

DEVELOPING A CONCEPTUAL LEAN BRIEFING PROCESS MODEL FOR LEAN DESIGN MANAGEMENT

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ABSTRACT:

Although the concept of lean design management in Architecture, Engineering and Construction (AEC) is still evolving and open to debate, it has helped to emphasise the importance of value and waste to the design team. An essential element of lean design management is briefing. Briefing is the process by which clients express and articulate their desires, and from which the design team develop their design. From a design management perspective briefing is a crucial stage in which values are explored and value expressed; and a process that could be better managed to help eliminate uncertainty and waste in the design and construction phases. A comprehensive literature review found that, aspects of process waste relating to ineffective briefing appear to have been neglected to date, which stimulated the idea of rethinking the briefing process to address waste at its origin. The research exposed limitations with current approaches to briefing and identified the potential for change. Applying lean thinking to the briefing process, with emphasis on value and flow, appears to provide an alternative approach to the traditional methods. A conceptual lean briefing process model is introduced by the authors, using lean management principles to achieve best value from the briefing process. This work reports the outcome of the first phase of the on-going research that aims to investigate and analyse the application of lean management principles in the briefing process for lean design management implementation; and to explore its validity within Architecture, Engineering, and Construction (AEC) projects' by looking at the theory and the application of lean design management. It is hoped that, this study followed by the outcome of the on-going research will contribute to the theoretical understanding and practical implementation of lean design management in AEC.

KEYWORDS:

Briefing; information flow; lean design management; design process waste; value stream

INTRODUCTION:

The early stages of a project life-cycle in a construction project consist of briefing and design; delays in many construction projects have been linked to deficiencies in these

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two stages. Lack in identifying client requirements, ineffective information flow, communication and decision making in the design phase are the causes of many problems that then have to be tackled later in the construction phase (Green, 1996; Barrett and Stanley, 1999). Project management deficiencies have also been shown to have a negative impact on the efficiency of the construction process in terms of the waste generated and contract variations occurring during construction while the success of a project and the value realised are highly dependent on the decisions made during the very earliest stages of a project's development (Tilley, 2005). Egan (1998) emphasised that a great deal of time and effort is spent on site in trying to make designs work. Yet, in many cases, insufficient value has been delivered to the client (Koskela et al., 1997; Emmitt et al., 2004). Despite this, much research effort has been, and continues to be, expended on the construction and design phases, with initiatives such as lean construction trying to deal with such challenges (Koskela et al., 1997; Ballard and Howell, 2003; Ballard and Reiser, 2004; Lichtig, 2005; Macomber et al., 2005; Mossman, 2009; Sacks et al., 2010; Arayici et al., 2011; Zimina et al., 2012; Lee et al., 2012). Recent research has highlighted the importance of the early design phases in helping to reduce uncertainty, improve quality, and consequently the overall performance of construction projects. Thus, the importance of managing this stage effectively and efficiently has been made clear (Latham, 1994; Green, 1996; Tilley, 2005).

Ensuring the requirements are clearly identified and information is well managed through design process leads to a significant improvement in the decision making; with the result that, better project quality, better client relations, and savings in terms of both time and cost. This research explores the potential use of lean management principles to improve the briefing process.

BRIEFING

Client needs and requirements play a vital role in decision making since they are the basis upon which clients judge their satisfaction with project outcomes. In order to ensure that client needs are met and satisfied, it is important that they are understood at the very early stages and always referred to in the project development process. It represents a cornerstone for achieving client satisfaction (Othman, 2005). There have been calls on the UK construction industry to apply more effort and resources to the definition and articulation of project requirements, and to the understanding of the client's needs thereby realising maximum value for all clients (end-users and stakeholders) (Latham, 1994; Egan, 1998).

In the UK, client's needs and requirements are normally presented in the first stage of the architectural design process in the form of a strategic brief (or client brief). The brief is a document produced as an output to the briefing process which plays a vital role in the presenting and communicating client requirements to the design and construction teams. Kelly (2002) define the brief as "the first tangible step in any facility's life-cycle. It is one of the most important because it sets the agenda for the remainder of the facility's life-cycle from inception through to completion and use/operation even perhaps its disposal". However, according to BS 7832: 1995 the brief is "a working document which specifies at any point in time: the relevant needs and aims; resources of the client and user; the context of

the project; and any appropriate design requirements within which subsequent briefing (when needed) and designing can take place”.

