THE CHALLENGES OF STANDARDIZATION OF PRODUCTS AND PROCESSES IN CONSTRUCTION

Aki Aapaoja[1] and Harri Haapasalo[2]

ABSTRACT

Construction has been blamed for its low performance and productivity, and high amount of waste, for years, especially when compared with the manufacturing industry, which is mainly based on well-managed and standardized processes. This ongoing discussion about problems, such as low profitability and high construction costs, results in demands for higher value, cost savings, better quality, and longer guarantees in construction. However, construction is not manufacturing, but it does provide elements that can be exploited to improve processes and reduce waste. Moving towards better quality and more homogenous construction can be achieved by standardized processes and by using standardized products in those processes. Thus, this study aims to analyze what the major challenges for the standardization of processes and products in the construction industry are and how the challenges can be beaten.

The results indicate that the challenges of standardizing the processes are that the importance of accurate planning and front-end activities are not completely understood and the projects are still considered as unique entities. Additionally, the standardization of products has the following challenges: construction projects and solutions are still perceived as unique handwork, designers do not understand the benefits of standardized products, and planning processes do not support using standardized products.

KEYWORDS

Standardization, prefabrication, standardized products, standardized processes, Lean, construction

INTRODUCTION

For years, the construction industry has been blamed but also suffered for its low performance and productivity, and high amount of waste and variability, especially when compared with the manufacturing industry, which is mainly based on well-managed and standardized processes (Höök 2008). In addition, there have been only a few improvements in construction compared with manufacturing. These problems appear as low profitability, and the high construction and error costs result in demands for higher value, cost savings, better quality, and longer guarantees in construction.

[1] Doctoral student, Industrial Engineering and Management, Univ. of Oulu; Finland. aki.aapaoja@oulu.fi

[2] Professor, Industrial Engineering and Management, Univ. of Oulu; Finland. harri.haapasalo@oulu.fi

However, construction is not manufacturing, but it does provide elements that can be exploited to improve processes and reduce waste in production (Ballard & Arbulu 2004). The movement towards the manufacturing industry and culture has been called "industrialization," that is, the interface between the culture in traditional construction and the culture in the manufacturing industry. Because industrialized construction requires more accurately controlled processes than on-site construction (Koskela 1992), industrialization is mainly implemented through prefabrication which is defined as "making all or part of an object in some place other than its final position" (Ballard & Arbulu 2004).

The greatest benefit of prefabrication is in changing the mindset of the construction industry from a project focus with unique and one-of-a-kind projects towards a standard repetitive process focus, which prevails in the manufacturing industry. Hence using the standardization of products and processes can be considered as an essential, and even the most important, factor when it comes to the prefabrication. The ability to measure, understand, and manage variability is essential to effective project and process management (Ballard & Arbulu 2004). If there is no agreed upon standard, a new way of doing is simply one more version by some individual, and it is only practicing (Lander & Liker 2007).

However, defective planning and the haphazard development and implementation of standardization initiatives have led the industry to miss the possible benefits of preassembly and prefabrication (Gibb 1999 quoted in Alves & Tsao 2007). This study aims to analyze what the major challenges for the standardization of processes and products in the construction industry are and how the challenges can be beaten. To reach the objective, the following research questions must be answered:

1. How is standardization connected to current challenges of construction and Lean construction?
2. What are the most important characteristics that standardization has an impact on?
3. What are the major challenges for implementing the standardization of products and processes in construction?

To answer these questions, a literature review on standardization was conducted, while the main focus was kept on standardization. The empirical research consists of a survey that analyzed the major challenges of the standardization of products and processes in the construction industry. The last section proposes managerial implications, presents conclusions, and suggests areas for further research.

INTERCONNECTION OF LEAN AND STANDARDIZATION

Generally, the construction industry is suffering from problems in developing the means to increase productivity and quality and decrease costs (Höök & Stehn 2008, Winch 1998). Construction activities have traditionally been carried out at the final site of the constructed product, which is causing, at the very least, the following process control and improvement problems: variability, complexity, transparency, and benchmarking (Koskela 1992).

Variability arises from the lack of protection against intrusion and operations that are exposed to interruptions. Moreover, permanent safety fixtures are difficult to take

care of in the evolving environment and many times local materials and labor have to be used, which may increase variability as well (Koskela 1992).

