PERCEPTIONS OF THE VALUE AND VIABILITY OF IMPLEMENTING LEAN CONSTRUCTION WITH BUSINESS INFORMATION MODELLING

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Whilst research has been conducted on the theoretical links between lean construction and building information modelling, very little has focused on the areas of perceived value and on the perceived viability from utilising the methods together. Furthermore there has been little research to date on whether building information modelling implementation is regarded as potentially leading to an increase in the use of lean construction. To address these gaps in the literature data were collected from semi-structured interviews with site-based and office-based practitioners with knowledge and experience of lean construction and building information modelling. Analysis of the data identified three broad themes: 1) the drivers of lean construction and building information modelling; 2) the connections between lean construction and building information modelling; 3) barriers to implementation. In terms of the specific connections between the two methods the issues highlighted were a) the importance of educating the team b) the importance of early involvement of project participants and, finally c) the importance of managing change. Overall a strong potentially symbiotic relationship between building information modelling and lean construction was identified, as both share the same philosophy in terms of collaborative working and enhanced communication. The use of the two methods then was perceived as having the potential to add value in both financial and non-financial terms. However, not all interviewees believed that the increased use of building information modelling, if it materialises, would necessarily drive greater implementation levels of lean construction. Though there were some marked differences between the opinions of site-base versus office-based professionals, with the site-based practitioners being much more sceptical as to the value and viability of using lean construction and building information modelling together than their office-based colleagues.

Keywords: information management, information technology, information systems, modelling.

INTRODUCTION

It has been suggested that lean construction and building information modelling are two methods for improving performance of both individual construction projects and the construction industry in general. They form part of the wider move towards smart construction in an integrated and collaborative environment, which has been identified in the UK Government Construction Strategy 2025 as necessary to enhance performance at the project and industry levels. Furthermore, the UK government have highlighted the importance of successfully implementing these changes in order to

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enable the construction industry to achieve a competitive advantage over other nation's industries. Yet whilst there has been much research on different aspects of lean construction and building information modelling as individual entities there has been relatively little focus on utilising the two methods together. Hence the study focus on exploring in depth with a small group of industry practitioners their attitudes and experiences relating to the value and viability of implementing lean construction and building information modelling in tandem.

Lean construction and building information modelling are both responses to the challenge of achieving performance improvement in the construction environment, although, arguably, they have slightly differing emphases. Building information modelling involves the use of technology as a central tool to improve project delivery (Adriannese *et al*, 2012), whereas lean construction relates more to a change in management style and philosophy in order to achieve improvement. However, there are similarities between the two methods in that both require high levels of collaboration and an integrated project delivery in order to deliver maximum benefit from their utilisation (Cho and Ballard 2011; Ilzor and Kelly 2012). In terms of the outcomes from using lean construction and building information modelling it is suggested that both methods are able to contribute to increased efficiency, reduced costs, improved client satisfaction and ultimately increased profits.

As stated earlier there has been a small amount of work focused on utilising lean construction and building information modelling together, though much of this is conceptual in nature. Breit *et al* (2008) argue that building information modelling can actually be used to support lean construction methods. With the accurate planning tools available within building information modelling facilitating the use of methods associated with lean construction, such as pull-scheduling and Last Planner System®. Davis (2007) highlight that the manufacturing industry have used virtual simulation techniques - akin to building information modelling - to implement lean production, but that this potentially fruitful integration of methods has rarely been recognised nor made in construction. Sacks *et al* (2010) identified a number of areas of common interest between building information modelling functionality and lean principles, and, hence, suggested 55 distinct interactions between building information modelling and lean construction. Furthermore Khanzode *et al* (2006) provided a framework that links virtual design and construction with a lean delivery process. This framework has been further developed i.e. through CIRIA's 2013 *"Guide to Implementation of Lean Construction Principles with Building Information Modelling"*. In addition, The University of Salford have developed a maturity model for the implementation of building information modelling, which was based on eleven criteria points. The model was designed to provide a framework to assist with the implementation of lean construction and building information modelling and to assess a project's level of implementation of the two methods. Finally, given that building information modelling enables greater use of lessons learned taken from one project to the next, as the information is already recorded in a digital format, this can facilitate continuous improvement - a key lean principle. For this and the other reasons outlined above increasing use of building information modelling could potentially be a catalyst for lean construction.