Briefing plays a vital role in presenting and communicating client requirements to the design team. It is the process by which a client informs others of his or her needs, aspirations and desires, either formally or informally; it sets out a client's requirements in detail (Barrett and Stanley, 1999) and constitutes the formal communication technique in the construction business. Pena and Parshall (2001) stated that “construction briefing is a process leading to the statement of an architectural problem and the requirements to be met in offering a solution”. Blyth and Worthington (2010) defined it as “the process by which options are reviewed and requirements articulated with the brief as the product of that process”. They further distinguished construction briefing as an evolving process of understanding an organisation's needs and resources and matching these to its objective and its mission. However, there are two schools of thought about briefing process mechanism practices in the construction industry. The first school believes that, the brief should be static where client requirement and all other relevant information about the project to be established, collected, identified, agreed, fixed and eventually delivered in a form of briefing document before the design develop (RIBA, 2013). The other school sees the brief as a dynamic process an on-going activity starts on the project inception develops through the design stage and eventually need to be finish before construction stage (Salisbury, 1998; Blyth and Worthington, 2010). To our knowledge, a “lean” approach to briefing has not developed in AEC.

LEAN DESIGN MANAGEMENT

According to the Design Management Institute (DMI, 2012) “Design management encompasses the on-going processes, business decisions, and strategies that enable innovation and create effectively-designed products, services, communications, environments, and brands that enhance our quality of life and provide organizational success”. Design management simply manages the design resources required for delivering the design as a product (noun) throughout project stages (Emmitt, 2007). Effective design management leads to better building design development, and timely better decision making.

The design management process is a chain of activity but there is a need to allow ‘loops’ within the process to allow for the review and evaluation of different proposals and alternatives. The reality of project timeframes requires that a design should be developed through three key elements: imagining, presenting and testing (Koskela et al., 1997). However, Freire and Alarcón (2002) claimed that, design process in construction should be considered as a flow and value model rather than a conversion model in order to achieve more efficient and better quality outcomes. Research has indicated that material and information flows, and the generation of good value for the customers and end users, as well as transformations of inputs to outputs, may be achieved effectively using a lean design management approach (Tilley, 2005; Tribelsky and Sacks, 2011). However, the complexity of the relationship between the fundamental principles of project management and the transformation model/theory of production often work as obstacles, which hinder the process of finding effective solutions to management of the design process; this can result in poor levels of performance (Tilley, 2005; Jørgensen and Emmitt, 2009).

Improving the integration of design and construction has been identified as a key to the successful outcome and performance of a project as design cannot be considered separately from the construction process (Ballard and Howell, 2003; Jørgensen and Emmitt, 2009).

To date a few efforts have been directed towards lean design management implementation such as, target value design, set based design and building information modelling (BIM). Target value design (TVD) was adopted by Sutter Health System as a contribution to lean project delivery (Ballard and Reiser, 2004; Lichtig, 2005; Macomber et al., 2005). It takes the concept and the best features of target costing in manufacturing by making use of a lean management philosophy to develop the best possible design that can be constructed for the target cost, and realise client value in terms of time and cost. Zimina et al. (2012) has implemented this approach and developed a target value design process that reveals the features of design to target costing practice. Jacomit and Granja, (2011) claimed that the design to target cost approach was directed at reducing the maintenance and operational costs, whereas the target costing approach was to produce profit that is, considering all costs and revenues that occurs during manufacturing life cycle only. This difference in the concept leads to contextual differences. However, generally as cost becomes a creation in target value design, so the quality and function will be significant challenged. More recently Lee et al. (2012) used Toyota's concept of set-based design, which relies on the best design solution as a mix of the original design options. Lee et al. (2012) has proposed a set-based design (SBD) approach to structural building information modelling (S-BIM) to increase the efficiency of the selection of the optimal solution. However, the challenge of set-based design is to identify the last responsible moment for deciding on a solution. This may result in process waste because of the extra time and effort required to develop and review all of the available options. There are also some trials that have applied BIM (the most recent mature intelligent technological aspect of design) in lean project delivery. These trials have helped to set up some basic ideas regarding the interface between them and the use of BIM as a lean enabler (Sacks et al., 2010; Arayici et al., 2011).