Compared with the stable circumstances at factories, where only the material flow through workstations must be planned and controlled, the spatial flow of workstations and construction teams has to also be coordinated on site, which increases complexity. The rapidly changing working environment makes visual control and layout planning challenging, and hence causes transparency problems. Together these three aforementioned problems and decentralized production rule out benchmarking and improvement activities.

In the automobile industry, the Toyota Production System (TPS) developed Lean thinking and a production philosophy that has been proven to bring benefits to several other industries as well (Höök & Stehn 2008, Lander & Liker 2007). Lean thinking and its principles can be implemented in any industry (Womack et al. 1990), but implementing it in new environments is only possible when the purpose of particular tools and of TPS in general is understood and assimilated (Lander & Liker 2007). Applying Lean in construction has since been verified (e.g., Höök 2008, Howell 1999, Koskela 2000). Diekmann et al. (2004), for example, argue that Lean improves the cost structure, value attitudes, and delivery capability of the construction industry, and hence seizes the problems connected with on-site production. According to Womack and Jones (2003), Lean thinking can be summarized in the following principles:

- Product specified value
- Identified value stream for each product
- Value flow without interruptions
- Pull production
- Aim for perfection

Prefabrication (includes preassembly, and modularization) has been viewed as one potential way to assist the development of construction (Koskela 2000) and increase value for money (Pasquire & Gibb 2002). Additionally, it can be argued that there is a potential way to put Lean principles, or at least some of them, in practice. In particular, enables smooth value flow (Koskela 2000) by reducing the waste of on-site production (Warszawski 1990). In their research, Tam et al. (2007) calculated that wastage generation (concrete, reinforcements, plaster, and tiles) and its cost can be reduced up to 84.7% by adopting prefabrication.

However, the full benefits of prefabrication cannot be achieved unless the standardized processes and standardized products or components are used (CIRIA 2001). Despite that, it is surprising how poorly standardization and its benefits are understood by many involved in construction and its processes (Gibb 2001). Liker (2004) has said that the right processes produce the right results. Thus standardized tasks and processes are the basis for continuous improvement and employee involvement, revealing problems, and using only reliable technology that serves your people, processes, and products.

In addition to Liker, Höök (2008) found that standardized and predictable processes are the most essential to obtain if a Lean culture is aimed for. Moreover,

"unique" projects should be managed as a repetitive process, because "standardization is dependent on specific projects being managed within a recurrent (and standardized) production process, with a smooth and standardized production pace" (Höök 2008, p. 66).

STANDARDIZATION

A standard is something set up and established by an authority as a rule or norm for the measure of quantity, weight, extent, value, or quality (Merriam-Webster Dictionary 2014). Briefly a standard defines what something should do or perform. Standards are created by bringing together all of the interested parties, such as the manufacturers, consumers, and regulators, of a particular material, product, process, or service. All parties benefit from standardization through increased product safety and quality as well as lower transaction costs and prices. (European Committee for Standards 2009.)

Standardization is the wide use of components, parts, procedures, or processes in which there is regularity, repetition, and a successful practice and predictability (Gibb & Isack 2001, Pasquire & Gibb 2002). Some of the items can be standard by their nature (generic standardization) or as assigned by the legislation of a country (national standardization). Both clients and suppliers may have standard processes or products. As a minimum, project teams should standardize their actions whenever they can. (Gibb 2001.)

However, there has always been a problem between maximum standardization and flexibility – in other words, similarity and customization – which may lead to design impotence, but should be used to ensure optimal implementation and compatibility. Hence, the focus of standardization in construction is the interfaces between the components, rather than the single components themselves. However, the standardized processes are the most crucial things in construction, because there is no use for standardized products or components if those processes are not used properly and effectively. (Gibb 2001, CIRIA 2001.) Therefore it can be argued that in construction, standardization is not about the standard systems or products, but the systematic approaches to perform things. Only by that can the benefits of standard products or components be exploited effectively.

Generally, process standardization may vary from absolutely standard documentation and procedures at the detailed level, to a more strategic approach. The former represents a coercive approach (e.g., legislation or regulations) that points out what you should and should not do, while the latter is more like a directional and proactive approach that emphasizes the identification and assessment of the risks. At the moment, the strategic approach is perceived as producing better results. (Gibb & Isack 2001.)

