here is the right to stay ‘in accordance with the provisions governing the employment of nationals’, as where such provisions are weak, as in the UK, so too will they be for migrants from elsewhere in Europe.

One of the most important characteristics of the construction industry everywhere is its mobility and increasingly global nature. It has always been an important sector for migration. In Britain since the war, workers came first from Ireland, then the Caribbean and elsewhere in Europe, and more recently from Eastern Europe, especially Poland, Bulgaria and Romania; in Germany, much labour came from Italy, later Turkey, and in
the 1990s from Britain; while in France concrete work has long depended on workers from Portugal. It is difficult to estimate the number of migrant workers in the construction sector, though this has certainly increased since 2004, largely attributable to workers coming from East European countries. In proportion to their numbers, migrants are over-represented in what is classed as lower skilled work and under-represented at higher-levels (Chan et al., 2010). The latest official figures for the British construction industry show that 12% of the workforce of 2.1 million are migrants, with the largest concentration of foreign-born construction workers (both from within and from outside the European Union (EU)) in London where they represent about half the workforce (Rolfe and Hudson-Sharp 2016). However, whilst some of these migrants may be considered as ‘posted workers’ (those working temporarily whether as subcontracted or agency labour or even self-employed), many posted construction workers will not be classed as migrants.

Posted workers are especially prevalent in the increasingly global engineering construction sector, where much resentment has arisen over the last decade on the part of UK-based workers constructing large projects, including Staythorpe, the Isle of Grain and several biomass power stations (Barnard, 2009). Here, some contractors and subcontractors took free movement as an excuse for wage dumping and for discriminating against the recruitment of UK-based labour - a factor that contributed in no small way to the outcome of the referendum. It also highlights the peculiarity of the British situation, where the free movement of labour has existed in the context of weak regulation and concerted attempts by government at deregulation. For instance, the British government’s transposition of the EU Posted Workers Directive, intended to regulate the movement (posting) of labour as opposed to services transnationally, required only minimum legal provisions instead of customary or collectively agreed terms and conditions. Various decisions (Viking, Laval etc.) of the European Court of Justice, giving freedom of competition precedence over fundamental social rights, have only added to the boiling resentment on construction sites (Lillie and Greer 2007). However, many EU countries, including Denmark, Germany and even Switzerland, have made concerted attempts to combat breaches of the Posted Workers Directive and associated wage dumping. For instance, recently on a Danish university site a large building services contractor from Spain was expelled for not remunerating its employees on an equal basis to Danish-based workers on the site.

The resentment in Britain has been fuelled by failure to implement perhaps the most widely respected and recognized collective agreement remaining in Britain, the National Agreement for the Engineering Construction Industry (NAECI). This is a centralized agreement covering large engineering construction sites such as power stations, and safeguarded by the trade unions - Unite and GMB - and the Engineering Construction Industry Association (ECIA), consisting of 300 predominantly global companies. The Engineering Industry National Joint Council of employers and unions has wide-ranging powers regarding the application of NAECI, including final ruling on any disagreements, categorising work, approving Supplementary Project Agreements, and adjudicating if grievances and disputes cannot be resolved at a local level. On prestigious projects such as Heathrow Terminal 5 and the Olympics, Major Project Agreements (MPAs) were also put in place to safeguard employment and working conditions (Clarke and Gribling 2008). Whilst the detailed provisions on employment relations vary from project to project, such agreements tend to echo NAECI and to provide for:
• Standards on employment, including direct employment and the avoidance of false self-employment, as principles to be cascaded through the contractual chain
• Opportunities for trade union representation and involvement
• Provision and targets for skills training, the engagement of local labour and opportunities for non-traditional entrants, including women and those from black and ethnic minority (BAME) groups into the industry
• Controls over subcontracting tiers
• More effective standards on health and safety management, including the requirement that all workers are in possession of a CSCS (Construction Skills Certification Scheme) card, indicating health and safety awareness and a particular qualification level
• An auditing process, including over the weekly remuneration of all workers.

This amounts to the imposition of the internal regulation of sites, so common in construction in many European countries and in place alongside the free movement of labour.

Engineering construction represents however the most regulated and one of the most unionised sectors of the construction industry. Elsewhere, many of the two-million strong workforce in construction is employed casually, with nearly 50% classified as ‘self-employed’, and many working long hours and in poor working conditions (ONS 2016). If employment rights are significantly weakened through Brexit, it is all the more important that MPAs and agreements such as NAECI are in place throughout the industry and not just on mega sites in order to safeguard conditions.

The free movement of labour has been to the great advantage of the construction industry across Europe, both for workers and employers, but the intention was never that it has supremacy over basic social rights (Cremers 2010). Free movement of labour should not mean a free for all. Switzerland provides a good example of an alternative approach. There, 24% of the total population of eight million are migrants, with many working in the construction sector, where almost 60% belong to the union UNIA, of whom 75% are migrant (Pedrina 2015; Perieran 2007). Three years ago in a referendum in Switzerland on immigration the Swiss narrowly voted to ban Europeans entering to work in the country, so curtailing free movement of labour. The EU subsequently advised the Swiss government that, if it imposed discriminatory measures against Europeans, then access to the Single Market would be lost. Instead of controlling immigration through the cumbersome bureaucracy of visas and permits, the Swiss decided on internal controls compliant with EU rules on free movement of labour and based on a requirement that, for instance, in some cases firms should advertise posts with local job centres. Qualification requirements for particular jobs and ID checks on social security contributions are other options. Then why does the UK not consider this alternative approach of internal regulation rather than external border controls?

The collapse of VET and recruitment requirements

Following the Brexit vote, it is unclear where the estimated 31,350 new construction workers required in the UK every year, many in highly qualified areas, are to come from without a transformation of the VET system and continued free movement of labour (CITB 2016b). One possibility is through training. However, employers in Britain have slowly abdicated from responsibility for the VET of the workforce, and increasingly come to rely on recruiting labour from elsewhere in Europe. The declining number of
construction trainees and those undertaking an apprenticeship in the UK is not a result of migration though but can be seen as part of a long process since the 1980s, long before EU enlargement in 2004; it has now plummeted to reach an historical low, at a same time as the workforce is required to be ever more qualified (Clarke et al., 2013). In 2015/16, there were 11,586 first year construction ‘craft’ trainees, of whom only 35% were undertaking some kind of work-based training with the remainder on full- or part-time courses in Further Education (FE) colleges. Only 16% of all construction trainees pursue a National Qualification Level 3 qualification, equivalent to three years training, which is the standard in much of mainland Europe and in some countries even the minimum construction qualification level (CITB 2016a). In 2015/16, only 3,000 were following an apprenticeship programme, far more in the north of the country than the south, 70% at level 2 and only 30% at level 3. In an industry employing nearly 2m, this represents less than two apprentices for every 1,000 workers, compared to about 40 per thousand in Germany, where they are all at the equivalent of Level 3. In terms of particular trades too, in 2015/6, the number of trainees in Britain in the wood trades, an occupation in high demand, was 4,316, down from 5,893 in 2013/4, whilst those in bricklaying declined from 3,313 to 2,614 in the same period (CITB 2016a). Only 66% of those in the wood trades and 44% of bricklayers are following an apprenticeship programme.

The collapse of the VET system has contributed to ever lower levels of productivity and to the ever greater dependence on migrant labour - thus posing a threat of extreme skill shortages with or without Brexit (Farmer 2016). However, it is all too easy to blame the industry; it has rather been a failure of regulation by successive governments since the 1980s to curb the decline. The crisis in VET is a political and structural problem, related to the imposition of an employer-based training system in the context of employer disengagement from training. This disengagement is complex, attributable to the degree of fragmentation and to difficulties in even identifying the ‘employer’. 92% of construction firms employ less than 13 people whilst only 0.4% employ over 80 and 0.04% more than 600 (ONS 2016). Just since 2005, the total number of firms has increased from 182,644 to 273,775. Added to this an estimated 50% of construction workers are self-employed and thus in no position to train others (UCATT 2016). This hardly provides the sound infrastructure needed for broad-based VET and work experience, given that large firms do not employ, smaller firms have problems providing the breadth of experience required or the necessary mentoring, and the self-employed are in no position to train.

Government policy has increasingly excluded employee and educational representation, transforming the Construction Industry Training Board (CITB) from a tripartite body to one containing no single employee representative and only one independent FE college member. Yet employee representation is vital because workers have an interest in acquiring, through education, qualifications that are of long-term value over working life; short-term imperatives, in contrast, underpin employer interests. The system is thereby skewed in favour of short-term employer’ rather than long-term worker’ interests. The policy assumption has been that VET is the sole responsibility of the employer and reliant on ‘learning by doing’ rather than ‘education’. Ironically, however, most of the little training that now takes place is in Further Education (FE) colleges, and not in the workplace. At the same time, the existing and future workforce depends for its livelihood on the development of more up-to-date and comprehensive knowledge, skills and competences (KSC), of value in the long-term over working life, than can be acquired with a single employer, especially a small firm or subcontractor (Clarke and Winch 2016). The construction VET system has generally failed to keep pace with advances in
the construction labour process, which with increasing mechanisation, prefabrication and
digitalisation has become demanding of broad occupational profiles and a high level of
abstract abilities, especially with low energy construction (Clarke et al., 2016). Such
abilities are often best developed in the classroom or well-equipped workshop than on a
hazardous building site.

Without massive long-term investment and a transformation of the VET system,
therefore, current labour requirements cannot be met, with or even without Brexit. With
Brexit, however, as in the Swiss case, the solution of internal regulation and the
continuance of free movement remains a possibility. The Construction Skills
Certification Scheme, or CSCS, a system developed for recognising qualifications by the
industry in Britain, despite the sorry state of construction VET, would facilitate such a
solution. If this scheme were statutory, applied universally throughout the industry, and
with more stringent controls on qualifications, it could provide a means for ensuring the
recruitment of a qualified workforce, whether from within Britain or elsewhere, without
resort to the difficulties of applying immigration quotas to an increasingly mobile and
global labour force. The CSCS was launched in 1996 and has nearly two million
cardholders (approximately 1.5 million covered by the core scheme, including
professionals and managers and the remaining 0.5 million with affiliated partner schemes
e.g. in plumbing, electrical contracting and scaffolding). Supported by trade associations,
employer organisations and unions, CSCS requires individuals to achieve occupational
qualifications meeting national occupational standards for the occupation in question and
to pass a Health and Safety test, owned and managed by the CITB (Clarke and Gribling
2008).

Currently the CSCS is a voluntary scheme and the principal (tier 1) contractor decides if
it is required, so it is less likely to be used on smaller sites and by smaller contractors or
sub-contractors. Its main purpose is to certify that cardholders have passed a health and
safety test. For the majority of the larger contractors, it is a requirement for site access
and part of the procurement process, with organizations only short-listed if the personnel
hold cards. Despite problems with fraud and proxy training (someone standing in for
someone else), CSCS has the potential to act as one means of regulating the recruitment
of workers throughout the industry and ensuring a qualified workforce is employed, with
qualifications aligned to the European Qualifications Framework.

Regulation of employment and working conditions

The lack of regulation of VET by successive British governments is especially evident
with respect to employment rights and working conditions in construction in Britain, an
area which has relied on EU directives. The fairly comprehensive and structured set of
health and safety directives over thirty years has significantly contributed to a lower
number of fatalities and a safer working environment. There have been no ‘home grown’
UK health and safety laws in this period, though there has of course been UK
involvement in developing these directives through representation in the Council of
Ministers, the European Parliament, the European Economic and Social Committee and
the Social Dialogue (representatives of the trade unions and employers associations at
European level). Indeed, the Social Dialogue has been a means to facilitate employee
participation and trade union coordination across Europe, another being European Works
Councils. It is thanks to such procedures that we have the Construction Design and
Management Regulations, to facilitate the coordination and management of health and
safety issues on sites, as well as the Working Time Directive, the first attempt to regulate
working time in Britain. The latter introduced paid holidays and breaks and, were it not
Construction Industrial Policy in the UK

for the ‘opt out’ demanded by the UK government and widely applied throughout the construction industry, maximum working hours, and hence a better work-life balance and more inclusive working environment. The revised Construction (Design and Management) Regulations 2015 (CDM 2015), which came into force on 6 April 2015, aim to clarify responsibilities, from designer through principal contractor, for effective management of health and safety on site.

Other directives have also played an important role in helping to regulate employment in the industry and overcome some of the worst abuses. These include the Agency Workers Directive, introduced in 2010 and entitling agency workers who have worked for more than twelve weeks for an end-user the same basic terms and conditions as permanent staff. These include holidays and rest breaks, basic salary, and personal performance and piecework bonuses and other perks, but not contractual sick pay, pensions, long-service bonus or redundancy pay.

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safety, long hours, and continued male-domination. A possible indication of government realisation of the need for such regulation is evident from the setting up of a Gangmasters and Labour Abuse Authority (GLAA) under the Immigration Act of 2016, though its terms of reference are still unformulated. The construction trade unions have long demanded the extension of the previous Gangmasters Licensing Authority to the construction sector, as did the Donaghy report (2009) on health and safety in construction. The GLA, combined with statutory application of CSCS and effective implementation of existing Directives relating to employment and working conditions, provide the rudiments of internal regulation.

CONCLUSIONS

The puzzle remains how the construction sector in Britain, which is dependent on the European labour market, regulation, and know-how, can be productive if the free movement of labour is curtailed and external border controls instead of internal regulation are imposed. Internal regulation of the construction labour market implies the application of measures such as:

- Controlling bogus self-employment and limiting the scope of agencies and pay roll companies
- Controlling for qualification levels through extending requirements for CSCS and making these mandatory
- Auditing subcontractors and subcontracting tiers
- Giving preference to locally-based labour in recruitment and involving trade unions.
- These measures, if enacted, are also in compliance with EU rules on free movement.

As the latest report on the industry, the Farmer report commissioned by the Construction Leadership Council, commented, an ageing workforce coupled with low levels of new entrants and a long-standing reliance on migrant labour together constitute an impending crisis for the industry, particularly with Brexit pending:

The construction industry and its labour model is at a critical crossroads in terms of its long-term health. Whilst the diagnosis points to a deep-seated market failure, there are certain industry trends and wider societal changes happening now that represent both unprecedented risk and opportunity for the industry and its clients. If the opportunities are not harnessed, the risks may become overwhelming. (Farmer, October 2016: 8)

As outlined here, the opportunities include developing effective labour market controls, building on existing embryo measures such as CSCS and the GLAA, as well as extending the remit of the NAECI and effectively implementing existing EU employment regulation, including the Posted Worker and Working Time Directives. Without free movement of labour and at the same time a comprehensive construction VET system in place, however, the risks for the labour force, for potential young recruits and for the productivity of the industry are acute.

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Clarke


THE POLITICAL ECONOMY OF CONSTRUCTION
INDUSTRIAL POLICY IN THE UK

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In many areas of construction research at some point a question of policy arises, namely, what needs to be done to enable recommendations for change to be adopted and implemented. Potentially one of the most promising means of understanding policy is the use of Political Economy (PE) theory and the associated method of Political Economy Analysis (PEA) which have both been used extensively in a diverse range of policy areas. Yet despite an inherent affinity between PE and industrial policy, PEA has seldom been used in the analysis of construction policy. The theory, scope and purpose of PEA are explored and an initial analytical framework for use with construction policy is assembled. The suitability and potential for use of the framework with Construction Industrial Policy is assessed as a scoping study. PEA is found to be a well-established, if sometimes imprecisely and inconsistently defined, set of methodologies the strength of which is rooted in its systemic perspective. In conclusion, the value of research into the processes of Construction Industrial Policy can be considerably enhanced by the use of the PEA framework which addresses aspects which have tended to be neglected in the literature.

Keywords: industrial policy, policy, political economy, political economy analysis

INTRODUCTION

Policy which impacts on construction is no less diverse than construction activity itself. Yet it is well recognised that frequently construction policy, for whatever reason, tends not to meet the expectations either of those active within the policymaking process or of other stakeholders (Foxell and Cooper 2015). Research on such policy tends to focus on the contingent challenges of the individual policy rather than on the policy process itself and Foxell and Cooper (ibid.) led calls for research into the common themes of policymaking in order to stimulate what they termed 'policy literacy' within the construction community. Indeed, attempts have been made to identify and begin to test the use of specific disciplines and techniques of analysis from outside of construction (Fernie et al., 2006; Smiley et al., 2014; Müller 2016).

The problems and challenges of policy formation and implementation within construction are likely to be shared to some degree with other policy areas and hence political science needs to be seen as a major candidate discipline which is available for use by those seeking to understand construction policy. In addition, Construction, as an industry, is a major sector of the economy and any consideration of policy processes which affect the sector must also address economic questions at both macro- and micro-level. The simultaneous, integrated, application of both of these disciplines is known as Political

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Economy (PE). PE explores why 'actual' policy tends to differ from the apparently 'optimal' (Drazen 2000: 7), whatever policy context is examined.