El. Reifi and Emmitt (2013) found significant shortcomings in application of design management. Based on an extensive questionnaire survey they found that the development of design value is most hindered by the briefing process. Generally their finding revealed that there is a fundamental problem in current practices which makes it inadequate for effective communication and therefore not serving its purpose. The findings supported earlier work that inefficiency in the current briefing process and document content are well known (Green, 1996; Barrett and Stanley, 1999; Yu et al, 2007).

The iterative nature of the design process and the usually large number of changes during the process increase the complexity of the problems in briefing theories. Design is by nature an iterative process and the proposed solutions often also cause evolution in the client requirements such as exploiting new business opportunities and installing improved technological systems not available during the brief and design stages. Furthermore, the project team has to make rapid decisions on how to solve a specific issue, and it is often difficult to identify all interdependencies. Thus, a solution which meets one requirement can have a significant negative effect on another crucial requirement. Boyd and Chinyio (2006) argue that since projects take

extended periods of time, personnel and stakeholders can change thus the content within the brief will continually be challenged to meet the needs of the new project members. There is, usually, a need to leave some issues to be solved further down the line as people become involved who are more aware of the problem and hence better positioned to come up with an appropriate solution. Restructuring and development of current briefing practices are essential to better capture client requirements at the right time and bridging the communication gap between clients and the design and construction team. Summed up nicely by Ries (2012) who stated that “we must learn what customers really want, not what they say they want or what we think they should want”.

Tribelsky and Sacks (2011) posit that design managers can reduce waste and improve value by paying attention to the characteristic of information flow and sharing of information (using lean principles). Stable design information flow, with small batches, frequent transactions and lower occurrence of flow interruption may lead to higher quality design documents. Emmitt (2007) highlighted the importance of mapping and understanding the information flows within the design management process, and understanding the waste associated within this context. According to Tribelsky and Sacks (2011) information is the designer’s raw material and unpredictable project outcomes are due to unstable information flow. Inefficient flow of information results in some forms of waste, such as waiting (for information) and rework (as information becomes available).

In general the main approach of any lean design management strategy should be to maximise the overall value from the project for clients, end-users, and for society as whole (Pasquire and Garrido, 2011); while maintaining a high level of performance from the design process by designing communication structures throughout the design development process. Briefing is an essential element in helping to explain and understand values, and agree the value parameters for a project. A few lean design management publications focus on eliminating one, or a combination, of the seven wastes. But it is striking to note what little attention has been given to variation and its origin. Hence, the importance of this research which is trying to address the problem at the source.

LEAN BRIEFING START UP

The best way to understand waste is to explore the ways in which the process and people interact, and discover how and why people adopt or work around the process (Terry and Smith, 2011). Waste elimination requires a deep understanding of the system of value creation and measurement of those against the definition of value and waste. It is important to ask the following before any lean start up (Terry and Smith, 2011):

- Is the process (value stream) producing the desired value?
- If not why is the value stream not producing value, which specific process requires fixing?
- What is about that specific process or task that needs changing?

From the research conducted by El. Reifi and Emmitt (2013) and from a lean perspective it appears that a large chunk of waste in the design management process

comes from inefficiency in briefing practice and whether this should be fixed or dynamic through the design and construction process. This waste contributes, directly or indirectly, to the waste experienced in both the design and construction phases, as well as post occupancy. Barrett and Stanley (1999) observed that briefing in the UK is done in a lot of different ways dependent on the experience of the individual professional. Ries (2012) stated that "Information is the designers' raw material what is missing is the process that controls the raw material into a real world".

Briefing is the first stage in the project by which other project stages are derived. So far, there were some trial for improving construction briefing these include; checklists & standard methodology (e.g. BS7832:1995/ ISO 9699:1994, Salisbury, 1998); engaging the client and stakeholders (e.g. Barrett & Stanley, 1999; Pena & Parshall, 2001); the application of automation and IT support tools (e.g. Kamara and Anumba, 1999; Bouchlaghem et al., 2000); dynamic briefing ideology (e.g. Blyth & Worthington, 2010); value management methodology, facilities management and risk management approaches (e.g. Kelly et al., 2005; Othman, 2005); and quality functional deployment (QFD) and the house of quality (HoQ) (Kamara et al., 2002). However, despite all this, the briefing process generally remains problematic, and has continued to present challenges to the construction delivery process. There is no formal education of professionals in briefing, and there are no general accepted procedures to carry out the process. Rethinking in the briefing process and how to develop another approach that can combine both views (fixed and dynamic), in addition to any other effectiveness features that need to be in the process (e.g. a continuous communication, stable information flow, and coordination) in a way that helps decision making at the right time is essential.