THE BENEFITS OF STANDARDIZATION

The standardization of both products (which also includes modularity) and processes has been shown to bring many benefits. When it comes to process-related factors, Gibb and Isack (2001) found that standardization decreases the cost, and naturally has a positive impact on processes as well. In addition, a positive impact on people issues, and quality and design were noted. Standardized processes also allow the project's parties to understand what is required, from whom, and by when. Standardization has

led to fewer claims, conflicts, and change orders, and therefore less unplanned cost. (Gibb & Isack 2001, Tam et al. 2007, Pasquire & Gibb 2002.)

By using standardized products or components, customers believe that saving costs is the most important thing, but there are also shorter lead-in times, higher quality, and operational benefits (Gibb & Isack 2001, Li et al. 2008, Pasquire & Gibb 2002). Basically, the operational benefits become apparent when less time is spent on having to re-train people to use a new design of a product or machinery (Gibb & Isack 2001). However, it can be assumed that there is a cause-effect relationship between processes and operational benefits, because effective processes create a basis for the effective use of products (CIRIA 2001). In other words, high quality, reasonable costs, and effective product delivery are the results of repeatable, predictable, and measurable processes (Gibb & Isack 2001, Li et al. 2008, Pasquire & Gibb 2002). In addition, having standardized components and products means the construction users and the end-user understand what they are getting and how it should be used (Gibb & Isack 2001). Table 1 summarizes the benefits of standardization for processes and products (e.g., Gibb & Isack 2001, Pasquire & Gibb 2002).

Table 1. The characteristics of standardization.

Characteristics of standardized processes	Characteristics of standardized products and components
Organizational interfaces	Track record
More predictable on-site activities	Increased productivity due to familiarization
Increased productivity	Less waste
Less waste	Use of the same products and components in follow-on project
Less disruption	Reduced lead-in times
Quality benefits	Predictable and measurable quality
Cost benefits	Off-site inspection
Process benefits	Available replacement parts
People/operational benefits	People/operational benefits
Time benefits	
Design benefits	

THE CHALLENGES FOR IMPLEMENTING STANDARDIZATION

The description of the challenges for implementing the standardization of products and processes is based on information from Finnish construction experts. The analysis is part of a research project, "LCIFIN2 – exploiting Lean in construction," funded by the Finnish Technology Agency.

The process of collecting and validating the information was comprised of a survey and a workshop carried out during the research for late 2013 and early 2014. The primary data was collected by the researchers through a survey. It was sent to 40 people who represent the partner organizations and companies in the LCIFIN2 project. Because only eight responses to the survey were received, the authors decided to validate the data in one project workshop (3-4 hours), which was attended by 30 people from 10 different LCIFIN2 (partner) organizations/companies from the fields of renovation, design, construction, maintenance, consulting, project management, software (BIM)provider and public authority.

This research aims to understand the main differences in using standardized processes and/or products and the current practices in the Finnish construction industry, but also to show the challenges they impose. Tables 2 and 3 summarize the findings of this research. In table 2 and 3, the first three columns ("characteristics," "standardized processes/products," and "in construction") are laid out mainly on the basis of the literature studies and desk work, while the last column ("challenges") represents the main findings and the opinions of informants. In more detail, Table 2 shows a summary of the main differences in the standardized process (like TPS) and the current process in the Finnish construction industry, plus the resulting challenges. Table 3 is consistent with Table 2, but instead of processes it is concerned with standardized products and components.

Table 2. The differences in the standardized and current processes faced by the Finnish construction industry.

Characteristics	**Standardized processes**	**In construction**	**Challenges (in Finland)**
Organizational interfaces and responsibilities	Defined and straightforward	Vague	Fragmented supply chain (i.e., lack of collaboration).
On-site activities	Predictable	Non-predictable	Hard to plan for and unlevelled schedule.
Productivity and effectiveness	High	Low	High variability. No standard methods (tacit work knowledge). No feedback loops in production.
Amount of waste	Low	High	Low process discipline, no standard methods.
Disruption	Low	High	Hard to plan, balance and standardize work.
Quality	High	Low/Medium	Low process discipline.
Value for money (e.g., cost-benefit ratio)	High	Low/Medium	The importance of front-end design is not understood properly.
People/operational benefits	Yes (standard tasks, activities)	No	Hard to standardize the jobs of operators and work knowledge.
On time/schedule	Yes	No	Variable takt time and unlevelled schedule.
Number of change orders	Minimal	High	The importance of front-end design is not understood properly.

Table 3. The differences in the standardized and current products faced by the Finnish construction industry.