PE can be seen as an umbrella discipline, which is inter-disciplinary in nature. However, its importance lies in the widening of enquiries into economic decision-making and behaviour to include questions of power, influence and motivation among relevant actors, including 'political mechanisms and constraints' (Drazen 2008: 23). Regarding its relevance to Industrial Policy (IP), Glykou and Pitelis make the case that the modern concept of IP rests on PE 'foundations' (2011: 461) including theories of the State and of the Firm. Hence, not only is PE relevant to any analysis of policy, it has a special relevance when aspects of industrial policy are in question. A PE approach has been used extensively, and effectively, in many policy contexts in sectors other than construction (Tompson and Price 2009).

On the other hand while, as indicated earlier, examples of research exist where specific analytical tools have been applied to isolated instances of construction policy, there appears to be an absence of a method of analysing and explaining policy processes in a systemic (that is, a system-wide or holistic, Wallis 2014) sense which has been applied to construction policy within developed economies. This apparent absence of a systemic method exists irrespective of whether the method might be based on PE or another analytical technique.

Put another way, there seems to be strong evidence that research into Construction Industrial Policy can and should benefit from the use of PE methods which have been deployed effectively elsewhere. Such is the opportunity which this paper seeks to investigate and test, within the context of a scoping study for a more detailed programme of work.

Political Economy Analysis (PEA) can be seen as the methodological approach which has evolved from PE theory. PEA has been used in a very explicit format in the Development sector, that is, for analysis of reform in developing countries. The guidance available from the Development sector includes a number of analytical models or frameworks. This depth of experience, and set of apparently usable tools, constitutes a precedent for what could ultimately become available for use in the investigation of construction policy. Therefore, a literature review will be used as the basis for the design of an initial framework for construction policy analysis.

Construction Industrial Policy (CIP) as a whole has been selected to demonstrate the potential application of the framework. No a priori assumptions are made regarding the form or legitimacy of CIP. Included within this paper is an assessment of the kinds of questions which would need to be asked, the process of investigation, the nature of the learning which could be achieved, and the purposes to which such learning could be put. The consequences for future phases of research, including more specific policy areas, are appraised.

The paper concludes with an assessment of the validity of the PEA approach for use in construction policy research. Ultimately the relevance of the PEA approach would lie in being a contribution towards improved policy in the future rather than being mere explanation of past outcomes (Drazen 2000: 7; Pearce 2005: 9). The framework developed here is expected to contribute to such an ultimate goal.
LITERATURE REVIEW

Political Economy - Scope and Themes

As a field of study Political Economy is said to predate the period in the 19th century when Economics came to prominence (Groenewegen 2008). In recent decades the term PE, and the associated modes of thought, have come back into usage (Caporaso and Levine 1992). A PE approach has been used in a wide variety of policy, industry and country contexts including manufacturing, aerospace, automobile, pharmaceuticals, tourism, media, oil, film and health (Tompson and Price 2009; Craig 2015).

According to Drazen (2000: 5), Political Economy is ‘concerned with how politics will affect economic choices in society’. For the economist Pearce (2005: 8) a PE approach begins with a search for explanation as to why the most economically efficient policy solution is often not the option which is implemented or capable of being implemented. Pearce expressed this idea mathematically as the need to consider the 'political welfare' maximising equilibrium rather than just a social welfare equilibrium. In other words it is inevitable that the multiple political constraints on decision making are considered. This view is not dissimilar to that of Buse (2008), who insisted that it is necessary to look at the political economy 'environment' and 'political dimensions' of reform. The application of PE theory in a more explicitly systematic way is known as Political Economy Analysis (PEA) (Edelmann 2009).

While PE theory begins from a recognition of the need to address a problem of welfare optimisation, there is no pre-defined limit to the number or categories of methods of enquiry which may be used in analysis. Drazen (2008) set out the core concerns (in addition to economic modelling):

- 'Political actors: Leaders, citizenry, ‘selectorate’, and smaller groups which keep the Leaders in power
- The objectives of each of the actors
- Political mechanisms and constraints'

While game theory is perhaps a default methodology, especially for economists using a PE perspective (e.g. Pearce 2005: 8; Drazen 2008: 38), there is an ever-widening 'family of approaches' which are relevant (Weingast and Wittman 2006: 3). These approaches include: analysis of 'institutions' in the sense of informal and formal practices (North 1990), how these interact over time with structure (those aspects less likely to change) and with 'actors' (meaning people as well as organisations). The dynamic nature of many of these interactions was stressed by Buse (2008: 13) in that 'agency shapes structures, which in turn condition agency'. In the search for what might be considered subject to or susceptible to change, more recently disciplines such as 'anthropology and history' have been brought into the fold (Weingast and Wittman 2006: 22). Having introduced PE and PEA, it is necessary to consider why they are considered so relevant to Construction Industrial Policy.

Why Use A Political Economy Approach?

Methodologies for analysing policy processes are legion. Cairney (2012) presents an accessible review of the field and Sabatier and Weible (2014) include assessments of recent developments in particular specialist areas by many of the leading practitioners. There is undoubtedly more scope for researchers in construction policy to deploy some of these mainstream analytical tools (such as Punctuated Equilibrium, Multiple Streams Analysis, Advocacy Coalition Framework and many others). Some of these
methodologies are associated with publicly available databases of case studies, searches of which suggest that construction policy has rarely been considered. On the other hand the literature on construction policy analysis, limited as Foxell and Cooper (2015) indicate it is, does demonstrate that the use of some of the tools of policy and change analysis has been attempted (Fernie et al., 2006; Smiley et al., 2014; Müller 2016; Schweber and Harty 2010; Rasmussen et al., 2017). Similarly, Bresnen (2017) contends that institutional theory has been underused in the sector; and Harty (2008) makes the case for the use of Actor Network Theory. Each of these approaches and, potentially other innovative thinking on policy in general such as that of Hajer (2005) and Bletsas et al., (2012), contribute to a deepening of understanding about policy.

Some of the concepts used in policy analysis are shared with Political Economy (structure, institutions and actors). However PE, and hence also PEA, offer not just an approach to the analysis of policy and change but also a means of placing such analysis within a broader context of economic as well as political activity. Interest in PE, in the context of industrial policy and change, arises out of a consideration of the boundary between state and the firm, and the way in which this is contested. For example, the PE concept of Varieties of Capitalism (Hall and Soskice 2001) makes a link between varying electoral systems, the ways in which a government communicates with or influences business and the kinds of industry and skills which as a consequence might flourish in any given context (Thelen 2004). A further example is the PE literature on the theory of the firm discussed by Glykou and Pitelis (2011). Of great relevance also is the debate within PE circles, reflected in wider current UK political discourse, concerning whether the concept of an active industrial policy is of value and whether this should extend to the sector level (Bailey et al., 2015).

Therefore PEA builds on the insights offered by PE and, in the form described here, represents a specific application of PE for use in the analysis of change. PE and PEA both benefit from the 'family of approaches' increasingly available from other fields of enquiry. PEA itself then becomes an integrating framework which both brings fresh insight (often due to the willingness to look directly at issues of power) and also allows the results from more specific applications of policy analysis tools (game theory, say) to be integrated within the framework. PEA therefore should not be seen as an alternative to any of the tools of policy analysis referred to earlier, but on the contrary allows them to be seen in a wider context and enhances their value.

Political Economy - the research gap

Despite the widespread use of PE in many policy contexts (Tompson and Price 2009), and its apparent relevance, there is limited evidence for its application to Construction Industrial Policy. For developing economies work has been published on such subjects as the PE of 'Roads' focussing on rural road networks (Wales and Wild 2012) and 'School Construction' (Martinez-Bravo 2016). In terms of developed economies the scope of published work includes 'Infrastructure' investment decisions in the UK (Coelho et al., 2014), and housing provision and affordability in England (Evans 1991; Coelho et al., 2016). Christophers (2013) addresses housing provision in Sweden and the consequences for 'socio-economic inequality'. The published papers have tended to relate to aspects other than construction policy per se. In most cases, while the words 'Political Economy' appear in the title, the concept as such is left under-theorised or its meaning is simply treated as a given before the case analysis is presented. The reasons for such scarcity of application of PE to construction policy may lie in the more general observation that construction management researchers tend to under-utilise learning available in other
management and social science disciplines: for example see Bresnen's (2017) discussion of the use of institutional theory.

What is certainly absent altogether is an explicit methodology grounded in PE theory which can be used in a systematic manner across a range of different construction industrial policies in developed countries. In contrast, explicit PE methodologies have been evolving for some years in relation to Development (Edelmann 2009; Poole 2011; McIoughlin 2014). Hence the literature review has identified, first, the gap in research: namely, the use of PE with CIP in a method capable of being applied in a repeatable manner. Secondly, also identified are the beginnings of a possible approach based on learning from another sector (Development). The following sections begin to construct a possible PE framework for analysis of policy and change, based on PE theory and borrowing some of the methodology from the Development sector. Such a framework has the potential to address the absence in the literature of a systemic means of analysing and explaining policy processes for construction, and ultimately to contribute - for any specific policy area - to more effective policy.

Political Economy Analysis

The key elements of PE have been summarised earlier as structure, institutions, actors and the study of the dynamic interactions between these elements in order to determine change processes and potential future options for change. The next section examines a number of existing PEA frameworks and methodologies before attempting to adapt elements of them for use in the analysis of CIP.

Frameworks used in Development Economics

In terms of a single integrated methodology resting on an established PE basis DFID (2009) represents perhaps the leading example of an approach capable of being considered for adaptation for use with CIP, and includes guidance on questions to be asked during research and guidance on the process of research itself. On the other hand, in terms of a visualisation of the PEA method, Poole (2011: 3) presents a framework for ‘sector and project’ level assessment: (1) problem definition, (2) institutional arrangements, mapping of institutions and policy processes, (3) PE ‘drivers’ (‘why are things this way’), stakeholder analysis, historical legacies and social trends (4) proposals for action.

A slightly expanded visualisation of a problem-driven framework is offered by Harris (2013: 5). Harris, who credits Poole for the ‘earlier iteration’ of the model stresses the dynamic nature of the multiple interactions between structure, institutions and actors and hence brings steps 2 and 3 of Poole's model into a single - but highly iterative - step 2. Step 3 of Harris' model therefore deals with examining potential pathways of change and the analysis of change processes: thus Harris's step 3 is the equivalent of Poole's final step covering proposals for action.

Of the two visualisations of the PEA approach discussed here, Harris' stress on the dynamic interaction (the capacity for mutual influence) of structure, institutions and actors, seems to capture the essence of PEA in that it directly addresses the search for explanation of change (and absence of change) and leads to identification of alternative futures and their viability.

A FRAMEWORK FOR CONSTRUCTION INDUSTRIAL POLICY

The visualisation offered by Harris (2013) includes all the core concepts of PEA plus the explicit recognition of the dynamic interaction between actors and institutions. Building
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on the recommendations of DFID (2009), and bearing in mind the orientation of the present research towards a specific sector (UK construction) with an apparently mis-firing policy process, the following steps are proposed:

- Definition of the ‘Problem’ (what are the symptoms, what were the ‘theories of change’, if any, which supported previous attempts at change)
- Analysis at the country (national) level (structures, institutions, actors/agents)
- Analysis at the sector level (structures, institutions, actors/agents)
- Analysis at the ‘problem’ level (structures, institutions, actors/agents)
- Each of the three core areas of focus for PEA (structures, institutions and actors) requires a certain type of data to be assembled, and in turn, each of these may require a different kind of data source and collection method. For example, aspects such as determining motivation and values of certain actors may require a semi-structured interview approach.
- the mutual influences and interactions between structure, institutions and actors need to be identified and explored
- In terms of the questions to be asked during the research process, DFID (2009: 12) suggest a set of ‘sample questions’, which can be adjusted slightly in order to be more appropriate for the present context (namely, CIP in a developed economy). These questions are designed to prompt lines of investigation and, as generic questions, need to be adjusted to each ‘policy problem to be investigated.
- The final, analytical stage, where past and future potential change is evaluated
- The above steps are expected to be iterative

The methodology is flexible enough to allow the use of different formats ranging from a brief desk-based study through to the use of a multi-disciplinary team over an extended period of time to conduct a comprehensive or even a continuous PEA review (DFID 2009). The value of the collective PEA effort might lie less in the technical process of data collection and analysis and more in the interactions within the team being part of the change process itself (ibid. 20).

APPLICATION TO CONSTRUCTION INDUSTRIAL POLICY

The diversity of the applications of PEA discussed earlier points towards a potential application in construction policy ranging from very specific subsector issues (say, the implementation of Building Information Modelling) up to a consideration of the whole field of industrial policy which might influence construction, namely CIP. Any understanding of a single, discrete, policy area is likely to share some common ground with the overarching analysis at CIP level, and so the latter is prioritised for consideration here to illustrate, but not limit, the potential use of PE/PEA.

Different economists and political economists will inevitably have different views on the use of policy and the point at which intervention is triggered - whichever category of policy instrument is in question whether regulatory, deregulatory, or by means of voluntary action such as codes of practice. The question of whether, when and how to intervene in markets - and whether lack of action can itself amount to a choice of policy - lies behind policy at both the micro scale and at the level of policy for industrial sectors. This is in essence a question of Political Economy (Chang 1994; Aiginger 2007; Rodrik 2008; Warwick 2013). Use of PE thinking can help to explain why specific solutions work in one (national, cultural, economic) context but not another (Thelen 2004; Hall and Soskice 2001)
The concept of and need for an overarching industrial policy, and a sector based policy in particular, is contested (Aiginger 2007). Nevertheless in the UK there have been repeated attempts at reform of the sector and attempts to formulate some form of construction sector policy or strategy (Green 2011; Wolstenholme 2009; HM Government 2013). Such a context where change is championed by some but where the implementation of change in practice is apparently slower than desired, and perhaps lacks legitimacy or support, suggests CIP itself as a candidate for the use of PEA. In addition, as has been noted earlier, the concerns of industrial policy can be seen as very compatible with those of PEA and methods of analysis can be very similar (Grant 1982; Glykou and Pitelis 2011). Therefore the application of PEA to Construction Industrial Policy would seem to be a natural fit, and CIP should be prioritised for research. The research would need to take account of the context outside of construction (‘why should there be any kind of industrial policy? What are the 'structural' constraints on IP in the UK? How is economic and construction activity measured?’) As well as the institutions and actors within the sector (‘is CIP the sole concern of major firms? What is the distinctive role of smaller firms? Are they engaged in CIP? What are the options and potential routes and processes for change? What are the tensions between the wider PE of the UK and any active CIP?’). Application of PE/PEA thinking prompts questions concerning what institutions and structures would better support industrial policy in general and CIP in particular (for example: ‘To what extent is the Construction Leadership Council set up in 2013 a necessary, legitimate or sufficient means of strategic engagement between government and Industry? To what extent should the devolved authorities, and the regions, cultivate local CIP?’). Finally, PE/PEA enables consideration of the processes of change required to move from the status quo towards any future CIP design or governance arrangements. Hence the expected outcomes from research would be identification of change processes both historic and future. Applying PE thinking at sector level is only the first step, and the new understanding which is likely to flow from sector level analysis should be seen as a foundation for a second phase of work at the level of individual policies and sub-sectors of construction.

Implications for Future Research

The PEA framework would have potential application in construction policy contexts where proposals for reform, from whatever source, are apparently challenged implicitly or explicitly. The initial application to construction will be focussed on proving and refining the method, beginning with CIP itself and later examining progressively more specific policies. Later work is expected to be able to encompass the use of the framework as an on-going process (DFID 2009: 20) and has the potential, with the participation of appropriate stakeholders, to be a catalyst for change itself (Edelmann 2009: 72-74). Finally, while initially the need is for research and refinement of methodology, the experience of the use of PEA in Development suggests that the value of PEA for construction ultimately will lie in its use by those involved in the policy process for construction including any of its stakeholders.

CONCLUSIONS

The concepts used in modern political economy have been introduced, and their particular relevance to policy for industry has been identified. An initial framework to be used in the political economy analysis of Construction Industrial Policy has been assembled, based on a transfer of knowledge from the Development sector. An indication of future areas of application has been set out: in effect these elements contribute towards a roadmap for a continuing programme of research.
PE and PEA allow great flexibility in method, style and purpose of investigation. This flexibility can be both a hindrance and an advantage to researchers. The interpretive nature of PEA methodology carries the risk that results are not repeatable - though a consequence of this is to stimulate rather than diminish the need for rigour in method. The value of PEA may lie in being a process, and part of the process of change, rather than being constrained by the format of a single written report. By making political aspects of change processes explicit, PEA to an extent creates a licence for stakeholders to consider questions of power and influence in a structured way, which may otherwise tend to be suppressed while seeking the best technical solution. Use of PEA enables a system-wide view to be taken. Hence, PEA may be of greatest value when used to challenge assumptions about the nature of the existing constraints on policymaking, hence enabling new directions for policy, rather than being merely an explanatory lens. In conclusion, the value of research into the processes of Construction Industrial Policy can be considerably enhanced by the use of the proposed PEA framework which addresses aspects which have hitherto been neglected in the literature.