Reviewing lean management theory and its success in enhancing the efficiency of value delivery process's led to the hypothesis that the briefing process can be truly value-adding by applying lean management theory. The literature review has helped to establish the basis of a conceptual model (Figure 1), and some preliminary ideas that need to be reflected in the planning, processing, and designing of a lean briefing process model.

The idea behind lean briefing is to design communication structures where effective flow and coordination of information provides the basis for better decision making and therefore the development of "design for production" solutions that meet project value. This is highly reliant on the ability of those charged with managing the process. According to the proposed RIBA outline plan of work (2013) brief is developed between Stage 1 (Preparation) and Stage 2 (Concept Design) and should not be altered after this point (Final project brief). Generally the development of the brief through stages 1 to 2 is divided into two major stages initial brief and project brief. Initial brief is when project objectives, the client's business case, sustainability aspiration, and other parameters or constrains are identified. Project brief is when the initial brief is developed into a detailed project brief from which design can develop. However, the two main objects of lean briefing process are: first, having a clear initial brief to give a project a strong start; and, secondly, organising project brief in phases, in line with the development of the design from inception all the way through construction.

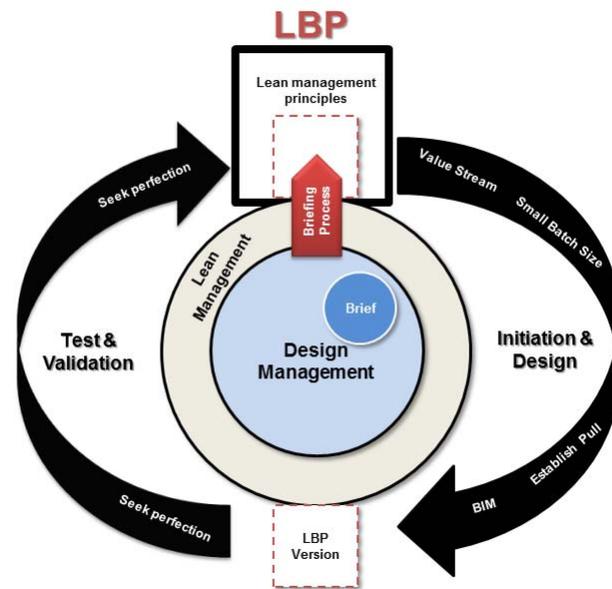


Figure 1: The Conceptual Lean Briefing Process Model (LBP)

Yu et al., 2007 stated that: “Briefing is an iterative, creative process, a journey to support the client, design and construction teams in achieving the user’s expectations”. Clients actually need the architect’s sketches and drawings and some time the real space to find out what their accommodation needs really are. The new lean system must help both client and the design team comfortably make the right decision by providing the necessary basis and required details for that and considering the integration nature of design and construction in construction. It has to be in a way which truly help client articulate their conscious and hidden in consistent and repeatable ways that built shared understanding of what value was and how it was to be delivered. Thus, there clearly should be space for limited flexibility that enhances project value over time as making processes too flexible can cause problems. Hansen and Olsson, (2011) stated that, “The approach of do it right the first time, which an important slogan in production, should be applied with caution in design, as design freeze may be postponed until the last responsible moment”. To enable effective flexibility, a concept with layered decisions to be introduced to the decision making process where decision should not be made until it has to be made (Hansen and Olsson, 2011). However, the system cannot be fully effective without the aid of communication tools such as face-to-face meetings and visualisation technique’s; these play an important role in establishing effective communication. It allows discussion that might offer access to other ideas that did not exist at the start of the process and which were, at this point, unknown to both the design team and the client. So, virtual design technologies such as (BIM) need to be built in the process and may be works as enabler of lean briefing.

The briefing process needs to be aligned to design stage gateways. Which are then signed-off. The outcome at each briefing process stage needs to be relevant to the information required. This can be achieved via regular input throughout the design development process to ensure that the brief is kept up to date. Furthermore, reporting at the end of each stage, filling gaps with missing information, and establishing 'design cut-off gateway'; as a way of measuring and managing any changes; are

essential. So, the key is to freeze information at the right time when the right information is available. The six additional principles of what they call lean consumption that was set out by Womack and Jones and correspond closely with those of lean production can be considered for achieving that.