As the implementation of building information modelling can result in waste reduction - one of the key principles of lean construction - it is suggested that building information modelling will naturally result in increased lean processes (Dave *et al* 2013). In this respect Arayici *et al* (2010) found some evidence that when building

information modelling technology was implemented lean process improvements were achieved. Here the role of building information modelling in facilitating easier implementation of lean principles is maximised through encouraging early integration of the project participants, as building information modelling requires such early input from the project team to develop the models (Ilzor and Kelly 2012). Specifically building information modelling implementation can contribute directly to achieving lean goals through such functions as clash detection and improved information exchange (Dave *et al* 2013). Additionally building information modelling could help users visualise the project and gain a better understanding of the project, improving information exchange and assisting collaborative planning - which is a key lean construction tool (Dave *et al* 2013).

In terms of practical applications of lean construction and building information modelling, one of the most notable examples is the Sutter Health Castro Valley project in California, where lean construction and building information modelling were implemented (Sacks *et al* 2010). This was a $320 million state-of-the-art medical centre where the two methods were used together to deliver an accelerated schedule of 30% compared to the expected timeframe and to meet aggressive budget cuts (ibid). Other notable UK projects that have utilised lean construction and building information modelling include Terminal 5 Heathrow airport and road projects by the Highways Agency. These projects, demonstrate the benefits that can be achieved when lean construction and building information modelling are successfully implemented together and how building information modelling facilitates the implementation of lean construction and vice versa (Dave *et al* 2013).

Whilst the UK government are pushing the implementation of building information modelling within the UK construction industry, the implementation of lean principles is not being as overtly promoted in a similar fashion. Nevertheless, if the widespread adoption of building information modelling that is being mandated is actually realised, this could potentially result in greater implementation of lean principles and lean construction. As building information modelling becomes the norm and is implemented to greater levels of maturity it has, arguably, the potential to facilitate the greater adoption of lean methods that have shown to be successful on individual projects (Dave *et al* 2013). Yet, countering this potential is the fact that despite the, albeit limited, focus on the unifying concepts of the two methods and some notable published successful case studies - as outlined above - it has been noted that it is still quite rare for lean construction and building information modelling to be used together effectively (Gerber *et al* 2010).

One reason for this rarity could be the cultural change required to extract maximum value from the two methods and a resistance to the change that adopting them together would require in relation to knowledge, skills, attitudes and behaviours (Brewer and Gajendran 2012). Beck (2011) argues that to change people's core beliefs you have to demonstrate the value of change to help make change the logical choice. Yet whilst some research has been conducted on how building information modelling supports lean, very little has demonstrated the value of using lean construction with building information modelling. One study was undertaken by Gerber *et al* (2010) who analysed three projects that used building information modelling with lean construction, however no comparisons were made between the projects and the research generally focused on the techniques used and some of the specific advantages of using the two methods, rather than on the overall value of using the them together. Hence the research aimed to explore the viability and the value of using lean

construction and building information modelling together. Understanding the value is particularly important as a lack of recognition amongst those working in the construction industry as to the benefits that can be realised has previously been cited as a reason for not using methods such lean construction and building information modelling by a number of authors (Davis 2007; Mossman 2009; Knutt 2010).

RESEARCH METHOD

To achieve the aim stated above, qualitative data were collected from industry practitioners with knowledge and experience of lean construction and building information modelling, through in-depth and semi-structured interviews with seven practitioners. This research approach was chosen as it is appropriate to gain understanding of individual perceptions of a particular topic (Silverman, 2010). In this case the topic is the viability and value of implementing lean construction and building information modelling together. The sampling framework comprised of industry practitioners that were split between office-based staff, such as consultants, with an expertise in building information modelling and lean construction and site-based participants working for main contractors. The reason for ensuring representation from these two broad groups was that as a pilot to the study the researchers had analysed the case of a project that had used building information modelling, in order to gain a deeper appreciation of the practical issues associated with utilising both building information modelling and lean construction to a specific construction scenario. The case involved the design and build of a new school, with a total value of £7.5m, in the UK. The design involved a multi-disciplinary team which included an architect and engineers who all worked with Autodesk Revitt building information modelling software. It was the main contractor's first building information modelling-enabled construction and was promoted as the first fully integrated building information modelling project involving designers, main contractor and supply chain partners. During the course of analysing the case it became transparent to the researchers that there were specific difficulties in integrating building information modelling on site - hence the decision to include both groups in the schedule of interviews. The small sample of interviewees reflected the difficulties in finding people with the requisite knowledge and experience of the two methods and the resources required in undertaking the data collection. The sample was obtained through the researchers utilising their own networks of contacts with industry professionals and, whilst small in number, was deemed as satisfactory given the exploratory nature of the research.