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SOCIAL RESPONSIBILITY
AN EXPLORATION OF SUSTAINABILITY DRIVERS OF SUSTAINABLE REGENERATION PROJECTS: THE UK CONSTRUCTION ORGANISATIONS PERSPECTIVE

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The construction industry has largely been part of efforts aimed to deliver the UK’s sustainable regeneration agenda. Many construction organisations have played various roles in an attempt to deliver sustainable regeneration projects in line with the sustainable development objectives. However, to date, the delivery of such sustainability objectives of sustainable regeneration projects have continued to be an on-going challenge for these organisations involved in the delivery of these projects. There is an acknowledgement that a significant number of construction industry organisations involved in the delivery of sustainable regeneration projects are promoting the sustainability principles based on their priorities, understanding, perceptions and interests for the projects. This has largely impacted, and in most cases, undermined many sustainable regeneration projects from delivering their core sustainability objectives, particularly the social and economic ones. The study adopted a qualitative research approach, using a semi-structured interview to collect data from 18 practitioners’ organisations involved in the delivery of sustainable regeneration projects in the UK. The findings revealed that out of the six drivers, enhancement of reputation was the most important social and economic sustainability driver while the least important driver was legislative and legal requirement.

Keywords: social, economic, sustainability drivers, sustainable regeneration

INTRODUCTION

Sustainability Practices of Sustainable Regeneration Projects

It has been acknowledged that a significant number of regeneration initiatives which have been formulated to deliver regeneration projects over the years have been driven by practitioners’ priorities for the projects. Adopting such practices, according to Evans and Jones (2008), has undermined many sustainable regeneration initiatives from achieving their desired sustainability objectives. Similarly, the over reliance on environmental drivers has also played a significant part in limiting the integration of social and economic sustainability factors into the mainstream practices of practitioners. According to Abdel-Raheem and Ramsbottom (2016: 549), numerous studies that have been undertaken to study the sustainability aspects of construction projects have “focused more on the environmental aspects rather than the social and economic ones”. Some schools of thought have sought to question whether in fact, much of what has been termed as sustainable regeneration should rather be labelled as renewal or redevelopment, due to the limited consideration given to the projects’ related social and economic sustainability factors (Reyes et al., 2014). A subsequent work by Akotia et al., (2016) and Clapham (2014), supported this view by suggesting that much of what has been perceived to be sustainable regeneration in recent years in urban communities has been the improvement

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of the physical ‘outlook’ rather than addressing the social and economic sustainability needs of the communities concerned, hence their inability to address the fundamental objectives underlying sustainable regeneration initiatives. Their works went on to indicate that, despite the numerous strategies that have been undertaken by government and other regeneration practitioners to enable regeneration initiatives to deliver the required social and economic sustainability benefits to alleviate poverty in the communities, to-date there has not been any well-established evidence pointing to the achievement and delivery of such social and economic sustainability benefits of the projects (Akotia et al., 2016, Clapham, 2014). It is said that social and economic sustainability issues are deeply rooted in our community set up, and for that reason, focusing on their core drivers has enormous potential to drive regeneration projects towards the attainment of their sustainability objectives (CLG, 2008). It is believed that meeting society’s social and economic sustainability needs is one major means by which society can become truly vibrant and sustainable (Clapham, 2014). Hence, the pursuit of the delivery of sustainability objectives calls for a fundamental change towards the promotion of social and economic sustainability drivers that enable regeneration projects to be wholly sustainable. It is also acknowledged that social change can be the determinant of economic change, in that many of the social features of sustainability co-exist with the economic features of sustainability in regeneration (CLG, 2010). The principles underpinning the social and economic sustainability requirements seek to provide collaboration between individuals’ social progress and economic prosperity, and these are in-tune with the sustainable regeneration agenda. And if future regeneration projects are to make a greater sustainability impact on communities, then the current regeneration projects’ drivers will have to be altered to meet the social and economic sustainability needs of these communities in a sustainable manner (Clapham, 2014; Henderson, 2011).

The main aim of the study is to explore the most important social and economic sustainability drivers of practitioners involved in the delivery of sustainable regeneration projects in the UK. The paper begins by providing literature background on social and economic sustainability drivers of sustainable regeneration projects. A discussion is then presented on the findings from an exploratory study which adopted semi-structured interviews with eighteen practitioners of leading construction industry organisations involved in sustainable regeneration projects in the UK, and draws a conclusion.

LITERATURE REVIEW

Social and economic drivers of sustainable regeneration

The construction industry has been recognised as a major driver towards the delivery of the UK sustainable development and regeneration agenda (DBIS, 2013). The UK government’s strategy to deliver sustainable construction sets the agenda and challenged the construction industry to drive its operations in a manner that delivers sustainable products to achieve the sustainable regeneration objectives. The industry is being called upon to shift from its traditional way of delivering sustainability projects to a more modernised one which will ultimately lead to improving the sustainability performance of their projects (DBIS, 2013). Conventionally, the construction industry has been driven by cost, time and quality objectives (DBIS, 2013), and the consideration of sustainability adds to these objectives. Striving to achieve sustainable construction calls for the adoption of sustainability practices in a manner that makes regeneration projects achieve their social and economic sustainability benefits for society and the organisations delivering the projects (Shen et al., 2010). Generally, the performance of regeneration projects is demonstrated and driven by many of the social and economic sustainability
opportunities (e.g. jobs and apprenticeship, etc.) created by these regeneration projects. In a series of stakeholder consultation events reported in CLG (2008), the majority of participants suggested that social and economic sustainability benefits should be seen as a key driver for sustainable regeneration outcomes. The participants emphasised the need for sustainable regeneration to pay a greater attention to deliver tangible social and economic sustainability benefits in a practical manner. It has been acknowledged that a significant number of regeneration initiatives which have been formulated to deliver regeneration projects, have been driven by a number of factors (CLG, 2010). Some influencing factors reported to be driving most practitioners’ organisations in promoting sustainability in the UK include: incentive mechanisms, government policy frameworks and regulations on green buildings (Turcsanyi and Sisaye, 2013; Häkkinen and Belloni, 2011; Pitt et al., 2009). Empirical work by Pitt et al., (2009), which collected data from 200 Royal Institute of Chartered Surveyors (RICS) members in the UK, has also found financial incentives, building regulations, client awareness/demand as the most influential factors that were driving many construction organisations to promote sustainability on their projects. Other drivers identified by Turcsanyi and Sisaye (2013), in line with Pitt et al.,’s (2009) findings for adopting sustainability principles include; image/reputation improvement as well as improvement in the overall economic fortune of their organisations. For many construction organisations involved in the delivery of regeneration projects in the UK, their social and economic sustainability strategies of regeneration have focused on financial gains (Henderson, 2011). In a study conducted by Smith and Sharicz, (2011) on organisation sustainability and profitability, nearly 51 percent of respondents who took part in the study believed that adopting sustainability into their organisations’ business operations would help build the economic future of their organisations. Integrating the core elements of sustainability in regeneration processes and practices offers a considerable opportunity for construction organisations to run a responsible business. For example, integrating the principle of corporate social responsibility (CSR) in an organisation’s strategies and practices will enable the organisation to enhance its reputation, gain competitive advantage and also continue to win more contracts from its clients (Duman, et al., 2016). It is also argued that the demands from clients and their stakeholders can be a determining factor for promoting sustainability principles by organisations. This is because clients and their stakeholders are the ones who initiate and provide the financial resources to undertake these projects. It is asserted that the adoption of sustainability for most of these projects has been determined, and in many cases dictated by the requirements and demands from clients and their stakeholders (Kraus and Britzelmaier, 2012). Highlighting further, Turcsanyi and Sisaye, (2013) argued that with the current economic condition, clients and other key stakeholders are increasingly becoming cautious and are demanding more accountability from organisations before entering into any form of investment or partnership with them.

**RESEARCH METHOD AND APPROACH**

The study sets out to explore 6 (six) important organisational social and economic sustainability drivers identified through literature review (Table 1) as the most cited (social and economic sustainability) drivers that were driving practitioners to promote sustainability on the sustainable regeneration projects in the UK. In order to explore the drivers in-depth, qualitative research method was adopted for the study. Plano Clark (2010) suggested that the application of a qualitative research approach presents advantages to viewing a phenomenon in its real social context, and by so doing offers a greater depth of understanding and flexibility to explore social matters. According to Petty et al., (2012), the major advantages associated with qualitative research approach
include its capacity to produce more detailed explanations of human phenomena in a way that cannot be fully captured with a numerical approach.

Table 1: Social and economic sustainability drivers and the literature sources

<table>
<thead>
<tr>
<th>Social and economic sustainability drivers</th>
<th>Literature source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reputation / image enhancement.</td>
<td>Cheng et al., 2014; Turcsanyi and Sisaye 2013; Okoro 2012; Kraus and Britzelmaier, 2012; Smith and Sharicz, 2011; Pitt et al., 2009.</td>
</tr>
<tr>
<td>Competitive advantage.</td>
<td>Okoro 2012; Kraus and Britzelmaier, 2012; Henderson, 2011; Häkkinen and Belloni, 2011; Shen et al., 2010.</td>
</tr>
<tr>
<td>Client requirement.</td>
<td>Turcsanyi and Sisaye, 2013; Kraus and Britzelmaier, 2012; Häkkinen and Belloni 2011; Pitt et al., 2009.</td>
</tr>
<tr>
<td>Stakeholder demand.</td>
<td>Turcsanyi and Sisaye, 2013; Kraus and Britzelmaier, 2012; Häkkinen and Belloni 2011; Pitt et al., 2009.</td>
</tr>
<tr>
<td>Corporate social responsibility.</td>
<td>Duman, et al., 2016; Turcsanyi and Sisaye, 2013; Shen et al., 2010; Pitt et al., 2009.</td>
</tr>
</tbody>
</table>

Hence, to begin the qualitative data collection process, three construction organisations were selected through a purposive sample technique, from the list of top construction organisations with the experience and knowledge in sustainable regeneration projects in the UK. Formal letters and proposals were sent out to these organisations for permission to use their projects for the study. Follow up telephone calls were also made to these organizations to further explain the purpose and the context of the study. Face-to-face in-depth semi-structured interviews were then conducted with the 18 practitioners, made up of, 6 practitioners from each of the three selected construction organisations, with each interview lasting between 50-60 minutes. The interviews were conducted in an interactive and open manner with a minimum interview structure in an attempt to obtain more detailed information and also to gain a deeper appreciation of the issues with practitioners (Denzin and Lincoln, 2008). All the semi-structured interviews were recorded and later transcribed verbatim to enable the raw interview data to be extracted and presented in a textual form to enable readability of the data. Open coding approach was undertaken which enabled the interview transcript to be examined sentence-by-sentence. The text segments containing relevant information were manually coded to discover patterns/themes, which were subsequently used for analysis. Specific text segments identified as key recurring themes were also coded for use as quotations to highlight salient references identified during the analysis of interview findings. Table 2 presents the profiles of practitioners who participated in the semi-structured interviews of the study while Table 3 presents the results of the interviews (based on the importance given to each driver by practitioners).

From the semi-structured interviews, all the eighteen (18) practitioners presented their views on the six (6) social and economic sustainability drivers (from literature) put to them. However, it emerged from the analysis of the interviews that there were multiple responses to the (6) drivers by practitioners as shown in Table 3.
They provided their responses based on the level of importance given to each of the drivers put to them. In their responses it was clear that, although all the six drivers were considered important, they however, prioritised some drivers as being more important over others. For example, while some drivers were considered as important (response importance of drivers- 1), others were seen as less important (response importance of drivers- 6) in driving their social and economic sustainability agenda of their organisations. The discussions of the findings are subsequently presented accordingly.

**Table 3: Semi-structured interview results of the social and economic sustainability drivers**

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Organisation Total N = 18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhancement of reputation as a ‘sustainable’ organisation (ERSO)</td>
<td>18 100%</td>
</tr>
<tr>
<td>Competitive advantage (CA)</td>
<td>16 89%</td>
</tr>
<tr>
<td>Clients requirements (CR)</td>
<td>15 83%</td>
</tr>
<tr>
<td>Corporate social responsibility (CSR)</td>
<td>13 72%</td>
</tr>
<tr>
<td>Stakeholders demands (SD)</td>
<td>10 56%</td>
</tr>
<tr>
<td>Legislation and legal requirement (LLR)</td>
<td>5 28%</td>
</tr>
</tbody>
</table>

**DISCUSSION OF THE RESULTS**

**Enhancement of Reputation as a ‘Sustainable’ Organisation (ERSO)**

The potential for regeneration projects to generate social and economic sustainability benefits has long been recognised. The delivery of successful sustainable regeneration projects ultimately relies on the sustainability principles that are promoted by practitioners who are involved in the delivery of such regeneration projects. From the results in Table 3, it can be observed that all the practitioners unanimously indicated that enhancement of reputation was a driver for them to promote social and economic sustainability principles on their sustainable regeneration projects. All the eighteen (18) (100%) practitioners who took part in the semi-structured interviews were of the view that enhancing their reputation was a major driving factor for their organisations to pursue social and economic sustainability principles on regeneration projects. This became obvious when the authors sought to enquire from practitioners during the interviews about the sustainability principles that were driving the adoption and implementation of social
and economic sustainability principles on their regeneration projects. A typical response given by one of the practitioners was: *For us, adopting sustainability helps to enhance our reputation as a sustainable organisation. It makes us more appealing to future clients. They know that we will be able to fulfil the promises that we make when we tender for work.*

In line with the aforementioned view, another practitioner commented by saying:

*... Obviously, as an organisation, taking on sustainability enables us to build our brand and reputation as an organisation. We are seen as the best company of choice and we get more recognised as the provider of best practice in terms of sustainability and that gives us a real advantage over our competitors.*

All the practitioners strongly believed that adopting the principles of sustainability by their organisations was the best way of building up their organisations’ reputations, which was vital for them to continue to appeal to their potential future clients. The works of authors like Cheng *et al.*, (2014); Turcsanyi and Sisaye (2013) have argued that the majority of organisations were adopting sustainability principles as a means of improving their reputations, to remain in business for a long time. With this finding, it can be suggested that, at least, a sizeable number of practitioners involved in the delivery of sustainable regeneration projects, believed that there is a good business case for their organisations to adopt and implement social and economic sustainability principles on their projects. They believed that getting such ‘image branding’ is the best way to continue to appeal to their potential clients as a ‘sustainable organisation’. This belief is premised on the fact that, currently, most of the local and national governments’ contracts are being awarded to organisations that are seen to be delivering such sustainability benefits, in particular, the social and economic ones for the communities. Hence, practitioners who may be involved in the delivery of such governments’ sustainable regeneration projects may only be superficially seen to be promoting the social and economic sustainability principles, while in the real sense, they may be projecting their own interests and objectives.

*Competitive Advantage (CA)*

Following the above driver, gaining competitive advantage was the next most important social and economic sustainability driver by majority of practitioners who participated in the study. The result obtained from the interview indicated that, 16 (89%) of the 18 practitioners believed that promoting social and economic sustainability factors was one major means for their organisations to gain a competitive advantage over their competitors in the market place. Considering the economic climate, it will not be out of place to also assume that the majority of practitioners’ organisations will be attempting to integrate sustainability objectives into their business practices, to enable them to gain competitive advantage over their compatriots in the market place, to stand a better chance of winning future work from their clients. This point was highlighted by one of the practitioners by saying: *Seeing our organisation to be delivering social and economic sustainability benefits, gives us a real potential advantage over our competitors, especially looking at the current situation we are in now, because we know exactly how it works, how much it costs and how the value is to us and our clients.*

This comment was also echoed by another practitioner by saying: *From the business point of view, and with the current economic climate, it definitely gives us advantage over our competitors who are not taking advantage of it.*
Drawing from the findings it can be observed that some practitioners involved in the delivery of regeneration projects may not be truly committed to the sustainability agenda but may only be doing so because they believed will enable them to remain competitive in their market place. According to Henderson (2011), the idea of gaining competitive advantage has been more often the goal of private sector practitioners looking to maximise their returns by outperforming their competitors in some key areas of their activities. However, In an attempt to obtain such competitive advantage, practitioners may be tempted to adopt short term practices (cut corners especially during the tender stages) to win over their competitors, which may potentially result in a long term negative impact on the achievement of the social and economic sustainability benefits of the projects. Such practices may also lead to concentration on ‘winning more contracts’ to increase turnover and profit margins for practitioners’ organisations. Henderson (2011) further suggested that it is only when practices that are promoted are focused on core sustainability principles, that a number of practical problems associated with the current delivery of social and economic sustainability of regeneration projects can be overcome.