Characteristics	Standardized products	In construction	Challenges (in Finland)
Track record	Accurate	No	"Unique" products (inability to see parts to be standardized).
Using standard products in follow-on projects	Yes	No	The value of standard products/components (modularity) is not understood. Hard to learn from past actions.
Amount of waste	Low	High	High product variety.
Lead-in times (e.g., production runs)	Short	Long and unpredictable	Many custom items. The value of standardization is not understood properly.
Predictable and measurable quality	Yes	No	No standard methods (tacit work knowledge). No feedback loops in production.
Inspection	Accurate and off-site	Ad-hoc and on-site	No standard methods and routines.
Available replacement parts	Yes	No	"Unique and customized" solutions.
People/operational benefits	Yes	No	The current design processes do not support using the standard products and components. The inability to order (and offer) standardized products and solutions.

RESULTS ANALYSIS AND DISCUSSION

In general, construction projects operate in a very different environment than that for which standardized processes (such as TPS) are usually developed for and hence they faces a set of challenges that make the implementation of standardized processes and products more difficult. Moreover, both the characteristics and challenges of standardization interact with each other, which make the implementation of standardization a bit harder, but not impossible.

When it comes to the standardization of processes, the best results would be gained if a holistic view was taken to resolve the problems that occur. In other words, the purpose of standardization should be in finding the root causes that prevent the implementation of standardization and by that create a hospitable environment for implementing standardization effectively. On the other hand, it is also possible to solve challenges one by one, but this probably would not solve the root causes and it could even create new problems. And above all, such an approach goes against the Lean philosophy, while the purpose is to use and understand Lean. However, Höök (2008) emphasized that moving forward should be slow to ensure that all employees get time to adjust and become loyal to the development and settled mutual objectives and strategy, because an understanding and acceptance of Lean philosophy is important to consider.

The results imply that a lack of collaboration between the project participants consequent upon the fragmented supply chain (and the culture and habits in general) may be one of the root causes that prevents process standardization. Aforementioned

problem reflects in the design phase which essential role and the impact on project value creation is not assimilated, and especially, the importance of front-end activities and thorough planning should be emphasized in order to increase the buildability of the end products. Similar kinds of results have also been found in previous studies (e.g., Lessing et al. 2005, Björnfot & Stehn 2004).

Moreover, the company representatives also described how the construction industry and its projects are still perceived as a handicraft profession that produces unique and customized products. Unfortunately, the low productivity seems to support that viewpoint. In that case, for example, the methods, the workers' jobs, and work knowledge are basically impossible to standardize. In sum, somehow it seems that the scheme of things must be changed, and therefore construction projects should be looked at a more repetitive process.

Due to their interconnected nature, the challenges of using standardized products and components are partly consistent with the challenges in process standardization. Hence, it can be argued that process standardization demands the use of standardized products. At least, if we want to exploit all of the benefits of standardized processes. However, construction, and especially its solutions, are seen as unique, with an inability to see which parts and products could be standardized, and therefore the value of standardized products is not understood either. When the variety of the products gets high, most likely the amount of waste gets higher as well. At the same time, when there are no standardized processes and products, quality cannot be measured and is not predictable, which ultimately leads to the fact that continuous improvement is basically impossible. However, the results indicate that these aforementioned challenges are not the root causes of this lack of standardization, but more or less consequences. According to the company representatives, the most serious problem is that the current design processes do not support and enable the use of standardized products and components, because their value is not understood and therefore they are not offered.

Overall, the findings of this study indicate that the standardization of processes and the use of standardized products is a kind of "a rat race" in that they support and complement each other. In other words, processes must be defined in such a way (e.g., tacit work knowledge and methods) that they enable the effective use of standardized products or components, and vice-versa. Naturally this leads to a conclusion that in order to make the most of the benefits of standardization, product and process standardization should be utilized in parallel in construction deliveries. Womack and Jones (1990) have stated that the construction industry suffers most from variability. Unpredictable and non-standardized processes and products cause all kinds of waste, not just of long lead times and excess inventory but also it results in the fluctuation of the production flow (Yu et al. 2009).This is why we recommend that construction industry should focus more on prefabrication and takt time –thinking, because prefabrication (i.e., modularization) relies on standardized homogenous products and off-site production (i.e., low variability and good quality) while the takt time – thinking is based on standardized and synchronized on-site processes (i.e., value flow and pull production). Pasquire and Connolly (2002) have emphasized that takt time - thinking removes multi-layered time contingencies to reduce process waste by using real time planning and drive just-in-time delivery. Ultimately the implementation of prefabrication and takt time –thinking leads to more industrialized and "Leaner"

construction (Figure 3). Björnfot & Stehn (2004) especially, but also by some other studies (e.g., Höök 2008, Lessing et al. 2005), which have summarized:

- applying Lean in construction promotes buildability and a buildable process (top-down approach),
- product modularity promotes the Lean construction process (bottom-up approach),
- product modularity (i.e., exploiting standardized products and components) promotes buildable designs, and
- Lean construction and philosophy advocate modularity.

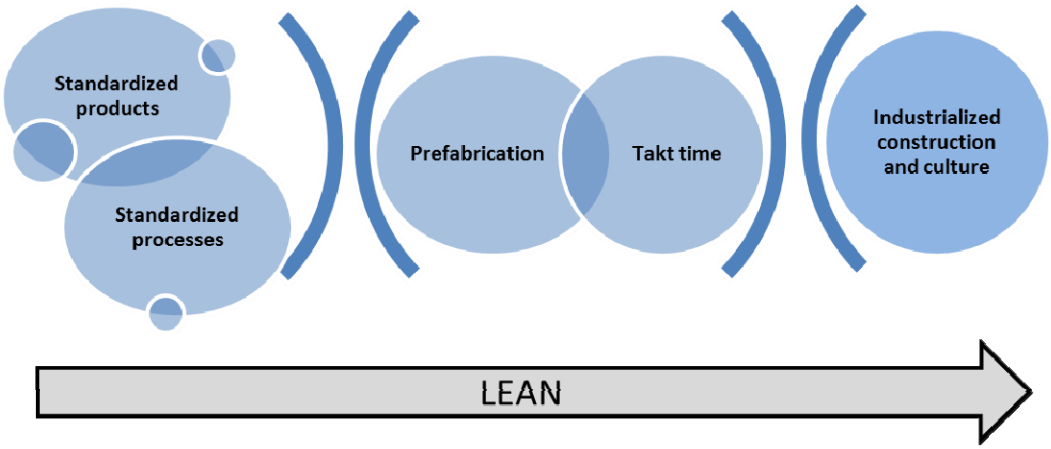

Figure 1: Towards industrialized construction.

The previous studies and theories have mainly considered the development of processes and enhancing the exploitation of standardized products equally. Alternatively there is an option that product and process standardization is done at different time. In that case, the process development and standardization is more important and hence must be done first. Just like in the manufacturing industry, fine and expensive machines are useless if no one knows how to use them properly (i.e., process management). In addition, our argument is confirmed by the fact that, especially in Lean philosophy, the top-down approach is essential when change is pursued. However, exploiting products and process standardization – prefabrication and takt time –thinking – at the same time is recommended.

CONCLUSIONS

The construction industry is well aware of waste, productivity issues, and technological advancements, and at the same time the customers have started to demand more value for their money. The development of production methods has been found to be a potential way to fix some of the defects, and in particular, the standardization has received a lot of attention during the past ten years. It aims at shifting the "one-of-a-kind" perspective and construction processes towards the perspective and methods of the manufacturing industry, which has trusted in standardized processes and the use of standardized products for decades.

This paper focused on revealing the major challenges for process standardization and why the use of standardized products and components is so difficult and relatively rare. The study was conducted through a literature review and empirical research. The findings imply that the standardization of processes and using standardized products go hand in hand. At the moment, there is a shortage of using standardized products because the processes do not support taking advantage of them. In other words, why bother to use standardized products if they do not provide any benefits. Based on that, it is argued that the construction industry must pay attention to process development (the top-down approach) in particular, where the importance of front-end design (for example, set-based concurrent design and collaborative design) is emphasized. From that, it can be ensured that the design and plans are as accurate and correct as possible. Further, front-end design enables and acts as a driver for applying prefabrication in a larger scale. Product standardization (the bottom-up approach) should not be forgotten either, but first there must be processes that are able to exploit standardized products and modularity. However, it is expected that the best results are obtained if the product and process standardization are used simultaneously. In practice, it techniques like prefabrication/modularization (i.e., product standardization) and takt time –thinking (i.e., process standardization) should be applied in a larger scale.