A step by step and continuous improvement concept, grounded in lean thinking, will be the main concept of developing the conceptual model. There are some other issues that need to be considered in planning lean briefing. This includes; the project context, the procurement method, and details of who manages and controls a lean briefing process. However, this is an initial concept and it needs further development through shared understanding. The next step in this research is to conduct a series of interviews with industry practitioners to better understand the challenges and opportunities related to current and future briefing practices.

CONCLUSION

Effective briefing is essential as it will help in getting requirements right as early as possible which in turn can result in a significant improvement in product quality, better client relations, and savings in time and budget. Briefing initiates the design and controls it throughout the project process and by which communication between project parties is maintained. It is the process by which the most project value is delivered. However, inefficiency in briefing process does exist and it seems the conflict against its process (static or dynamic) form large part of this inefficiency.

Most approaches and research that have been done previously regarding briefing have treated changes in client requirement as a fact and focus on how better to manage these changes and mitigating risk of its result, and/or for a specific client through introducing and employment of different tools to the briefing processes. None of them try to deal with the origin of the problem and why it occurs, which is the heart of this research. Clients are directed to make some assumptions early on and therefore designs are worked out based on soft assumptions that are liable to change. Designers allow space for changes and then try to employ a way to mitigate it. Arguably, this is not the most efficient approach. There is a need to employ a system that helps the client comfortably make the right decision by providing the necessary basis and required details for that; rather than pushing the client to make inappropriate decisions that are almost certain to change over time. A process where steps are taken efficiently, and by which just the right amount of value of each step is delivered, which in turn contributes to achieving the overall project value.

Reviewing lean design implementation has helped to establish that lean design management is still under debate in terms of what is it, and how best to do it. It has helped to reinforce the initial hypothesis that lean briefing is an essential element of lean design management implementation. This has been taken further and has shaped the on-going research that aims to develop a Lean Briefing Process model (LBP) for effective design management. Essentially a process by which a client may articulate their conscious and hidden values in consistent and repeatable ways that build shared understanding of value; and how it needs to be delivered through design development.

It is hoped that, this study followed by the outcome of the on-going research will contribute to lean design management interpretation and implementation, and consequently contribute to greater project management efficiency in AEC.

REFERENCES

- Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C. and O'Reilly, K., 2011, 'Technology adoption in the BIM implementation for lean architectural practice', *Automation in Construction*, vol.20, p.189-195.
- Ballard, G. and Reiser, P. 2004, 'The St Olaf fieldhouse project: A case study in designing to target cost', *Proceedings IGLC-12*, Elsinore, Denmark.
- Ballard, G. and Howell, G., 2003, 'Lean project management', *Building Research & Information*, vol.31 no.2, p.119–133.
- Barrett, P. and Stanley, C., 1999, *Better Construction Briefing*, Blackwell Science, Oxford.
- Blyth, A. and Worthington, J., 2010, *Managing the Brief for Better Design*, 2nd edition, Taylor & Francis Group, London.
- Bouchlaghem, D., Rezgui, Y., Hassanen, M., Cooper, G., and Rose, D., 2000 'IT Tools and Support for Improved Briefing', CIB, W078, International conference: Construction Information Technology- Taking the construction Industry into the 21st century, 28-30 June 2000, Reykjavik-Iceland.
- Boyd, D. and Chinyio, E., 2006, *Understanding the Construction Client*, Blackwell, Oxford.
- BS 7832/ISO 9699:1994, 1995, 'performance standards in building- checklist for briefing- contents of brief for building design', BSI.
- DMI, 2013, 'What is design management?', Available online from http://www.dmi.org/dmi/html/aboutdmi/design_management.htm, Accessed 31/05/2013.
- Egan, J., 1998, *Rethinking construction: Report of the construction task force on the scope for improving quality and efficiency in UK construction*, HMSO, London.
- El.Reifi, M. H. and Emmitt, S., 2013, 'Perception of lean design management', *Architectural Engineering and Design Management Journal*, vol.9.
- Emmitt, S., Sander, D. and Kirk Christoffersen, A., 2004, 'Implementing value through lean design management', *Proceedings IGLC-12*, Elsinore, Denmark.
- Emmitt, S., 2007, *Design Management for Architects*, Blackwell Publishing, Oxford.
- Freire, J. and Alarcón, L., 2002, 'Achieving lean design process: Improvement methodology', *Journal of Construction Engineering and Management*, vol.128 no.3, p.248-256.
- Green, S., 1996, 'A metaphorical analysis of client organizations and the briefing process', *Construction Management and Economics*, vol.14 no.2, p.155 – 164.
- Hansen, K and Olsson, N. O. E., 2011, 'Layered project- layered process: Lean thinking and flexible solutions', *Architectural Engineering and Design Management Journal- special edition*, vol.7 no.2, p.70-84.
- Jacomit, A. M., and Granja, A. D., 2011, 'An investigation into the adoption of target costing on Brazilian public social housing projects', *Architectural Engineering and Design Management Journal- special edition*, vol.7 no.2, p.113-127.
- Jørgensen, B. and Emmitt, S., 2009, 'Investigating the integration of design and construction from a "Lean" perspective', *Construction Innovation*, vol.9 no.2, p.225-240.
- Kamara, J. and Anumba, C., 1999, 'Client Requirements Processing in Construction: A New Approach Using QFDa', *Journal of Architectural*, vol.5, p.8-15.