Table 1: Practitioners knowledge, experience and work-base

Interviewee	Years Experience	Base	Building Information Modelling Knowledge/Experience	Lean Construction Knowledge/Experience
1	8	Office	4	5
2	30	Office	5	3
3	7	Office	3	4
4	33	Site	2	1
5	16	Office	5	4
6	14	Site	4	1
7	10	Site	4	1

Key: knowledge/experience 1 -lowest 5-highest

The specific knowledge and experience and whether site or office-based of those interviewed is shown in table 1 above. Participants rated their own knowledge and experience on a scale of 1 - 5. The questions were structured into three areas: how lean construction is implemented? How business information modelling is implemented? How can the two methods be implemented together? What is the value of undertaking such integrated implementation?

Thematic analysis was used to identify themes through coding (Braun and Clark 2006). In this manner themes were drawn amongst all the respondents and areas of commonality and differences were identified. This coding hierarchy helped further develop potential themes within the data and facilitated the analysis of the frequency and coverage of each initial code. This demonstrated not only how many times each code was mentioned but also in how much detail participants discussed each code therefore suggesting the importance they placed on that topic.

FINDINGS AND DISCUSSION

The high-level themes that emerged where as follows: 1) the drivers of lean construction and building information modelling 2) connections between lean construction and building information modelling 3) barriers to implementation. Within the theme of *"connections between lean construction and building information modelling"* 3 second-level themes were identified: a) Educating the team b) The importance of early involvement c) Managing change. The next section discusses of these themes in turn and finishes with observations on different perspectives between the site and office-based interviewees.

The drivers of lean construction and building information modelling

The first driver identified by some interviewees was the need to remain competitive within the industry, with failure to do so resulting in missed opportunities and ultimately business failure - especially with the UK Government building information modelling mandate coming into effect in 2016. Rather than government pressure mandating building information modelling, in the case of lean construction interviewees suggested that the current market conditions is forcing increased use of lean principles as people try to implement more efficient methods of working to be able to meet the increasingly reduced programmes and budgets. The interviewees suggested that people were increasingly turning to lean methods to be able to operate successfully and deliver client demands.

So, the increased use of lean due to market demands and the increased use of building information modelling due to government pressure should theoretically result in the increased combined use of both methods. However, one interviewee suggested that whilst the use of lean construction and building information modelling will increase they believed that rather than using the methods in their entirety certain aspects of each will be utilised for each individual project, partly due to the barriers to full implementation (see later section). Such approaches could prevent the maximum benefits of utilising the two methods together being realised and in the worst case scenario could result in their being adopted as part of a tick-box exercise rather than as a way of adding meaningful value to a construction project.

Connections between lean construction and building information modelling

All of the interviewees made the connection between the two methods, with the greatest focus of connectivity revolving around both methods being able to improve efficiency and collaboration. Building information modelling is perceived as driving

collaboration and it was recognised that lean construction work best when in a collaborative environment, so it was proposed that a greater use of building information modelling will create an environment that facilitates greater use of lean principles. Furthermore, the interviewees saw an emphasis of building information modelling on improving efficiency - a key lean principle; and the ability to more easily facilitate continuous improvement, due to the improved information management and reporting available within building information modelling - another key lean principle. Therefore, this would suggest that as the use of building information modelling increases the use of lean principles will be able to increase and there exists great potential in the future to implement lean construction and building information modelling together.

However this theoretical development of building information modelling followed by lean construction was met with mixed reactions. Three out of the 7 interviewees opined that increasing use of building information modelling won't necessarily lead to increased use of lean construction. This could be attributed to the understanding of lean construction principles as some participants may focus only on lean construction tools and techniques, such as pre-fabrication or collaborative planning and feel that building information modelling use will not have an impact on these activities. Countering this it could be argued that building information modelling could even help increase the use of these methods as well. It was also suggested by some that the use of lean construction with building information modelling will very much depend on the nature of the project, with a belief amongst some that it would only be suitable for larger project. As stated by Interviewee 4: *" lean construction and building information modelling should go hand-in-hand on large projects as there are benefits of both and they both, as far as I'm concerned, tie in to try and achieve the same goal"*