There are still a number of important questions to be addressed in further research, such as how customers understand and react (positively or negatively) to standardization and to prefabrication in a more general level. In addition, especially projects where the takt time - thinking has used or is going to be used, would another interesting issue to be studied.

ACKNOWLEDGEMENTS

Authors would like to thank Tekes – the Finnish Funding Agency for Technology and Innovation for financing the LCIFIN2 research project. There is also the website for LCI-Finland at www.lci.fi to raise awareness of the latest innovations in build environment and national research projects focused on developing it.

REFERENCES

Alves, T. da C.L., and Tsao, C.C.Y. (2007) “Lean construction – 2000 to 2006. Lean construction journal, 3 (1) 46-70.

Ballard, G., and Arbulu, R. (2004) “Making Prefabrication Lean”. In Proc. 12 Annual Conference of the International Group for Lean Construction (IGLC-12).

Björnfot, A. and Stehn, L. (2004) Industriazation of construction – a Lean modular approach. Proceedings of IGLC-12, Copenhagen, Denmark.

CIRIA (2001) Clients’ Guide and Tool Kit to Standardisation and preassembly. Construction Research and Information Association, 100pp.

Diekmann, J.E., Krewedl, M., Balonick, J., Stewart, T. and Won, S. (2004) “Application of Lean Manufacturing Principles to Construction.” CII Report No.191, The University of Colorado at Boulder.

European Committee for Standards (2009) What is a standard? (available at http://www.cen.eu/cen/NTS/What/Pages/default.aspx)

Gibb, A.G.F. (1999) Off-site Fabrication: Prefabrication, Pre-assembly and Modularisation. John Wiley and Sons: New York, NY.262pp.

Gibb, A.G.F. (2001) "Standardization and pre-assembly – distinguishing myth from reality using case study research." Construction Management and Economics, 19: 307-315
Gibb, A.G.F. and Isack, F. (2001) "Client drivers for construction projects: implications for standardization." Engineering, Construction and Architectural Management, 8(1) 46-58.
Howell, G. (1999) "What is lean construction–1999." Proceedings of the 7th IGLC Conference, University of Berkeley, California, July, pp. 1–10.
Höök, M. (2008) "Lean Culture in Industrialized Housing: a study of Timber Volume Element Prefabrication." Doctoral dissertation, Luleå University of Technology
Koskela, L. (1992) "Application of the new production philosophy to construction." CIFE technical report #72, Stanford University.
Koskela, L. (2000) "An exploration towards a production theory and its application to construction." Doctoral Dissertation, VTT - Technical Research Centre of Finland.
Lander, E. and Liker, J. K. (2007) "The Toyota Production System and art: making highly customized and creative products the Toyota way." International Journal of Production Research 45(16): 3681–3698.
Lessing, J., Stehn, L. and Ekholm A. (2005) Industrialized housing: definition and categorization of the concept. Proceedings of IGLC-13, Sydney, Australia.
Li, H., Guo, H., Skibniewski, M.J., and Skitmore, M. (2008) Using the IKEA model and virtual prototyping technology to improve construction process management, Construction Management and Economics, 26(9): 991-1000.
Merriam-Webster dictionary (2014) Standard. (available at http://www.merriam-webster.com/dictionary/standard).
Pasquire, C.L. and Connolly, G.E. (2002) Leaner construction through off-site manufacturing. Proceedings of IGLC-10, Gramado, Brazil.
Pasquire, C.L. and Gibb, A.G.F. (2002) "Considerations for Assessing the Benefits of Standardisation and Pre-Assembly in Construction." Journal of Financial Management of Property and Construction 7(3) 151-161.
Tam V.W.Y., Tam, C.M., Zeng S.X. and Ng W.C.Y. (2007) "Towards adoption of prefabrication in contsruction." Building and environment 42, 3642-3654.
Warszawski, A. (1990) Industrialization and robotics in building: A managerial approach. Macmillan, New York.
Womack J, Jones D & Roos D (1990) The Machine that Changed the World. New York, NY, Free Press.
Womack J.P and Jones D.T. (2003) Lean Thinking: Banish Waste and Create Wealth In Your Corporation. New York, NY, Free Press.
Yu, H., Tweed, T., Al-Hussein, M., and Nasseri, R. (2009) "Development of Lean Model for housing construction using value stream mapping." Journal of Construcition Engineering and Management, Vol. 135, No. 8, 782-790.