Clients’ Requirements (CR)
In the context of promoting the sustainability concept on regeneration projects, clients and their requirements also play a major role. The results from interviews further revealed that clients’ requirement was the third most important social and economic sustainability driver. 15 (83%) of the 18 practitioners were of the view that the requirements from clients were their main driver to promote the social and economic sustainability factors whenever their organisations were involved in the delivery of sustainable regeneration projects. One thing which became clear was that a sizeable number of practitioners were only promoting the social and economic sustainability factors to meet their clients’ requirements, to enable them win their (clients) projects. To confirm the above position, one such candid view which was expressed by one of the practitioners during the course of the interview discussion, emphasised this by saying: ...

Kraus and Britzelmaier (2012), sought to suggest that the majority of organisations who were found to be promoting the sustainability principles were doing so because the contracts required them to do so. In the construction industry, for example, clients are the ones who generally initiate, provide the financial resources and also decide what they require from their projects. They can be instrumental in influencing the practitioners they hire to deliver their projects, to promote the social and economic sustainability factors on their regeneration projects. Equally, practitioners who are involved in undertaking the projects should also be seen not only to be reacting to meeting such clients’ requirements. They should also be prepared to act on practices that they truly believe will enable them to deliver the social and economic sustainability benefits of the projects. However, this will also require practitioners to be well knowledgeable themselves about sustainability factors and practices which will enable the delivery of the projects to be carried out in a cost effective manner.

Corporate Social Responsibility (CSR)
The promotion of sustainability principles calls for practitioners to fulfil their CSR obligations. As the discussions developed during the interview, it was refreshing to note that some practitioners were giving prominence to CSR issues as a means of meeting their organisations’ corporate sustainability objectives. Notably, it was considered as the
fourth most important social and economic sustainability driver by practitioners. It can be observed from the results in table 3 that a good number of practitioners, 13 (72%) of the 18 practitioners, have commented that CSR was an important driver for promoting the principles of social and economic sustainability factors on their regeneration projects. It is believed that the organisations which are seen to be genuinely adopting the CSR principles will also stand a better chance of improving their business economic performance and growth over a long period of time (Shen et al., 2010). This position was shared by one of the practitioners during the interview by saying: ...I think it’s a win-win kind of thing really. As we help to provide these local jobs and all kinds of skills training schemes for young people, the long term benefit for us is that, it keeps us in business. ....And that also helps our long term economic growth as well. Although the primary objective of organisations may be to make financial gains, it is important that they are seen to be contributing to the sustainability quota, through their CSR strategy. Turcsanyi and Sisaye (2013) argued that the economic performance of an organisation can be well sustained when such organisation integrate CSR into its business plans and when it is genuinely adopting and applying its principles on its projects.

Stakeholders’ Demands (SD)
The quest to promote sustainability practices on sustainable regeneration projects can also be dictated by demands from stakeholders. Out of the 6 drivers, the results obtained revealed that demand from stakeholders was the fifth most important driver for practitioners who participated in the study. A further examination of the interview results (table 3) revealed that 10 (56%) of the 18 practitioners held the opinion that demand from stakeholders was the key driver for their organisations towards the promotion of social and economic sustainability principles on their regeneration projects. This was evident when the following question was put to them: “Do you consider the demands from your stakeholders as a driver for your organisation to promote social and economic sustainability factors on your regeneration projects?’’. In a response to the above question, one of the practitioners for instance commented by saying: ...Absolutely, yes we do. It has always played a major part in our decision to promote sustainability on our regeneration projects. ....Their demands determine what social and economic sustainability factors we take or we can take on for a particular project. If our funders for example want us to take on local labour on the project, we go with their demand. This finding sought to provide an indication in which it can be suggested that a significant number of practitioners are still not committed to genuinely pursuing sustainability principles on their own without being asked to do so. Such an approach could partly be responsible for many sustainable regeneration projects in the UK not realising their potential social and economic sustainability objectives (Brandon and Lombardi, 2011). It is said that greater sustainability impacts can be achieved if practitioners recognise the potential benefits of pursuing the sustainability agenda to themselves and to their stakeholders and accordingly, respond to such demands (Pitt et al., 2009).

Legislation and Legal Requirement (LLR)
LLRs are also fundamental in establishing and driving the requirements that are necessary for a greater achievement of sustainability objectives on projects. As per the results obtained, legislation and legal requirements was the least considered driver of the 6 drivers presented to practitioners. Out of the 18 practitioners who participated in the study, only 5 (28%) were found to be driven by legislation and legal requirements to promote social and economic sustainability factors on their regeneration projects. Some of them were of the view that meeting legislation and legal requirements was the best way to continue to attract the attention of the authorities. For example, one such practitioner
who held that view indicated this by saying: ...Obviously, legislation and legal requirements play a major part in what we do on our regeneration project. ...Because we have to comply with procurement laws, health and safety regulations and others set by the local government, particularly in the areas we work to meet their social and economic sustainability requirements of the projects. That helps us to attract their attention for future works. Clearly, this result shows that a significant number of practitioners are not driven by ‘legislation and legal requirements’ to promote the social and economic sustainability factors on their regeneration projects. With the above finding, it can be argued that the absence of ‘legislation and legal requirements’ to drive practitioners towards the promotion of social and economic sustainability outcomes can have an implication for the delivery of successful social and economic sustainability benefits of regeneration projects. Evidence from the literature has shown that construction projects can well be delivered when there are legislation and guidelines in place to direct practitioners (Häkkinen and Belloni, 2011). For example, the introduction of health and safety requirements and regulations in the UK’s construction industry has had a profound impact on reducing accidents on many construction projects. Hence, it can be argued that the successful delivery of social and economic sustainability benefits for any regeneration project will not materialise by itself or by chance, unless it is backed by legislation and legal requirements.

CONCLUSIONS

The study explored six most cited social and economic sustainability drivers obtained from literature, with practitioners involved in the delivery of sustainable regeneration projects in the UK. From the finding, it emerged that all the practitioners 100% who have participated in the study unanimously indicated that enhancement of reputation was the most important social and economic sustainability driver towards the promotion of sustainability principles on their regeneration projects. They believed that enhancing their reputations as ‘sustainability organisation’ was a means to continue to secure contracts from their potential clients, such as the local and national authorities who wanted such ‘sustainability organisations’ to bid for their projects. The findings also revealed that nearly 90% of practitioners who participated in the interviews were of the view that gaining competitive advantage was an important driver. They believed doing so was giving them the opportunity to gain advantage over their competitors. The findings further revealed that 56% of the practitioners were also being driven by stakeholders’ demands. An indication provided by this finding sought to suggest that a good number of practitioners were still not committed to genuinely promoting sustainability principles on their own without being asked to do so. Lastly, legislation and legal requirement, was the least most important driver as less than a third (28%) of practitioners have cited it as an important driver towards the promotion of sustainability principles on their regeneration projects. Based on the findings from other drivers, it was suggested that ‘legislation and legal requirement’ was very important to drive practitioners towards the promotion of social and economic sustainability factors on their regeneration projects.

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‘LOCAL CONTENT’ OF CORPORATE SOCIAL RESPONSIBILITY IN INTERNATIONAL CONSTRUCTION

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‘Local content’ is increasingly stipulated in international construction business. While it is agreed that ‘local content’ is a part of corporate social responsibility (CSR) agenda, what exactly constitutes a ‘local content’ remains controversial. The primary aim of this study is to (a) map out the status quo of ‘local content’ patterns as portrayed by International Construction Companies (ICCs), and (b) offer deeper insights on the concept by relating it to CSR localisation. By applying text mining to ICCs’ CSR reports, it is found that local contents implemented in various host regions are largely uniform. As for the indicators, ‘materials’ (EN1) and ‘Product and service labelling’ (PR2) are the most reported local content initiatives. Besides, ICCs also pay much attention to implementing other local content aspects, such as diversity and equal opportunity (LA4), local communities (SO1), and public policy (SO3). These research findings help deepen the understandings of local content and CSR concept, which could help ICCs and public project sponsors to better promote CSR in the international construction context. The findings could also be used for further investigation of the causal factors (e.g. impacts of institutional distance) leading to the different local contents.

Keywords: local content, corporate social responsibility, CSR, localisation

INTRODUCTION

‘Local content’ is introduced as a part of CSR agenda by international companies recently (Tordo et al. 2013). In line with the social impact compensation argument (Warner 2011; Ado 2013), local content can be viewed as the reasonable benefit in return to local communities and economics, which may have been negatively affected by the operations of international companies. Local content is always regarded as one strategy for the resource-rich economies to avoid the ‘resource curse’ and to build sustainable capacity for the local while they join the irreversible economy globalisation. It is also frequently stipulated in the international construction markets, especially in the tender conditions on requirements of an engagement of local labour, equipment and materials, and local subcontractor (Han et al. 2010). In the construction market of Nigeria, for example, local content is emphasized by encouraging local companies to participate and improve their performance in the long run (Babatunde and Low 2013).

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Although local content is increasingly stipulated in international construction projects, particularly for those sponsored by international organisations (e.g. the World Bank, the African Development Bank), what exactly constitutes the ‘local content’ is still unclear. Local content is a complex and fast-evolving area as mentioned by a World Bank study (Tordo et al., 2013). It is generally agreed that Grossman (1981) provided the first and most important intuitive foundation for the small theoretical literature in the field of local content.

In his study, ‘domestic content’ was used instead of ‘local content’, which was demonstrated as the percentage of domestic value added or domestic components embodied in a specified final product. Grossman’s study was followed by many theoretical works in the economics literature (Munson and Rosenblatt 1997; Lahiri and Ono 1998; Qiu and Tao 2001; Lahiri and Ono 2003; Veloso 2006). In these works, local content is regarded as one kind of requirements, stipulating that firms producing a good are to procure a certain proportion of intermediate inputs domestically (UNIDO 1986; Belderbos and Sleuwaegen 1997; Gu and Yabuuchi 2003; Kuntze and Moerenhout 2012). For resource-rich countries, local content has a wider understanding that it refers to value addition for the industry or the country by using local staff, local materials, and local services (Heum et al., 2003). Its major objectives were transfer of technology, provision of local job opportunities, creation of backward and forward linkages, and increase in ownership and control (Ado 2013).

Putting it in the CSR agenda, local content is related to social impact compensation (Warner 2011; Ado 2013), which argues for the adoption of local content policies as a way to influence job creation and value addition for the local communities. This proposed several questions: (a) what is the exact interpretation of local content? (b) What is the relationship between local content and CSR localisation? (c) What is concluded in local content for International Construction Companies (ICCs) to implement? and (d) how do they implement the local content initiatives? Richer interpretations of ‘local content’ and CSR concept are desired by both ICCs and public project sponsors with a view to better promote both concepts in the international construction business.

The primary aim of this study is to (a) deepen the understanding of the concept of ‘local content’ by relating it to CSR standardization and CSR localisation, and (b) map out the status quo of ‘local content’ patterns as portrayed by ICCs. The remainder of this paper is structured into four sections. Following the introduction section, the two main constructs, local content and CSR localisation are elaborated. The research methods section provides a detailed description of the sample and research methods, wherein text mining of the CSR reports disclosed by ICCs is at the core. The fourth section presents the analyses, findings and discussion. Conclusion and limitations are presented in the last section.

**Constructs Explanation**

**CSR Localisation**

CSR can be understood as a management concept, whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders (Communities 2011). When companies act in different parts of the world, their social and environmental concerns may be different due to the various cultures, social norms and value systems of the respective stakeholders (Bustamante 2011). This means that CSR activities need to be adapted to the specific situation of the region wherein the companies operate (Wang et al., 2016). CSR localisation is introduced to correspond to that, which refers to companies in host countries have a considerable
degree of autonomy to develop CSR strategies that are responsive to the local context and local stakeholders (Muller 2006). Localisation strategy is always under consideration compared with standardization strategy due to the “integration-responsiveness grid”, describing the forces for global integration on the one hand and the local responsiveness on the other hand (Pratlamad and Doz 1987). As a strategy, CSR localisation would be shaped by three main factors including the issue in question, the character and distribution of major stakeholder groups and the general organizational approach and culture of a company (Bustamante 2011). As for the issues in question, Bustamante (2011) made a matrix measured by two aspects: degree of gloablity and degree of culture-sensitivity. In his opinion, those issues with low degree of gloablity and high degree of culture-sensitivity would more likely conform to the strategy of CSR localisation.

Local Content

Local content is similar to CSR localisation since they both emphasize the adaptation to the specific situation of the region where a company operates. However, local content holds different meanings which incorporate more culture-specific expectations and local value addition than CSR localisation. On the one hand, local content is the implementation of CSR strategies. It cares more about the CSR issues, which require high degree of culture-sensitivity. In other words, those issues are characterized by a strong cultural grounding and which would require the adaptation to the local environment (Bustamante 2011). Poverty caring, social security or local employee training projects are examples for that. In this perspective, local content could be different from CSR localisation; the latter is a corporate strategy considering not only CSR issues but also corporate stakeholders, strategic approach as well as organizational culture. On the other hand, local content requires local value addition on the perspective of the industry or the host countries. For example, the Republic of Trinidad and Tobago (2004) defines local content as “local value-added” in terms of ownership, control and financing by citizens of Trinidad and Tobago. Paul (2013) suggested the definition that local content is the input to activities directly involved in operations along value chain, which are provided by nationals. Therefore, local content is regarded as local CSR in this study which refers to CSR implemented in the operating countries caring about local culture and local value addition.

RESEARCH METHODS

Samples

The sample of ICCs was determined by referencing to the Top 250 International Contractors List in 2015 compiled by ENR, an US-based construction, building and engineering-oriented magazine. Some of the ICCs are excluded due to the lack of CSR reports/sustainability reports. More ICCs in the Global Reporting Initiatives (GRI) list collected from the GRI’s Sustainability Disclosure Database were added into the sample in addition to ENR lists. As a result, seventy-five ICCs are chosen as the sample for the analysis. They are from twenty-five countries. Nine companies from North America, two from Latin America, thirty-four from Europe, twenty-seven from Asia and Australia, and three from South Africa. CSR/sustainability reports of the sample ICCs over the past five years (2011-2015) were retrieved from their websites or GRI’s Sustainability Disclosure Database. There are 270 reports collected for the analysis due to some missing reports in certain years.
GRI Guidelines as the Analytical Framework

An analytical framework is identified for the further analysis. It is based on the GRI Construction and Real Estate Sector Supplement (CRESS) G4, which provides indicators and disclosures that are important or unique to the construction and real estate sector (Lu et al., 2015). There are 6 categories with 28 sub-categories of performance indicators in total (See Table 1).

Table 1: The protocol for decoding CSR reports

<table>
<thead>
<tr>
<th>Code</th>
<th>Categories</th>
<th>Sub-categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC</td>
<td>Economic</td>
<td>EC1-Economic Performance; EC2- Market Presence; EC3- Indirect Economic Impacts</td>
</tr>
<tr>
<td>EN</td>
<td>Environment</td>
<td>EN1- Materials; EN2-Energy; EN3-Water; EN4-Biodiversity; EN5-Emissions; EN6-Effluents and waste; EN7-Products and services; EN8-Transport; EN9-Land degradation, contamination and remediation</td>
</tr>
<tr>
<td>LA</td>
<td>Labour practices</td>
<td>LA1-Employment; LA2-Occupational health and safety; LA3-Training and education; LA4-Diversity and equal opportunity; LA5-Equal remuneration for women and men</td>
</tr>
<tr>
<td>HR</td>
<td>Human rights</td>
<td>HR1-Non-discrimination; HR2-Child labour; HR3-Forced or compulsory labour; HR4-Security practices; HR5-Supplier human rights assessment</td>
</tr>
<tr>
<td>SO</td>
<td>Society</td>
<td>SO1-Local communities; SO2-Anti-corruption; SO3-Public policy; SO4- Anti-competition behaviour</td>
</tr>
<tr>
<td>PR</td>
<td>Product Responsibility</td>
<td>PR1-Customer health and safety; PR2-Product and service labelling</td>
</tr>
</tbody>
</table>

*Source: GRI Construction & Real Estate Sector Supplement G4*

Text Mining

The analytical framework as shown in Table 1 is developed as the protocol for decoding CSR/sustainability reports. Given the large volume of texts to be analysed, an innovative method of text mining, rather than human decoding only, is used for the analysis of CSR/sustainability reports. Although humans interpret the specific wording of a document in the much larger context of their background knowledge and experience (Gabrilovich and Markovitch 2007), text mining with computer algorithms could deal with large number of texts and present a quick view of the collected reports. The process of text mining is presented in Fig.1.