Educating the team

Throughout all of the interviews it was clear that great importance was attached to not only using lean construction and/or building information modelling but also using them effectively and the corresponding difficulties in doing this. From the interviewees' responses this required having the right people and processes in place to effectively implement new methods. This highlights the importance of training the team to ensure maximum benefit; although this is something that the construction industry is notoriously bad at doing. Furthermore, this training of personnel should not just relate to the site team but also to the sub-contractors, as it is they who carry out the work and therefore it is vitally important that they are proficient in the methods used. This was raised particularly in relation to building information modelling where it is very important to have sub-contractor involvement. It was perceived that currently, other than the heavy design-oriented sub-contractors like M&E and steelworks, very few sub-contractors are building information modelling-proficient and this deficiency can only harm the effective implementation of building information modelling and lean construction. Therefore, the interviewees suggested that we need to educate the supply chain and take them on the journey towards full building information modelling implementation with the main contractor, in order to ensure maximum benefit. While some of the site-based interviewees argued that this would only go so far, the office-based participants suggested that this could go all the way through to the sub-contractors and then everyone should at least have an understanding of the fundamentals of building information modelling. This would facilitate a more integrated project and enable lean construction. This need to educate project participants doesn't just relate to the supply chain but also to clients. The

interviewees suggested that it is important for clients to fully understand the impact and potential of building information modelling and lean construction to be able to make a more informed decision on whether to require or support implement of the two methods.

The importance of early involvement
The importance of implementing building information modelling and lean construction from the start of a project was highlighted, with some interviewees suggesting that there is a tendency to bring lean in later in a project to try and fire-fight and get the project back on track. This point was reflected in the comments of Interviewee 2: *"To get anything to be successful it's got to be from day one and has to have the full involvement from everybody."* Interview 6

Managing change
The interviewees highlighted the importance of managing change effectively to facilitate a harmonious environment in which to implement methods. This ensures that the people tasked with implementing the methods will drive implementation. However, the participants suggested that this no easy task, as there can be resistance to change within the industry as people oppose new ideas and new methods. In the words of Interviewee 2: *"It's hard to change as no one likes a change but you have to change to move forward."* For projects and the construction industry as a whole to benefit from lean construction and building information modelling this resistance needs to be overcome through effective change management and by ensuring the people are adequately trained and appropriate processes are in place.

Barriers to implementation

The majority of the issues that were raised as barriers to implementation were consistent with those identified in the prior literature - as highlighted by Bernstein and Pittman (2005) and Yan and Damian (2008). Cultural issues within the construction industry were raised as a major barrier. Other key barriers that were raised were poor understanding of lean construction and building information modelling and a feeling that lean construction and building information modelling may not be suitable to a particular project context. Despite the fact that UK Government reports and existing literature on the topics suggest that lean construction and building information modelling are suitable for the majority of projects there was a widespread perception the methods would not be appropriate for anything other than large projects; with the belief that clients would be unwilling to pay for their use on the smaller jobs. The poor understanding of the two methods can be mitigated through education and training - as discussed above. This comes back to the need to educate clients to allow them to make the most informed choice on what they choose to implement. It was also suggested that some types of contract may not be as suitable for the implementation of lean construction and building information modelling. Interviewees believed that the more collaborative forms of contract would be more suitable, with the opinion being that only when the more collaborative contracts are common place will there be a suitable environment to implement lean construction and building information modelling.

The final barrier was the perceived high cost of implementing building information modelling or lean construction. This was particularly the case in relation to building information modelling. The interviewees suggested that the initial start-up costs of licenses, software and training can provide a significant barrier to implementation building information modelling. Particularly for SMEs as they may struggle to absorb these set-up costs. However it was recognised that these initial costs can be more than

recovered through future savings: *"There is always a learning curve with building information modelling but then after a while you will start using it all the time and it will become second nature and you will get fewer issues and more benefits"* (Interviewee 1).

Differing views of site-based and office-based professionals

The majority of the issues and potential barriers with lean construction and building information modelling were raised by the participants that were site-based rather than those office-based. One interpretation is the office-based practitioners view these two methods through rose tinted spectacles. As such they see the positives yet fail to recognise the potential issues and potentially negative impact of implementation. Furthermore, it could be argued that the site-based individuals have a better understanding of the true impact of implementing these methods on a construction project as they see how different methods impact on site. However, another interpretation is that the differences are indicative of the general resistance to change that exists amongst site-based practitioners and the need for effective change management in order to break down such resistance and to create a suitable environment for the effective implementation of lean construction and building information modelling.