- Kamara, J., Anumba, C. and Evbuomwan, N., 2002, *Capturing Client Requirements in Construction Projects*, Thomas Telford, London.
- Kelly, J., 2002, *Best Value in Construction*, Blackwell Publishing Ltd, Oxford.
- Kelly, J., Hunter, K., Shen, G. and Yu, A., 2005, 'Briefing from a facilities management perspective'. *Facilities*, vol.7 no.8, p.356-367.
- Koskela, L., Ballard, G. and Tanhuanpää, V., 1997, 'Towards lean design management', *Proceedings IGLC-5*, Australia.
- Latham, M., 1994, *Constructing the Team*, HMSO, London
- Lee, S., Bae, J., and Cho, Y. S., 2012, 'Efficiency analysis of set-based design with structural building information modelling (S-BIM) on high-rise building structure', *Automation in Construction*, Elsevier, vol.23, p.20-32.
- Lichtig, W. A., 2005, 'Sutter health: Developing a contacting model to support lean project delivery', *Lean Construction Journal*, vol.2 no.1, p.105-112.
- Macomber, H., Howell, G. and Barberio, J., 2005, 'Target value design: seven foundational practices for delivering surprising client value', *Lean Project Consulting*, p.1-3.
- Mossman, A., 2009, 'Creating value: a sufficient way to eliminate waste in lean design and lean production', *Lean Construction Journal*, p.13 – 23.
- Othman, A. A., 2005, 'Value and risk management for dynamic brief development in construction', *Emirates Journal for Engineering Research*, vol.10 no.2, p.23-36.
- Pasquire, C., and Garrido, J. S., 2011, 'Introducing the concept of first and last value to aid lean design: learning from social housing projects in Chile', *Architectural Engineering and Design Management - special edition*, vol.7 no.2, p.128-138.
- Pena, W. M. and Parshall, S. A., 2001, *Problem Seeking: An Architectural Programming Primer*, John Wiley and Sons, New York.
- Ries, E., 2012, *The lean start up: How constant innovation created radically successful business*, Pearson, London.
- Royal Institute of British Architects, 2013, *Proposed Outline Plan of Work*, RIBA
- Sacks, R., Koskela, L., Dave, B. A. and Owen, R., 2010, 'Interaction of lean and building information modelling in construction', *Journal of Construction Engineering and Management*, p.968-980.
- Salisbury, F., 1998, *Briefing your Architect*, Architectural press, Oxford.
- Terry, Y. and Smith, S., 2011, *Build lean: Transforming construction using lean thinking*, CIRIA, London.
- Tilley, P., 2005, 'Lean design management—A new paradigm for managing the design and documentation process to improve quality', *Proceedings IGLC-13*, Sydney.
- Tribelsky, E., and Sacks, R., 2011, 'An empirical study of information flows in multidisciplinary civil engineering design team using lean measures', *Architectural Engineering and Design Management - special edition*, vol.7 no.2, p.85-101.
- Yu, A., Shen, Q., Kelly, J. and Hunter, K., 2007, 'An empirical study of the variables affecting construction project briefing/architectural programming', *International Journal of Project Management*, vol. 25, p.198–212.
- Zimina, D., Ballard, G. and Pasquire, C., 2012, 'target value design: using collaboration and a lean approach to reduce construction cost', *Construction Management and Economics*, vol.30, p.393-398.