Step 1 is to convert collected CSR reports in PDF format to MS excel files. Step 2 is to extract the text in the MS excel files accordingly corresponded to country names around the world. There are 209 countries and other territories (e.g. Hong Kong, Bermuda) identified for this process. This step presents 5,956 descriptions of local content of an ICC in a certain year in a specific host country. In Step 3, stop words, such as function words (is, having, when, etc.), pronoun (it, you, etc.), are eliminated from the descriptions. Remained words with actual meanings are called ‘report words’.

Step 4 uses Explicit Semantic Analysis (ESA) method to do the text mining, which is proposed by Gabrilovich and Markovitch (2007). The idea underlying ESA is to represent and compare texts (from single terms to entire documents) as vectors in a high dimensional concept space (Gottron et al., 2011). In this step, each report word is assumed to convert to a vector weighted by the inverted index with 28 dimensions based on the protocol mentioned above. Firstly, key words for each sub-category are identified according to the interpretations of sub-categories in the GRI CRESS G4. For example,
for sub-category EN1-materials, 10 key words are identified such as ‘renewable materials’, ‘raw materials’, etc.

Fig. 1: The process of text mining

Weighted inverted index is built based on the key words for 28 sub-categories. Secondly, the semantic similarity between each report word and key word could be calculated, encoded into the general word corpus (i.e. Wikipedia), by dividing the frequencies of both words appearing in the Wikipedia corpus by the frequencies of each word. Thirdly, each report word could be expressed by a vector with 28 sub-categories, using the maximum semantic similarity between report words and key words in each sub-category. The vector for one description is the maximum of the vectors of its component report words, since it is assumed that the descriptions should be largely related to the sub-categories when report words show the high semantic similarity. These processes convert the descriptions into semantic similarity weighted vectors with 28 dimensions. When the score for a dimension is higher, the description is more likely to be classified into the corresponding sub-category.

Measurement of Local Content Similarity

In this study, each description represents local content implemented in a host country. The similarity of two implemented local contents is assessed by the cosine similarity between the corresponding weighted vector representations. Cosine similarity analysis is commonly used for measuring similarity between two vectors (Singhal 2001). Two vectors with the same orientation have a cosine similarity of 1, which means the maximum score of cosine similarity is 1. When the score of cosine similarity is approaching 1, the two vectors are similar. It could be implied that local content
implemented in host countries is similar when the score calculated by cosine similarity analysis is high.

ANALYSES, FINDINGS AND DISCUSSION

This study focuses on the regional market level only. The ENR adopts a convention to classify ICCs’ operations in nine regional markets, namely, North America, Latin America, Caribbean Islands, Europe, the Middle East, Asia/Australia, North America, Central and Southern Africa, and Antarctic/Arctic. Africa is regarded as one continent and few contractors operating in the Antarctic/Arctic. As a result, seven regional markets are adopted. By merging host countries into the seven regional markets, the focus is on how local content of ICCs is practiced in the host regions instead of host countries. This has been incorporated in calculating the averaging semantic similarity weighted vectors of local content in host countries.

Local content similarities among regional markets

ICCs from three home regions, i.e. North America, Europe and Asia/Australia are selected as groups for the analysis respectively. In each group, local content similarity for each two of the seven regional markets could be calculated and presented in Fig. 2. Each colour block represents the local content similarities between two regional markets. When the colour block is darker, it shows the higher similarity of the two regional markets.

![Fig. 2: Local content similarities among regional markets](image)

It is shown that local content implemented by ICCs from North America, Europe and Asia/Australia in various host regional markets is similar with all the similarity scores larger than 0.9, although there also exist some slight differences. For ICCs from North America (see Fig. 2 (1)), they implement quite similar local content initiatives in North America, Asia/Australia, Caribbean Islands, Latin America, and Africa, with the similarity scores larger than 0.97. Noteworthy, they do the most different local content initiatives in the Middle East compared to other host regions, evident by the lighter colour blocks for Middle East. It seems that ICCs from North America emphasize indicators related to environment very much, i.e. materials (EN1), energy (EN2), water (EN3) and biodiversity (EN4), when operating in their own region, but the situation differs in the regional market of Middle East. ICCs from European countries show the differential local content implementations in various host regional markets (see Fig. 2 (2)). North American market shows a big divergence of local content implementations from other host regional markets, especially with the market of Caribbean Islands. It is because that European ICCs implement local content very well in North American market, especially
in the aspects of biodiversity (EN4), supplier human rights assessment (HR5) and employment (LA1). For example, a UK ICC, Carillion, requires 100% of contracts will have a biodiversity action plan in place to manage restoration when acting in Canada. While in the market of Caribbean Islands, European ICCs seem not to concentrate on local content implementation. For ICCs from Asian/Australian countries (Fig. 2 (3)), they have a relatively high differential local content initiatives in Caribbean Islands evident by the relatively light colour blocks in Fig.2(3), but this may be caused as ICCs from Asia/Australian do limited projects there.

Fig.2 presents high degree of similarity for each ICC implementing local content in regional markets. This may be caused by the data which are extracted from CSR reports. CSR reporting is under the pressure provided by the increasingly uniformed guidelines. For example, the global reporting initiative (GRI) sets out minimum requirements in key areas of CSR and companies sign up to report in accordance with the requirements (Lu et al., 2015). The ISO 26000 also defines good practice and establishes standards (ISO 2010). Another explanation appears that differences may be reduced when considering the region level instead of the country level. Moreover, it must be taken into account that whether home region has larger impacts on local content implementations than host regional markets.

**Specific Indicator Analysis**

As mentioned above, extracted CSR initiatives are the ones specifically implemented in the host countries, which are regarded as local content initiatives. Based on the results of Step 4 in text mining, semantic similarity weighted vectors with 28 dimensions for each year could be calculated by making an average ignoring the host regional markets. The score for each dimension shows the relevance of local content initiatives to each sub-category. Fig.3 presents the local content initiatives for the years 2011-2015. It can be shown in the figure that Materials (EN1) and Product and service labelling (PR2) are the most reported local content initiatives according to the keywords identified. Based on the keywords analysis, specific materials, such as cement, steel, and concrete, are mentioned most. Renewable materials, raw materials, recycled materials and materials reused are frequently mentioned as the local content initiatives. Besides, product information, service information and safe use of service are included as the key words which attract remarkable considerations. ICCs also pay much attention to implement local content on other indicators, such as diversity and equal opportunity (LA4), local communities (SO1), and public policy (SO3). In the case of key words of these indicators, gender equality and age group attract much attention. Besides, local content related to local communities is always implemented by ICCs, such as welfare, young and children, work councils, and community healthcare projects.

**CONCLUSION AND LIMITATIONS**

This study reviewed the concept of local content, and tried to further enrich the concept by putting it into the context of international construction. Local content in this study refers to those CSR activities tailor-made in different host countries while conducting international construction business. 270 CSR/sustainability reports of ICCs over the past five years (2011-2015) are collected as the data source for analysing ICC’s local content patterns. CSR initiatives are extracted from the CSR/sustainability reports in line with their host country names. It is assumed that only those countries where ICCs implement specific CSR initiatives would be mentioned or stressed in the reports. Therefore, extracted CSR initiatives are the ones specifically implemented in the host countries, which are regarded as local content initiatives.
By triangulating the results from computer-aided text mining and human analyses, it is found that local content implemented in various host regions is similar. This may be caused by the joint, yet dilemmatic isomorphic forces of CSR (reporting) standardization on the one hand while CSR localisation on the other. However, their local content implementations may be affected by both home regions and host regions. As for the indicators, Materials (EN1) and Product and service labelling (PR2) are the most reported local content initiatives. Besides, Diversity and equal opportunity (LA4), Local communities (SO1), and public policy (SO3) also attract much attention of ICCs.

Fig. 3: Local content initiatives implemented from 2011 to 2015

Further investigations on different levels are needed especially when they are placed in the context of institutional theory. Furthermore, the method of text mining is largely depended on the selection of key words, which would directly affect the results, therefore, the process of text mining including the selection of key words needs to be deeply considered.

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INVESTIGATING THE EXTENT OF COMMUNITY INCLUSION IN THE BUDDING SOUTH AFRICAN MEGA PROJECTS IMPLEMENTATION

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The myriad of problems besetting Mega Projects in South Africa have not only damaged the image of these huge infrastructure schemes, they have also been costly because of the endemic delays postponing expected commissionings. A scrutiny of a relationship between common contextual project implementational deficiencies of poor planning and management and the inadequate factoring of community involvement in enhancing project success is going to be executed. The study also assesses the awareness of the importance of the community's involvement throughout the project's implementation period in South Africa. Four megaprojects of Medupi and Kusile Power stations (energy sector) and the Gautrain and Gauteng Freeway Improvement Project (transport sector), were used to investigate the extent of community involvement in conceptualising, managing and implementing these projects. Questionnaires were used to solicit local communities' sentiments as well as interviewing government officials. Apparently there was a lot of 'urgency' in how most of the megaprojects in South Africa were implemented. This appears to have compromized the 'front end' consultation imperatives, but this shortcoming is exacerbated by a lack of long-term proactive community engagement strategies. This awareness necessitates a new narrative in community involvement to enhance the success of megaprojects implementation.

Keywords: mega projects, local communities, contextual, urgency, engagement

INTRODUCTION

Megaprojects are increasingly becoming a norm in today's globally connected business environment, and their size requires collaborations from partners coming from different parts of the world thus increasing the complexity of managing these projects (Kardes et al., 2013). The rate of their failures is well documented in terms of shooting the allotted time and budget spillage; this is exacerbated by the reality of the massive scope, scale and duration of these projects. The overarching resistance to these projects appears to be concerns about relocations and potential environmental degradation (Hart, 2015). Internationally the protests against these projects are driven by hidden social networks and overlapping protest group memberships (Teo and Loosemore, 2010). While tensions between developers and communities have always existed, they have been exacerbated by the new nature and scale of these developments (UN-Habitat, 2008). Current theoretical frameworks in peer-reviewed construction management literature tend to marginalise communities and are not adequate to address these new challenges (Teo and Loosemore, 2010). The aim should be to build a better theoretical framework that will enable a proper understanding, explanation and management of community concerns, alongside

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the challenges of delivering projects within increasingly demanding programs and budgets (ibid.).

In South Africa the implementation of these projects has been met with mixed and divergent reviews. The main source of a lot of disquiet is the poor communication and perceived disregard for the needs, expectations and aspirations of the local communities during the implementation of these projects. According to Teo and Loosemore (2010), there is a common and problematic assumption underpinning project management literature that no further consultation with the local populace is needed since consultations were conducted during pre-development approval stages. The main question of this study then is; what public consultation mechanisms are deployed throughout the different stages of megaprojects implementation in South Africa? A case study approach utilizing four cases where officials that were involved in implementing the projects were interviewed, as well as deploying questionnaires to garner information from the affected local communities. This case study approach was deemed adequate to address the main objective of assessing the adequacy of the consultation regimen in South Africa megaprojects, more so because it has been used by among others Gamson (2003), where community activism was being studied.

LITERATURE REVIEW

Although Megaprojects are new as the subject of research they have been around for a very long time. These projects which are usually above 1 $billion are called the "giants" among the projects or the "new animal" (Flyvbjerg, Bruzelius, and Rothengatter, 2003). Megaproject are considered multi-organizational enterprises (MOEs) which are characterized by (1) singularity, (2) complexity, (3) goal-orientation (technical, financial, time) and (4) the nature and number of project owners. It has been noted that successful projects are not selected but shaped, as the seeds of success or failure are planted early and escalated as choices are made (Flyvbjerg and Van Wee, 2008).

The 'front end' of a project -project definition, concept definition and planning- involves less than one-third of the time and expense and yet has a disproportionate impact on outcomes (ibid). Some of the projects in some jurisdictions are embarked upon as part of the mega-events and the 'urgent' character of these events is used as a legitimizing argument to garner 'consensus' around these new projects (Colomb and Novy, 2016). Most of the projects in South Africa were implemented before the FIFA world cup 2010 when there was a lot of construction of the world cup related infrastructure dubbed the 'legacy' projects, as some of them would continue to benefit the country post the event. It helps to investigate if a proper time was allotted for planning and accommodating local social and economic exigencies in the planning and execution of the current megaprojects given that background. It will also help to see what steps were taken to maintain contact with the local communities, in order to deal with their queries and assuage their anxieties about the direct project benefits.

Community Involvement in Megaprojects

The terms of megaprojects and local community have rarely been investigated together, but is a well-known factor that people and places can be affected by megaprojects development in different ways and the study by Xue et al., (2015) although it is in the right direction is limited to one case in China and besides it does not capture moral issues, different needs and expectations of the local communities. According to Teo and Loosemore (2010) construction management research needs to produce a new intellectual framework that is able to acknowledge that community concerns evolve.
during construction as the scale and nature of development becomes physically evident to communities. Unlike urban planning research which has a conceptualised understanding of community protest there is a significant gap in theory and knowledge in the construction project management because of a persistent notion of community irrelevance (ibid). This creates a situation where there is government sanctioned 'development approval', but no 'community approval', and the tension manifests itself in the triggering of NIMBY (Not In My Back Yard) standoffs through lengthy, costly and often acrimonious conflicts between communities, industries and governments (Chinyio and Olomolaiye, 2010). The study seeks to identify whether a lack of proper consultation throughout the project could be at the centre of public discontentment with the megaprojects implementation in South Africa.

Megaprojects Implementation in South Africa

Although there is a lot of activity on megaprojects in Africa, South Africa is generally regarded as a leader. At least USD 20.3-billion is being invested in Medupi power station and Kusile power station is costing USD 10.8 billion (Engineering-News, 2016). The Gauteng Freeway Improvement Project (GFIP) cost USD 1.46 billion (from the original 0.46 billion) and the Gautrain (metro rail project) cost USD 1.8 billion (from the original USD 0.25 billion). Medupi and Kusile have been met with all manner of industrial actions of people generally complaining about not being properly consulted about the proper implementation strategies and not being prioritized when employing workers for these projects.

There are also other issues around hiring foreign welders from South East Asia while the locals could have been trained for the same jobs and lastly the complaints were about the way the remains of the "ancestors" were handled by the project implementers, when communities were relocated. The GFIP on the other hand has been dogged by a plethora of protest and low compliance in paying the e-tolls to the extent that the provincial government has publicly acknowledged that the implementation of this project was flawed. The opposition parties and lobby groups have been engaged in rolling juristic disputations and making vociferous calls for a provincial referendum on this project. All this is indicative of a very superficial or misdirected consultation process (SABC, 2015). All these experiences in South Africa clearly show that on top of the usual challenges with the megaprojects South Africa has got other challenges that are contextual, and are related to social and cultural issues that frustrate the implementation of mega projects.

RESEARCH METHODOLOGY

A case study methodology was deployed here by investigating four cases. A case study is a holistic methodology useful when an in-depth investigation is needed, as they are designed to bring out details from the viewpoint of the participants by using multiple sources of data. They are sometimes referred to as multi-perspectival analyses as they consider not just the voice and perspectives of actors but also the relevant groups of actors and the interaction between them (Yin, 1994). Their utility in assisting to investigate the experiences of the homeless, environmentalists and social injustice in general is attested to by researchers like Klandermans (2003). A Case study is known as a triangulated research strategy; Denzel (1984) identified four types of triangulation: the first is data source triangulation, when the researcher looks for the data to remain the same in different contexts.

The others are investigator triangulation, theory triangulation (looking from different perspectives) and methodological triangulation when one approach is followed by another
to increase confidence in the interpretation. This study adopted the data source triangulation, which is strongly advocated for by Yin (1994), because of the strength of cross-referencing. That is why interviews and questionnaires were deployed for all the cases.

Interviews were conducted with two officials at OUTA and COSATU; organisations that have studied the GFIP project and have challenged the legitimacy of its consultative processes in the courts, through mass demonstrations and in the media. This research is interested in the depth of the data and in appreciating its breath hence using interviews for top management (Wimmer and Dominick, 1997). The two officials from the Gautrain (metro rail company) and officials from SANRAL (the road agency) were also interview as explained below. For the energy megaprojects four NGOs (2 per project) involved with the communities around Medupi and Kusile power stations were interviewed as well as Eskom officials, the government energy utility company. Interviews were deployed using open-ended questions to gain in-depth information on the issue (Frey and Oishi, 1995). Open-ended questions allow the interviewer, if they wish, to probe deeper into the initial response of the respondent to gain a more detailed answer to the question (Wimmer and Dominick, 1997). The richness of the data can thus be enhanced by this approach.

For the GFIP project a questionnaire was used and 1821 respondents cooperated in three shopping malls in Gauteng. On different days the respondents were issued with questionnaires dealing with Gautrain and 725 responded. The malls were chosen strategically depending on their catchment area and motorists were approached as they alighted their vehicles by trained student research assistants from the University of the Witwatersrand. For the E-tolls about 85% of the respondents were from the middle class and the rest were using public transport (trains, buses, minibus taxis), which in South Africa is mostly by people in the lowest rung of social stratification. For the Gautrain it was found that it is mostly used by the middle class and no responses were had from the general populace. Members of the community and general workers involved in the Medupi and Kusile project were also issued with questionnaires. For Medupi 405 people responded and for Kusile it was 503 people who cooperated.