CONCLUSIONS

The interviews highlighted the benefits of using lean construction and building information modelling, both individually but more usefully in combination. However whilst the interviewees highlighted the need to implement lean construction and building information modelling as government pressure and market conditions are dictating it, they did suggest that there are significant barriers to effective implementation of both methods. The interviews revealed the need to have the right processes and the right people in place for lean construction and building information modelling to be implemented effectively and the importance of managing the change effectively to ensure the methods are championed rather than resisted. Furthermore, the need to educate the supply chain and clients to provide a suitable environment in which lean construction and building information modelling can be utilised is necessary. All of the participants did make the correlation between lean construction and building information modelling. However only 4 of the interviewees suggested that they see building information modelling as a catalyst to increased use of lean construction. It could be argued that currently not enough practical research has been completed to push this correlation to the forefront of people's thinking and some of the more negative viewpoints towards the use of lean construction results in people resisting its implementation. As was mentioned in the interviews only when people fully realise the benefits will they be receptive towards these new methods of working.

In terms of value the interviewees noted the ability of lean construction and building information modelling to reduce programme durations, make projects more efficient and, therefore, achieve cost savings. Furthermore, for the cost savings to be realised the barriers to effective implementation have to be overcome to provide a suitable environment within which the potential cost savings can be realised. If this environment is created then the two methods could potentially be implemented together effectively and help deliver cost savings. Furthermore, as the government mandate dictates the use of building information modelling on public projects this has the potential to lead to increased use of building information modelling within the industry and potentially increased use of lean construction. Then over time, as the

methods become common practice, it will reduce the barriers and help increase the potential benefits.

While lean construction and building information modelling have the potential to be beneficial for construction projects individually and the wider industry, currently there is not always a suitable environment for participants to extract maximum benefit from implementing the methods. This has resulted in them often being implemented as an add-on or extra rather than an intrinsic part of the project from the start. It is important that the industry realises the importance of implementing them in an environment that is conducive to which the potential benefits will be realised. Furthermore, this tendency to implement lean construction and building information modelling as an extra has resulted in some construction professionals not fully understanding the potential benefits and instead viewing them as more of an inconvenience and an unnecessary cost. This has resulted in a resistance to change that needs to be overcome to achieve effective use of lean construction and building information modelling. While there are other barriers to successfully utilising the two methods through time and increased use these should be overcome.

However the cultural issues that affect the industry and restrict a collaborative environment could prove more difficult to mitigate for. Yet if these issues are not overcome the UK construction industry risks falling behind other nations that could utilise them more effectively in the future. This could have a detrimental effect not only our construction skills exports but also on the national market as more contracts may go to more efficient foreign contractors. To help overcome the issues discussed it would be beneficial for an in-depth case study to be completed on a project that implements building information modelling to at least Level 2 and expressly uses lean construction methods, such as LPS® and lean principles. The key would be that the methods are utilised from project inception, rather than using building information modelling for the design-related activities and lean construction later on in the construction phase.

Such research would uncover some of the practical implications of implementing lean construction with building information modelling and therefore provide the demonstrable evidence to industry professionals and clients as to the benefits of combining lean construction and building information modelling. This is particularly important in relation to clients as it is likely that many clients will only proceed with something that they can clearly see the benefits for. Furthermore, many of the innovations within the industry, of which lean construction and building information modelling are just two examples, need to client-led, as well as being supported by companies in the supply chain. The involvement of the clients is seen to be necessary by contractors, as they suggest that lean construction lean construction and building information modelling need to be client-driven to ensure that the methods are desired on the project and so will then get the full backing from the project team.

In practice it is difficult for trends to be accurately evaluated. Whilst implementation of building information modelling in particular has been quite fast moving it is still in its infancy. Therefore it would be beneficial to complete an evaluation of the extent to which building information modelling can act as a catalyst for lean construction through longitudinal studies over a period of years. It would be particularly useful if this were to be done after 2016 once the UK Government building information modelling mandate had come into effect as building information modelling should be

becoming more common practice at this stage. Hence it would also highlight the effect this mandate has on the use of lean construction.

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