A questionnaire enables quantitative data to be collected in a standardized way so that the data are internally consistent and coherent for analysis. This is so that when the questions are asked or presented, it is always in exactly the same format (Brace, 2013). According to Zeiger (2017) a questionnaire is designed to get information from a large audience in a short period, and it is particularly useful when a person could divulge information that could make them uncomfortable in a face-to-face setting. Zeiger (2017) argues that this method may be more effective for gathering sensitive information or when you want statistical data about what the majority of a certain group people think. It was for those reasons why the users of the transport projects and the members of the local communities around the power stations were approached as they would have been the target of any consultation drive.

The questionnaire was designed to touch on the issues that have been on the media about the public discontentment about these projects. Since most of the respondents especially around the power stations are not educated the questions were structured in such a way that they did not have to struggle to articulate their answer as the responses were straightforward. The questions dealt with the citizens’ early awareness of the projects and their attitude towards the implementation thereof. In all the projects people from diverse communities and background were utilized to try to minimize bias.
The multiple sources of data were opted for because this enhances the perspectival clarity of the research problem intensely (Creswell and Garret, 2008). The multiple viewpoints accorded by this approach pits the subjectiveness (which provides depth) of qualitative data against the objectiveness (which provides girth) of quantitative approach. This is complementarily beneficial in assisting researchers in properly appreciating the nature and extent of the phenomenon under scrutiny. The questionnaires were analysed by simple statistics in assessing the percentage of people that responded in a particular manner to a specific question.

Interviews elicited common themes from the respondents and the thematic analysis was used to code these themes, after which they were grouped in order to glean any commonalities that might be meaningful. There are two stages to treating themes, the semantic and the latent level. The semantic looks at the surface meaning of what the data says and does not go beyond what the respondent has actually uttered. The overall research design is Convergent Parallel Design where quantitative and qualitative data collection and analysis is done separately but the results of both the questionnaires and interviews are compared and related to offer a substantive interpretation. Not only does this approach offer corroboration from different methods but it proffers a more complete understanding from the two databases. From then on pattern-matching as promulgated by Trochim (1989) was deployed for analysing different cases of the entire study. The technique compares an empirical based pattern with a predicted one, if the patterns match, the internal reliability of the study is enhanced. According to Trochim (1989) the actual comparison between the predicted and actual pattern might not have any quantitative criteria and the researcher's discretion is required for interpretation. The expectation in this study was that consultation is not robust throughout the project duration.

**RESEARCH RESULTS**

**The Gauteng Freeway Improvement Project (GFIP)**

This project involves the upgrading of Gauteng roads, the overhauling of 34 interchanges and the introduction of 4 new directional ramps (fly-overs). This project has 1 million users per day with an anticipated growth in usage. The other improvements on the roads are the Travel Demand Management (TDM) through the introduction of High Occupancy Vehicle lanes. There is also the implementation of Intelligent Transport Systems (ITS) for the effective management of the network. ITS devices such as CCTV will assist in early detection of incident/crashes and assistance/clearance thereof. The provision of lighting which is required for ITS will also improve roadside security. This project has been met with stiff public protestations, low compliance in terms of paying the e-tolls, rolling juristic disputations and periodic concessions by the government, which do not seem to attract any interest from the general populace. This situation is turning this project into an economic 'white elephant' to the government while its free usage by the public continues unabated.

**The Gautrain (Metro Project)**

The Gautrain is a state-of-the-art rapid rail network in Gauteng. The rail connection comprises of two links, namely a link between Pretoria and Johannesburg and a link between OR Tambo International Airport and Sandton. Apart from the three anchor stations on these two links, seven other stations are linked by approximately 80 kilometres of rail along the route. With a project value of about R20 billion (USD 1.4billion), the Gautrain project led by the Gauteng Provincial Government (GPG) has been structured to ensure that the government and the concessionaire, the Bombela
Community Inclusion in South African Mega Projects

International Consortium, operate within a strict set of financial and time parameters. The financial parameters are designed to take account of the risk associated with South Africa’s fluctuating macro-economic situation. The project is a major metro rail project in South Africa. Although there were a lot of concerns about property devaluations as a direct result of tunnelling underground, the project has been embraced by the majority of the Gautengers. The major concerns of Safety and security on the trains, transport to and from the stations and ticket cost and affordability have largely been dealt with. The security on the train is world-class with no major breaches recorded, transport to the stations is provided by dedicated feeder buses which travel between the suburbs and business nodes to the stations. The cost is still a major problem though as the service is largely and almost exclusively used by professionals to the prejudice of lower classes of the community.

**Medupi and Kusile Power Stations Projects**

The construction of Medupi power station was started in 2007 to meet Eskom's declining capacity, which had started showing signs of weakness in meeting demand. Medupi is a Greenfield coal-fired power plant project located West of Lephalale, in Limpopo Province. When completed the power station will be the fourth largest coal plant in the Southern hemisphere, and will be the biggest dry-cooled power station in the world. The boiler and turbine contracts for Medupi are the largest contracts that Eskom has ever signed in its 90-year history. The planned operational life of the station is 50 years. The site was chosen because of land availability in close proximity to the primary coal source, the properties of coal from this region are suitable for efficient power generation and also the competitive coal prices in the area. The total output on completion will be 4800 MW and the baseload station will use direct dry-cooling due to the water scarcity in the area. The power station will directly grow the South Africa GDP by approximately 0.35% per year. This project was scheduled to be completed in four years from the commissioning of construction in 2007 but technical and other problems means only 2 of the 6 turbines has been commissioned thus far necessitating the new completion date to be moved to 2019.

Kusile Power Station (formerly known as the Bravo Power Station) on the other hand is still a coal-fired power plant under construction by state electricity utility Eskom, about 15 kilometres north of the existing Kendal Power Station near Witbank, Mpumalanga. It is expected that Kusile would consist of six 800 megawatt coal-fired generating units for a total generating capacity of 4,800 megawatts. Eskom plans that most of the coal required for Kusile Power Station will be obtained from Anglo Coal's New Largo operations, south east of the Kusile Power Station. Initially expected to take 6 years to complete, the project is not expected to complete Unit 1 until 2017 (approximately 8 years after initial works began) and the entire project not until 2021. In November 2011, Greenpeace activists chained themselves to a gate and some climbed a crane to protest against the Kusile power station and South Africa's dependence on coal. The local communities and labour unions have also been protesting about the conditions at work and like Medupi a lack of consultation on dealing with issues that directly affect the surrounding local populace.

**Transport Projects Results**

Of the two transport projects mentioned above the project that appears to be creating a lot of disquiet among the general populace is the GFIP. The SANRAL officials were for the most part defensive and they claim they complied with the consultation regulations as they stand; on the other hand OUTA and COSATU cited malicious compliance,
superficial consultation and no sincere attempt to engage with the general populace. The officials from the Gautrain demonstrated that there is a steady growth in the usage of this facility compared to the earlier years of operation. The difference between the two projects is shown in table 1; which compares the two projects with what emanated from the interactions with the respondents (users) as follows:

Table 1: Respondents responses to the Usage of the Facilities

<table>
<thead>
<tr>
<th>Themes from the respondents</th>
<th>GFIP</th>
<th>Gautrain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directly affected by the project</td>
<td>67%</td>
<td>30%</td>
</tr>
<tr>
<td>Awareness of the implementation strategies for the project</td>
<td>5%</td>
<td>72%</td>
</tr>
<tr>
<td>Supporting the project</td>
<td>18%</td>
<td>50%</td>
</tr>
<tr>
<td>Using the facilities daily</td>
<td>62%</td>
<td>25%</td>
</tr>
<tr>
<td>Involvement in protest against the project</td>
<td>13%</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

It is clear from table 1 that Gautrain is largely supported and a lot of people appear to know more about its implementation. The same cannot be said for the GFIP as a lot of people don’t know how the plan for its implementation was communicated and although the majority use it they are not happy about it. Some of the people have actually taken part in Marches to oppose the GFIP although almost nobody has protested the implementation of the Gautrain.

Energy Projects Results

The energy projects demonstrated different dynamics as they are not only potential big employers of the locals but they also involved the relocation of some people which resulted in the changing of their (relocatees) livelihoods forever. The Eskom officials cited a tremendous amount of pressure from their principals to ensure that the projects were implemented in a fraction of the normal times and issues like consultation received secondary attention although they were conducted. While on the other hand the NGOs who were assisting the local communities to secure their rights, echoed the sentiments articulated by the communities in the responses (See Table 2).

Table 2: The Experiences of the locals with the Energy Projects

<table>
<thead>
<tr>
<th>Themes from the respondents</th>
<th>Medupi</th>
<th>Kusile</th>
</tr>
</thead>
<tbody>
<tr>
<td>No respect for cultural norms</td>
<td>66%</td>
<td>67%</td>
</tr>
<tr>
<td>Not benefiting local business</td>
<td>34%</td>
<td>56%</td>
</tr>
<tr>
<td>Employment not as expected for the locals</td>
<td>18%</td>
<td>35%</td>
</tr>
<tr>
<td>Favourable job conditions</td>
<td>60%</td>
<td>68%</td>
</tr>
<tr>
<td>Satisfaction with skills transfer</td>
<td>45%</td>
<td>55%</td>
</tr>
<tr>
<td>Involvement in protest against the project</td>
<td>58%</td>
<td>35%</td>
</tr>
<tr>
<td>Opposition to foreign workers</td>
<td>20%</td>
<td>27%</td>
</tr>
</tbody>
</table>

The two projects appear to have created a lot of disquiet around the issues of proper consultation. Their introduction appears to have created a lot of false expectation about
the benefits to the community, to the local businesses and on job creation. Failure to meet these expectations might have fuelled a lot of protestations against the projects. The fact that outsiders were employed in certain areas made locals not to be happy about the skills transfer programme as they expected to be given first preference in such initiatives. A lack of continuous consultations and promotion of the project appears to have led to a lot of protests.

DISCUSSIONS

The problems encountered in these projects appear to be centred on a lack of proper consultation. This appears to be the root of all the problems articulated above. This appears to tie in with Flyvbjerg and Van Wee (2008) and Teo and Loosemore (2010) in demonstrating the importance of formulating congruence with the general populace, as failure to do so normally leads to the demise of the project. The fact that most of the big players are international partners, could explain why most of the sensitive issues were not handled properly. There was overdependence on the competencies of the local entities to deal with the appropriate stakeholders in order to mitigate challenges that could derail the implementation process. There was also a lack of proper oversight on these local partners to ensure that proper protocols are implemented in order to elicit the sentiments of the general populace in order to come to a common understanding around what the project could practically achieve and how to maximize the benefits for the local communities.

Since the culture of consultation is not well entrenched in the country and the regulation is not prescriptive enough, appointing a specialist company (even international) as postulated by Hart (2015) could have alleviated this shortcoming.

With the GFIP failure to deal with contentious issues throughout the project's tenure birthed new challenges and led to the festering of the normally minor challenges (a normally small number of tolls non-payers in other projects). This has come to a point where the complete lack of cooperation of the general populace has frustrated the very viability of the GFIP project, because of the minimal support from the local populace. On the other hand Gautrain, a project that was introduced properly and whose implementation was communicated properly to the public does not appear to have met any resistance and the future appears to be bright as the support for it is growing albeit only from a privileged sector of the society.

The notion of 'urgency' in South Africa is not used to legitimize the projects as postulated by Colomb and Novy (2016), as the legitimacy of the projects is not contested but the 'urgency' is used to overlook the 'front end' imperatives which have a long-term impact on the executability of the project. It is therefore clear that uncompromisable minimum standards in terms of the applicable durations and the necessary protocols dealing with consultative initiatives have to be set. The fact that SANRAL claim that they did what was dictated by the law shows that the legislation has to be more elaborate to prescribe the minimum standards.

With the energy projects, there appears to be a lot of disappointments on what the locals were hoping to benefit from the projects. This could be an indictment for Eskom for not following up on their promises or creating an impression that certain things were going to be provided that were never going to be provided. The common theme from all the responses is that the members of the community feel that they are not benefitting or benefitting enough as they should from the projects in their backyard. The fact that the projects were implemented under a lot of pressure from political principals means that maybe there was no proper plan devised to adequately channel economic benefits to the local community. Continuous engagement however could have improved common
understandings. It should however be mentioned that there were some start-ups which were encountered on site that were conceptualised and triggered by the opportunities offered at this project.

CONCLUSIONS

South Africa has forged ahead and positioned itself as the African leader in megaprojects implementation. Since it is a developing country there is a lot of partnering with international players when implementing these projects. It is therefore imperative that all who want to be involved in the country understand the contextual nuances that could make or break a project. The following appear to be imperative for any project:

- A well-articulated programme of public engagement spanning the tenure of the project should be in place to create mutual understanding on the practical benefits to the locals.
- Public consultation and proper community engagement should not be compromised by the 'urgency' of the project as this could come back to derail success of the project.
- Just as consultation was proactive during the pre-implementation stage it should still remain so throughout the project duration, as reactive approaches lead to project schedule spillage.
- A lack of prescriptiveness in the local regulatory framework dealing with public consultation leads to superficial engagement with the public resulting in debilitating resistance to project implementation.

The main lesson from the study is building on work done by Teo and Loosemore (2010) that the community is not irrelevant and is very much a part of the project and new strategies of communication should be promulgated and accepted as project deliverables. The study extends the work by Xue et al., (2015) that community expectations should be addressed and managed continuously to avoid any disruptions.

REFERENCES


SUPPLY CHAIN MANAGEMENT
CONCEPTUAL FRAMEWORK FOR TRACEABILITY IN THE CONSTRUCTION SECTOR

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Traceability is a major challenge for modern complex and fragmented construction product supply chains. However, there is a paucity of academic literature on traceability in the construction sector. Extant literature on traceability in other sectors (e.g. textile, pharmaceuticals, forestry and automotive) focuses largely on the practical aspects of the concept, as a compliance function. Thus, a conceptual understanding of traceability is lacking. The aim of this paper is to offer a conceptual underpinning of traceability as a construct. Based on a critical review and synthesis of extant literature, a conceptual framework for traceability is proposed. The framework draws on knowledge management theory, recognising that product data, information and knowledge are cognitive constructs relevant to understanding about the product. This conceptualisation provides definitional clarity to traceability as a theoretical construct, and clarifies its relationship with the closely-related concept of transparency. The theoretical grounding of the framework means it should have broader application value to other sectors and contexts.

Specifically, to the construction sector this paper raises questions whether the growing regulations fully support traceability; what are the implications of traceability for outsourcing trends and information sharing, and what are the economic benefits and costs of implementing traceability in the construction sector.

Keywords: construction supply chain, sustainability, traceability, transparency

INTRODUCTION

Nowadays most products have long complex journeys before they reach consumers. As a result, there is little awareness of where products come from and under which conditions they are sourced, produced and distributed. Traceability, defined as the “ability to trace the history, application or location of an object” (BSI, 2015: 20), is a key component to enhance such an understanding. From the perspective of sustainability, traceability helps to verify ethical and sustainability claims across product supply chains, addressing responsible sourcing, environmental impact of production and distribution of materials, modern slavery and health & safety conditions of employees. Therefore, it plays an important role in providing an incentive for sustainable production and ethical business behaviour. In contrast to other sectors (such as the food sector, textile sector, forestry, pharmaceutics, diamonds, automotive), traceability is still at an emerging stage in construction. Even though construction companies do trace and track their products (discussed in the next sections), little is understood about traceability as a concept and no guidelines exist on how to actually implement it in the construction sector and more generally, in other sectors as well. To support practical engagement with traceability in construction, this paper offers a conceptual underpinning of traceability as a construct,

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though it could be applied to many contexts and sectors. The next section of this paper analyses the current state of traceability in the construction sector. Then, schools of thought on traceability from a range of disciplinary literature bases are summarised and, based on that, a conceptual framework on product traceability is presented. Implications of the framework on the construction sector and future research are discussed in the concluding remarks, and as such, the paper provides the definitional clarity, and the theoretical grounding which has previously been lacking.

THE RELEVANCE OF TRACEABILITY TO CONSTRUCTION

The construction sector plays an important role in global sustainable development, as it is one of the world’s largest consumer of natural resources, yet it creates major social and economic value through generating employment and contributing to the economy. Construction suffers from a number of structural and operational challenges, reported extensively in literature and reports over the past century, for instance its supply chains are highly fragmented and complex in nature, consisting typically of many parties, often in adversarial relationships, in which each party aims to derive maximum benefit at least cost while transferring risks and responsibilities to their suppliers (Pryke, 2009). These factors combined indicate that traceability could have relevance in construction, but it is not well-understood as a concept (as will be explained later). Traceability can verify sustainable practices along supply chains, such as ethical sourcing of materials, environmental impact of production, modern slavery, and health and safety. In essence, there are four key problems in the construction sector that might be addressed by traceability, as discussed next.

First, there is a growing body of relevant legislation and standards. The standard on responsible sourcing BES 6001, introduced in 2008 by the Building Research Establishment (BRE) in the UK, verifies provenance of construction materials in respect to sustainability issues. In addition, the UK Modern Slavery Act 2015 requires large organisations (including construction companies) to demonstrate actions aimed at preventing modern slavery not only in their own businesses but also in their supply chains (TSO, 2015). Similar legal requirements exist in other countries (e.g. California’s Transparency in Supply Chains Act 2010 in the USA). Responding to modern slavery concerns, BRE launched the Ethical Labour Sourcing standard, BES 6002, to encourage ethical labour practices within construction supply chains (BRE Global, 2017). Hence, this landscape is encouraging and in some cases, urging, construction companies to investigate their supply chains more thoroughly.

Secondly, is the subject of outsourcing practices: even though the sector tends to use locally-sourced materials (EC Harris for BIS, 2013), globalisation has not bypassed construction. Growing imports of construction materials to the UK are raising environmental and social concerns (Upstill-Goddard et al., 2016). For example, 280,000 tonnes of sandstone annually coming to the UK from India are associated with allegations of labour rights violations (ETI, 2016). Imports of low-cost reinforcing steel from China drew criticism on grounds of quality, safety, ethical sourcing processes, and fair trade, and in response, UK Government released a policy encouraging procurement of sustainably produced steel, the provenance of which should be traced back to the origin (Crown Commercial Service, 2016). Traceability provides information that facilitates selection of sustainable materials, mitigating the negative aspects of outsourcing.

The third problem is inefficient procurement strategies. Construction companies tend to prioritise cost when purchasing materials (EC Harris for BIS, 2013), (Pryke, 2009), rather than sustainability factors, and procurement processes may lack transparency (Li et al.,
By revealing sustainability conditions along a product’s supply chains, traceability could support better decision-making in procurement.

Finally, construction supply chains lack the benefits of effective information exchange (Constructing Excellence, 2006); this may result in poor collaboration among supply chain partners, adversarial relationships, lack of accountability, and generally, low efficiency of supply chains (EC Harris for BIS, 2013). Traceability could improve information sharing across product’s supply chains.

**CURRENT STATE OF TRACEABILITY IN CONSTRUCTION**

In contrast to the food sector, for example, where consumer safety and quality are major concerns (McEntire et al., 2010), the main drivers of traceability in construction relate principally to sustainability practices and ethical concerns.

For instance, BES 6001 (BRE Global, 2016) includes traceability as a mandatory requirement; a minimum of 60% of the mass, volume or cost of input materials must be traced back to its source. Around 89% of concrete (MPA, 2017) and 90% of brick manufacturers (BDA, 2014) in the UK are certified to BES 6001; showing a good level of sector engagement with traceability. The Modern Slavery Act in the UK and the Ethical Labour standard BES 6002 also encourage traceability, as mentioned previously. Initiatives encouraging traceability exist for particular construction materials. The EU Timber Regulation 995/2010 prohibits trade of illegally harvested timber and requires record-keeping from suppliers and customers. The USA Lacey Act 2008 demands source declaration for timber.

In fact, several schemes are available for chain of custody certification to trace timber to the forest of origin, e.g. Forestry Stewardship Council, Programme for the Endorsement of Forest Certification, and the Sustainable Forest Management Standard. Reinforcing steel can be certified against the Eco-Reinforcement scheme (based on BES 6001), and CARES Sustainable Reinforcing Steel Certification scheme; both ensure material traceability of reinforcing steel demonstrates ethical sourcing and sustainable practices (Livesey and Hughes, 2013). Nevertheless, practical implementation of traceability in construction is accompanied by many concerns; little is understood about traceability as a concept, and regulations do not specify how to actually implement traceability. Accordingly, there is a minimal literature on traceability in the construction sector, with just a few studies addressing traceability from the perspective of responsible sourcing (Glass, 2011), (Livesey and Hughes, 2013), (Upstill-Goddard et al., 2015), and one more recent paper emphasising the need for conceptual underpinning of traceability (Katenbayeva et al., 2016). That said, it is worth noting that conceptual understanding of traceability is limited even in sectors where it is more widely established in practice. Therefore, in order to support practical engagement of traceability in the construction, first of all, it is critical to gain a fundamental understanding of it as a concept.

**THE EVOLUTION OF THINKING ON TRACEABILITY**

Many studies of traceability tend to focus on operational (practical) aspects, and a common understanding of the concept is somewhat lacking, but this section discusses existing schools of thought on the conceptual aspects of traceability.

The fundamentals of the concept of traceability were formulated by Kim et al., (1995), and then enforced by Moe (1998), based on the identification of a unique product and its activities. A product can be characterised by its type (varieties, form, proximity analysis, quality attributes, environmental attributes, etc.) and amount (weight, volume, number,
An ideal traceability system controls the quantity changes of the product over time (Kim et al., 1995). Activities describe the route of the product, i.e. buying, selling, handling, transportation, storing, etc. (Moe, 1998). Characteristics of products and activities go beyond the intrinsic; they include quality/environmental attributes. Golan et al., (2004) suggest traceability can be used to verify credence attributes, i.e. content attributes that affect physical properties of a product, but are difficult to identify (such as amount of chemical ingredients), and process attributes, which do not affect the content of a final product, but refer to characteristics of the production process (e.g. country of origin, eco-friendly, fair trade, etc.). Indeed, Regattieri et al., (2007) offer a framework based on four pillars: product identification, product routing, data to trace and traceability tools. “Product identification” and “product routing” correspond to the “product” and “activities” in Moe (1998), but “data” is distinguished as separate. Their framework confirms the relevance of manufacturing infrastructure as a means to improve quality, safety and environmental footprint of production processes.

A rather different interpretation is provided in the area of supply chain management and logistics. A conceptualisation of traceability by van Dorp (2002) has three layers: a physical layer (where unique identification of products is implemented through item coding); an information layer (where information on products and processes is exchanged with the help of information architecture), and a planning and control layer (for optimisation of product manufacturing processes). This underlines the potential of traceability to enable planning and controlling organisational processes. The significance of physical and information flows for traceability is also highlighted in the Global Traceability standard (GS1, 2012); this focuses on the logistic function of traceability, and states that traceability is based on an information exchange between supply chain actors in parallel to the physical flow of products.

From the perspective of data management, Folinas et al., (2006) state that traceability data management involves: identification and classification of traceability data; transformation and modelling of data in accordance with specific needs; processing of data according to final user requirements; and finally, presentation of traceability data in a “human readable format that optimizes the decision-making process” (Folinas et al., 2006: 631). Again, this confirms the decision-making potential of traceability.

Other scholars argue that traceability leads to supply chain transparency (Sarpong, 2014), and define it as the extent to which: “stakeholders have a shared understanding of, and access to, the product-related information that they request, without loss, noise, delay and distortion” (Hofstede, 2003: 18). Accordingly, “transparency combines tracking and tracing and takes a more metaphoric stance, looking into the chain from outside” (Hofstede, 2003: 20).

Within recent studies, the framework developed by the Institute of Food Technologies (McEntire et al., 2010) has gained popularity. It is based on two constructs: Critical Tracking Events (CTE) and Key Data Elements (KDE). Traceability requires recording appropriate data (KDE) in specified points of product movement and transformation, including: receiving, movement, transformation (including manufacture, production, grouping, splitting, mixing, aggregation, packing), storage, product usage, destruction, dispatching and change of status (GS1, 2012). Key data that should be recorded are: physical location of a product, lot number, amount of product, date and time when product was shipped/manufactured, etc. KDE can also be used in a broader sense, also including data on credence attributes.
The concept of traceability is therefore linked closely to supply chain transparency. However, it is important to differentiate these terms clearly. While traceability is clearly referred as an ability, or (firm’s) capability, supply chain transparency is defined as an extent, or state. One definition of supply chain transparency regards it as the extent to which supply chain partners have a shared understanding and access to the product-related information (adapted from (Hofstede, 2003)). Traceability is a pre-requisite to achieve supply chain transparency, though implementing traceability alone does not guarantee supply chain transparency (this will be explained later in more detail). Another distinction can be made by taking a supply chain perspective: traceability focuses on a focal company (Timmer & Kaufmann, 2017), whereas supply chain transparency “takes a more metaphoric stance, looking into the chain from outside” (Hofstede, 2003: 20). Yet despite all this, the links between traceability and supply chain transparency really are not well-established because literature does not explain in what ways traceability generates supply chain transparency, or which conditions are required to achieve transparency in supply chains, apart from traceability. Traceability researchers confirm the relevance of product attributes, activities, and data/information, as well as potential to support decision-making. However, none provides a holistic underpinning of traceability as a concept. To address this gap, the next section presents a framework on traceability, developed from a synthesis of existing literature on traceability from different fields, and as such, having a potentially broad scope in terms of its application, sectors and contexts.

A CONCEPTUAL FRAMEWORK FOR TRACEABILITY

Having set out a gap in knowledge, i.e. that there does not exist a firm conceptual understanding of traceability, Figure 1 presents a conceptual framework on traceability, which draws on knowledge management (KM) theory. KM suggests that data (defined as unprocessed raw representation of reality) transforms into information if put into context. Hence, information is data that has been processed in a meaningful way. In turn, processed information transforms into knowledge if it is actionable, so knowledge is referred to information that has been processed in some meaningful ways (Jean-Baptiste et al., 2008). This theory is highly relevant for traceability because the idea or notion of information is central to the function of supply chains. So, thus, the conceptual framework recognises that product data, information and knowledge are cognitive constructs relevant to understanding about the product; they represent different levels of abstraction from an understanding of existence.

![Figure 1: Generic conceptual framework for product traceability.](image-url)
transformations (such as mixing, splitting, aggregating, disaggregating, etc.). These activities represent a physical flow of products and correspond to the term “Critical Tracking Events” (McEntire et al., 2010). As products move and change through their journey, their past transformations and movements determine, directly or indirectly, the attributes of a final product, which can be content, process and supply chain related attributes, as explained earlier. To enable traceability, data on a product’s activities and attributes needs to be collected, recorded, stored, shared, accessed and its security should be ensured. All these are designated here as data management. Data management enables transforming data about a product’s past activities and its present attributes in a meaningful way to provide information required for traceability. Indeed, having an information flow which follows the physical flow of a product across a supply chain, is the core principle of traceability (GS1, 2012).

The second level of the conceptual framework is the “Information” level. The quality of traceability can be evaluated in respect to the quality of the output, i.e. information. Methods for assessing information quality are reported extensively within data science (e.g. Lee et al., (2002)). Criteria for measuring information quality include: information breadth (amount of information obtained), depth (how far upstream and downstream information can be traced), precision (accuracy of information) and access (how easily information can be retrieved) (McEntire et al., 2010).

Once information flows have been created, so traceability is achieved, then new questions arise on how to use this information proactively. Here, the “Knowledge” level can be described. Information can be used internally within a company, for example to improve supply chains, eliminate supply risks, facilitate recalls in safety or quality failures or it can be presented to a wider audience (customers, auditors, non-profit organisations) to maintain reputation, generate trust or conform to certificates and regulations, etc. Supply chain transparency focuses on the clarity of communication from the company to those outside of it (The University of Tennessee, 2016). Hence, traceability information alone is not sufficient to achieve supply chain transparency; arguably, this information needs to be manipulated (processed) and then communicated well. Several information disclosure strategies are commonly used by companies: transparent approach (which means a full disclosure of supply chain information to the public), secret (when traceability is implemented, but little information is disclosed), withheld (minimal public disclosure of supply chain information due to traceability failure or intentional avoidance of releasing information about non-ethical practices), and distracting (disclosing information in a manner that would distract an audience from adverse facts) (Marshall et al., 2016). Information manipulation theory suggests that information can be changed in a way to create a false perception of this information (McCornack, 1992). Importantly, in this framework, such manipulation does not necessarily imply any nefarious intent. Indeed, it might be essential to manipulate (i.e. process) the information to make it understandable by others.

Hence, the presented framework situates traceability within knowledge management theory as a theoretical lens, and thus recognises that product data, information and knowledge are cognitive constructs relevant to an understanding of the product. This conceptualisation provides definitional clarity to traceability as a theoretical construct; and distinguishes it from, and clarifies its relationship with, the closely related concept of transparency. Future developments of this framework will be addressed at the empirical validation stage, involving a number of construction organisations.
CONCLUDING REMARKS

It is understood that complex and fragmented supply chains, amplified by inefficient procurement, globalisation trends and lack of information sharing are closely linked to poor transparency in the construction supply chains. Traceability is an important antecedent for supply chain transparency, and the developed framework enhances our understanding of both traceability and supply chain transparency. It offers a novel interpretation of traceability from the perspective of knowledge management theory. For the construction sector this framework attends to four key issues, as follows:

First, traceability helps organisations to address a growing body of legislation, standards and policies for sustainability in the construction supply chains. However, regulations do not provide any conceptual clarity on traceability, so the framework addresses this by making traceability more understandable, so facilitating compliance. With the recent development of a standard for ethical labour sourcing (BES 6002), there is a need for further research to understand how companies do, and would wish to, undertake traceability studies (there are skills, resource, and assurance implications here). Moreover, does the current body of standards fully support traceability?

Secondly, concerning outsourcing trends (Upstill-Goddard et al., 2016), traceability of construction products helps to inform the choice of selecting sustainable materials, thereby, mitigating the negative aspects of outsourcing. However, it may mean that locally-sourced materials would be prioritised over internationally-produced ones, since they are easier to trace. So, for an organisation, changing global sourcing practices might raise concerns in areas such as freedom to trade, availability of materials, increase in cost and decrease in quality of materials, etc. Implications for the globalised flow of commodities thus require further investigation.

Thirdly, regarding inefficient procurement strategies (Pryke, 2009), the framework depicts attributes associated with product movement and changes. Such awareness would support decision-making towards selecting responsibly sourced and ethically produced materials rather than considering only cost. Since traceability requires investments in technologies, product differentiation processes, data management processes, and personnel training though, this might affect the final cost of materials. However, traceability investments are compensated in the long term through improvements in logistics and risk management. This warrants investigation within the construction project context, as this is not covered by previous studies.

Finally, construction supply chains lack in information sharing (Constructing Excellence, 2006). The conceptual framework emphasises information flow linked to a physical flow of products. Through sharing traceability information, companies would increase supply chain integration and collaboration and ultimately improve efficiency of logistic processes (Bosona and Gebresenbet, 2013) across construction supply chains. However, it might create a burden because it requires attention to data management processes (Bhatt et al., 2016); the impact of this requires research.

This research can serve as a base for future empirical studies in this field. Further research should concentrate on the following questions:

- How does the construction sector perceive and understand traceability?
- How is traceability implemented by construction organisations?
- Which conditions are required to successfully trace and track products?
- What is the optimal level of traceability and supply chain transparency?
This work is a part of ongoing PhD research on traceability, which seeks to elaborate, refine, validate and empirically test the proposed conceptual framework in the construction sector as a novel application context for the concept of traceability and also address the aforementioned research questions.

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TECHNOLOGY
PRIORITISING OBJECT TYPES OF INDUSTRIAL FACILITIES TO REDUCE AS-IS MODELLING TIME

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The cost of modelling existing industrial facilities is currently considered to counteract the benefits of the model in managing and retrofitting the facility. 90\% of the modelling cost is typically spent on labour for converting point cloud data to the final model, hence reducing the cost is only possible by automating this step. Previous research has successfully validated methods for modelling specific object types such as pipes. Yet modelling is still prohibitively expensive. We tackle a part of this issue by identifying the most frequent object types that require modelling in industrial plants to guide future work aimed at automating the tedious current practice. We determine a priority list of the object types in these facilities based on their frequency of appearance (\%) and intent of modelling. A parametric study based on Outer Diameter (OD) then finds the most frequent OD ranges for these objects. The results indicated that steel sections were the most frequent object type encountered in all case studies.

Keywords: 3D Modelling, facility management, industrial facilities

INTRODUCTION

Industrial plants can be divided into six main categories: (a) onshore and (b) offshore oil platforms, (c) chemical, (d) mining, (e) pharmaceutical plants and (f) food processing factories. The object types of industrial facilities belong to three different categories: (a) piping system, (b) steel sections and (c) equipment. More specifically, the object types of the piping system are pipes, elbows, tee and olets, valves, reducers, flanges and caps.

Maintenance, safety management and retrofitting of existing industrial facilities are vital operations in their lifecycle (BIFM 2012, Gorse and Highfield 2011). Poor maintenance and safety deficiencies lead to equipment failure, which can have significant environmental, economic and societal impacts. The Deep Water Horizon (Office of Maritime Administrator 2011) and 2008 Georgia sugar refinery (U.S. Chemical Safety and Hazard Investigation Board 2008) explosions are two recent examples of critical failures caused by poor maintenance. By 2050, the need for refurbishing and retrofitting 93\% of existing facilities to meet environmental regulations will be a major focus in the UK construction industry (Edwards and Townsend 2011).

Most existing major refineries were built before the advent of CAD in 1977, therefore working models do not exist to assist their maintenance operations (Bernard 2003, Cabinet office 2012). For instance, the newest refinery with significant downstream unit capacity built in the United States is in Louisiana (Garyville Refinery) and it began operating in 1976 (Marathon Petroleum Corporation 2014). Unprecedented incidents would have been avoided if computerized control system displays were better designed (U.S. Chemical Safety and Hazard Investigation Board 2007) and enriched 3D as-built

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BIMs (Building Information Models) were present. If the inspectors have enriched as-built 3D models, they will be more proactive in dealing with similar circumstances such as leaks and ignition (Umar 2010). However, there are significant challenges that need to be addressed to make automated as-is industrial BIMs a reality.

The significant time required to model the vast number of objects in industrial facilities impedes adoption of as-is 3D modelling for these assets. Modellers use the following four main steps to manually process as-built BIMs: (a) data collection (laser scans), (b) point cloud registration, (c) geometric modelling and (d) addition of accompanying information, such as topological relationships and material specifications. Point cloud processing remains the “bottleneck” during the 3D modelling of any industrial facility given how costly and time consuming it is. A recent case study of a sugar refinery, covering an area of 65 hectares, reported that more than 80% of the modelling time was spent on point cloud processing of the scans (3Deling). According to another recent study of an offshore facility, the laser scanning process was only 4 hours, whereas 3D semi-automatic modelling of 2,602 objects (planes and cylinders) was conducted in 15 days (Fumarola and Poelman, 2011). Given these facts, the modelling process should be efficiently automated.

Safety, retrofit purposes and maintenance are three modelling intents that can determine whether an object type is critical for detailed modelling (BIFM 2012). Examples of critical object types that should be considered are given below. Hazardous subsystems in terms of safety should be modelled in finer detail. Highly hazardous object types are separators, compressors, driers and flash drums, whereas moderately hazardous ones are pipelines and pumps (Umar 2010). These elements are considered dangerous based on failure rates assessed by the Health and Safety Executive (2012). Identifying hazardous equipment elements will remarkably improve safety management.

Valves are a control element in nearly all chemical process control loops and regulate the flow through piping systems. Operation of valves can be achieved either manually by a hand wheel/lever or automatically. The performance of an industrial plant can be improved by opening, closing or changing the position of a valve. Failure to quickly locate and identify control and safety valves during inspection can result in significant damages or even massive, unprecedented disasters like Texas City Refinery (U.S. Chemical Safety and Hazard Investigation Board 2007) or Piper Alpha (Oil & Gas U.K. 2008). Safety system deficiencies that occurred due to poor inspection and inadequate maintenance are reported as some of the main factors of the devastating incidents mentioned above.

Another important control measure in industrial facilities is maintenance of pipelines and pipe supports. Insulated pipes and pipelines carrying flammable, hazardous or toxic materials are highly important for inspection. One of the most important concerns of inspectors for maintenance of pipelines is corrosion. Pipes of Nominal Bore (NB) greater than 2 inches (50 mm) are considered critical for corrosion (Singh and Britton 2001). Pipe supports and hangers are the “foundations” of a piping system and if they are not properly maintained, the entire piping system is likely to fail (Sahazizian and Zlatko 2011).

Although the "arteries" of a Process Plant are its pipeline systems, since they carry its "lifeblood", structural steelwork is vital for its structural stability and oil and gas production especially in cases of fire. Given the short lifecycles of refineries, which range from 15 to 30 years, structural design is challenging since the layout should be flexible and expandable (Gourlis and Kovacic 2017). Fatigue of steel girders is critical
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for maintenance, however the contribution of structural failure to the total number of historic accidents is less than 10% based on worldwide data (WOAD Database 2014). Seismic retrofitting and energy retrofit for pipes are typical retrofitting operations in industrial plants (Autodesk 2009).

Figure 1 summarizes the critical elements for each category (maintenance, safety and retrofit). The higher the impact these object types have on each category the higher they are on the list. The graphical representation of the objects is specified by the Level of Detail (LoD). The American Institute of Architects (AIA) defines 6 LoDs (AIA 2017) of which LoD 300 is used for construction (Wang et al., 2015). According to LoD 300, the shape, size, quantity, location and orientation of objects are modelled. The most critical and most frequent object types for modelling are considered based on this specification.

![Critical object type list for (a) maintenance, (b) safety and (c) retrofit purposes](image)

**State of practice**

Numerous commercial software packages offer a degree of automation for 3D as-built industrial facility modelling. One recently developed commercial program automatically extracts 85% of the pipes in a plant room on a typical North Sea platform with 1-3% average error (ClearEdge 3D 2013). There was a substantial manual modelling time reduction in this project from 60 man-hours to 15 man-hours. The EasyConnect tool, which automatically couples straight pipe spools ("segments") to connect the pipeline layout, solved the problem of occlusions in industrial environments. The user manually fits connections like valves and flanges into the 3D as-is data. The cost and complex manual modelling required in current practice are a barrier to broader adoption of as-is models for industrial facilities.

Leading 3D CAD software vendors (Autodesk, AVEVA, Bentley and Intergraph) have also developed software packages that manually model as-built industrial environments. PointSense Plant by Kubit has integrated functionalities that can detect pipelines from 3D point clouds. It automatically finds the best fit for cylinders. However, all software packages only extract geometrical shapes, without being designed to classify the object types automatically. For instance, cylinders can represent pipes or handrails to name a few. This step is performed manually by the integrated MEP or structural steel/concrete standard catalogues.

**State of research**

As-built 3D modelling of industrial facilities is focused on the detection of primitive shapes and specifically, cylinders, planes, spheres and cones, by using model based methods. It has been proved that 85% of objects in industrial scenes can be approximated by the above-mentioned shapes (Petitjean 2002). As-built pipelines, although generally cylindrical, are a great challenge for modellers due to the variety of object types, shapes, diameters and randomness of their poses (Son et al., 2015). Automatic cylinder detection is mostly investigated (Kawashima et al., 2014; Patil et al., 2017; Qiu et al., 2014) by defining the five parameters that describe cylinder orientation, position and radius by a variety of methods. All the above-mentioned research efforts
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concentrate on straight pipes, thus sections of inclined pipe “spools” (segments of pipes) are neglected from this analysis. Semantic detection of object types is performed by Perez-Perez et al., (2016), in order to assign labels (wall, ceiling, floor, pipes) to the distinguished categories.

As-built modelling of industrial facilities is like a "zoom in" of an urban modelling problem (Patraucean et al., 2015). Weinmann et al., (2015) and Babahajiani et al., (2016) achieved automatic object classification by assigning semantic labels in 3D urban scenes. Therefore, interdisciplinary communication between different research fields is essential for the progress of as-built modelling.

A fully automated method that models the entire pipeline, structural members and equipment of industrial plants has not been achieved yet. Analysis on the most frequent and critical object types that will assist automation and improve quality of modelling needs to be considered. For the statistical analysis presented in this paper, only the topsides structure (structure above the sea level) of the offshore plants is considered, where crew quarters are located and typical operations take place, such as extraction, processing and storage of oil and natural gas. We can model these facilities efficiently by answering the following two questions: (a) which object types should be automatically extracted to reduce modelling time and (b) to what LoD should critical object types be modelled to have an enriched BIM model?

RESEARCH METHODOLOGY

We tackle the research question of the object types that need to be modelled by implementing a statistical analysis on the frequency of appearance of all object types present in typical industrial plants. We examine four case studies of 3D modelled industrial facilities to have a representative statistical analysis of the most frequent object types. Three case studies were typical offshore platforms with the fourth being a typical food processing refinery (sugar refinery) due to availability of data. Concerning offshore platforms, the subcategories that were examined in this paper are (a) a Gravity-Based Structure (GBS), (b) a Tension-Leg Platform (TLP) and (c) a fixed platform. The as-designed models accurately represent the as-built conditions. The only possible differences between the as-designed and as-built models are geometric, which do not affect the frequencies of the object types.

Our method is based on a statistical analysis of \( n \) objects with a range of OD \( (d_1, d_2, d_n) \) for each object type and their observed counts \( (c_1, c_2, c_n) \). We obtain object type counts from as-designed BIM models of these facilities. The objects investigated belong to three different object categories: (a) piping system, (b) steel sections and (c) equipment due to availability of data. Most of the object types encountered in industrial environments are presented in Figure 2. A priority list of object types was obtained by finding the percentages of appearance (%) of each object type in each facility and an average priority list for all facilities. Given the total number of objects present in a specific facility, we calculate the frequency of appearance by dividing the counts of each object type with the total number of objects.

The piping system is further subdivided in two meaningful subgroups with respect to their OD. Small bore pipes are the pipes whose OD is less than or equal to 2 inches (50.8 mm) and the rest (pipes with OD greater than 2 inches) are considered large bore pipes. This division is meaningful since large bore objects of piping systems carry flammable (oil, gas, gasoline, hydrocarbon) and highly volatile materials, whereas small bore are mostly used for hydraulic purposes or other less flammable liquids. An important geometric
parameter that is useful for the recognition of each element of the piping system is the range of OD. We conduct a parametric study on the OD of each object type, in order to observe trends on the most frequent diameter ranges and infer connectivity relationships between the piping objects present in the industrial plants investigated in this paper. Probabilistic distributions and statistical properties of each object type in the piping system are calculated to provide the range of ODs for each industrial facility.

![Steel sections, equipment and piping system representations of objects (AVEVA)](image)

Figure 2: Steel sections, equipment and piping system representations of objects (AVEVA)

The results of this statistical analysis will assist researchers to focus on automated modelling for the most frequent object types, whereas users will manually intervene to a small subset of infrequent object types. Time efficiency will indirectly result in cost reduction, which is a crucial parameter when modelling huge assets. There are many unclassified objects in the case studies, where many units are prefabricated and not included in the designs or object types that are classified in different categories. For instance, some modellers classified hand rails as structural components and others as parts of the piping system. The prefabricated units are transported to the facilities by engineering skids, thus the objects they contain are not modelled. Also, equipment includes electrical systems, plumbing and fire protection elements. We addressed the research question (b) with a priority list of critical objects in the introduction.

RESULTS: CASE STUDIES

Figure 3 shows the object type rankings in descending order for all case studies and the percentage of large bore objects in piping systems as well as the percentage of instrumented valves in total number of valves. The facilities are anonymized since rights are reserved by AVEVA and representative pictures of typical facilities are shown in Figure 3. Steel sections are more frequent in all offshore projects with an average frequency of 50.44 % for all case studies. Pipes and other elements of piping systems follow in percentages as well as equipment. These statistics are important since most software packages and research methods that were mentioned above prioritize the modelling of pipelines, which are only 22.24 % on average for all facilities. We also show the standard deviation of the average general frequencies, which is higher for steel sections meaning that the data are more widely spread from the mean (50.44 ± 14.94 %).
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Figure 3: Priority list of all object types in descending order, percentages of large bore objects in piping systems and instrumented valves in total number of valves for the (a) Gravity-Based Platform, (b) fixed platform, (c) Tension-Leg Platform, (d) sugar refinery and (e) average frequencies of all industrial facilities. Pictures illustrate typical industrial facilities in each case: all pictures of offshore platforms are taken from Devold (2013) and the picture of sugar refinery from KPMG (2007).

Different classes of the same object type exist based on their use, which are not investigated in this paper. However, instrumented valves (tagged as “instruments” in Figure 3) are significant, since they can be more easily damaged compared to hand-wheel valves, thus more frequent inspection should be provided. Figure 3 shows that they constitute 67.28% out of the total number of valves in the case of the Gravity-Based Platform, whereas they are not present in the fixed platform. We also investigate the percentage of large bore objects out of the total number of objects for each type of industrial facility. This indicates that large bore objects represent around 50% on average of all modelled object types considered in this study, so modellers should give equal importance to them.

Modellers use steel sections to represent structural members, hand rails, pipe hangers or supports. Equipment lists of as-designed 3D models are composed of unlabelled or prefabricated objects. Since many objects are prefabricated in engineering skids, like the case of the Tension-Leg Platform, there are more skids than the actual as-designed equipment. Another modelling issue with the equipment list of the fixed platform is that some pipe clamps (hangers and supports) are modelled in the equipment list leading to a higher equipment frequency (6.35%) compared to the other facility types.

We conduct a parametric study to quantify the frequency of appearance of the elements of pipe systems with respect to their OD following a discrete probabilistic approach. We cluster the data in bins of 25 mm (less than 1 inch) to achieve homogeneity for all projects and we calculate the probability density function curves based on these bins. Figure 4 shows the distributions of OD for all object types and four case studies presented above. It should be noted that the frequencies of caps were less than 1.5% for all case studies and inexistent in the fixed platform, thus their OD distribution is not further investigated. The right skewness of data is a trend prevalent in all object types indicating the wider distribution of large bore objects. The information inferred from Figure 4 is that elements with diameters less than 100 mm have higher probabilities of appearance.
and elements with diameters greater than 600 mm are distributed in ranges up to 1050 mm, with probabilities less than 10%.

This finding is in accordance with typical pipe catalogues in the manufacturing industry for both plastic (ASTM D2513 - 16a 2017) and steel pipes (ASTM A53/A53M - 12 2017). Specifically, oil pipelines for Tension-Leg Platforms (TLPs) range in size up to 18 inches (457.2 mm) NB and gas pipelines up to approximately 14 inches (355.6 inches), whereas pipe diameters on fixed platforms range from 4 inches (100 mm) to 36 inches (914.4 mm) NB. It should be noted that NB is less than the OD according to the European set of standards (ISO 6708 1995).

We analyse the distributions of data for piping systems by conducting a statistical analysis. The weighted mean of the distribution of each object type is found as following:

\[
\mu_i = \frac{\sum_{i=1}^{n} c_i d_i}{\sum_{i=1}^{n} c_i}
\]

…where \( n \) is the total number of counts of an \( i \) object type, \( c \) is the number of counts per each \( d \) OD. The weighted variance is also calculated to observe the dispersion of the datasets from the weighted mean. The formula of the weighted variance is as following:

\[
\sigma_i^2 = \frac{1}{n} \sum_{i=1}^{n} c_i d_i^2 - \mu_i^2
\]

…where \( n \) is the total number of counts of an \( i \) object type, \( c \) is the number of counts per each \( d \) OD and \( \mu \) the weighted mean of each object type. These statistical parameters (\( \mu, \sigma, OD \) range) are then compared for all case studies and a \{min, max\} range is given in Figure 4 for all object types and case studies.

The ranges of the statistical properties are similar for all industrial facilities, which clearly indicates a trend of connectivity between all object types of the piping system. Reducers and valves have the largest and smallest mean ranges respectively. The standard deviations of the mean are quite high for all object types, indicating wide dispersion of the data. Meanwhile, the OD ranges are similar for all objects types. Figure 4 also shows the mean probability density curves for all object types along with their 95% confidence intervals. These curves have no significant variations for ODs greater than 600 mm for all object types with probabilities close to zero, so the objects with the most frequent OD ranges are below 600 mm.

CONCLUSIONS

The two main challenges that modellers of industrial facilities face are the plethora of object types and quality of BIM models. Our frequency-based, statistical analysis showed that automated modelling of steel sections and pipes will save around 72% of the time required for manual modelling. These object types should be represented at LoD 300. A parametric study on the OD distribution of piping systems showed that objects with OD greater than 600 mm are not frequent, thus can be semi-automated.

Researchers can automatically model the primary object types that we identified and improve the cost-benefit relationship of as-is modelling. We solve the problem of large number of object types by the statistical analysis presented in this paper. Mapping the most important object types can substantially facilitate automatic detection and classification of the laser scanned objects of a facility, thus reducing modelling time.
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Figure 4: Mean probability density curves with respect to the OD of (a) pipes, (b) bends and elbows, (c) tee and olets, (d) valves, (e) reducers and (f) flanges for all case studies and [min-max] ranges of statistical properties for each object type

The proposed OD ranges will assist modellers to recognize false positives for object types out of the proposed OD ranges, for instance, hand rails or other cylindrical objects that are misclassified as pipes. The analysis provided herein will benefit industrial facility modellers in efficiently producing enriched industrial BIM models. These models will assist inspectors to locate critical objects easily, therefore they will contribute to maintenance, safety and retrofit of these facilities. Reduction of modelling time will significantly benefit the facility managers to obtain 3D BIM models in circumstances of required shut down of the plant. Every modelling hour saved can prevent critical failures or unexpected accidents, thus continuous production flow of these assets is achieved. Future work of this paper is to extend the object type frequencies to floors and walls and investigate objects in the engineering skids as well as structural sections.

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