CLASSICAL LEAN CONSTRUCTS AND THEIR TRANSFERABILITY TO THE CONSTRUCTION INDUSTRY

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Lean production, a new production philosophy first demonstrated in the car industry, has been acclaimed as a novel performance improvement method by many in the construction industry. First implementation attempts of lean principles were documented as early as 1992. Many attempts have been made since then to implement it on a wider scale. While some argue that construction theory can only develop through successful implementation strategies, others disagree and suggest that theory building is more fundamental. Whoever is right, surely clear and concise definitions and terms are needed to initiate a debate on lean implementation protocols and processes.

A coherent definition of the term lean is notable by its absence. Nevertheless, there are two dominant definitions of lean in current usage and notwithstanding the lack of concise terminology, these two perspectives on lean require closer examination. The first is based on the Toyota production philosophy whereas the other, which is termed the abstraction of lean, focuses on the elimination of waste. This paper scrutinizes both of these approaches and concludes that, while Toyota's approach is deemed to fail in construction, the abstraction of lean is no new philosophy but just good old project management.

Keywords: lean construction, lean production, manufacturing, project management, value.

INTRODUCTION

History of lean production

Lean Production is a term first coined in 1990 by researchers at the Massachusetts Institute of Technology (MIT) in their study of the automobile industry. They found that certain companies in Japan required only half the production time, production space and development time compared to their competitors in the USA or Europe. In their findings the research team described certain production patterns in Japan which they termed lean.

Lean production did not emerge as a phenomenon overnight, but was rather a slow, long, ongoing process which was initiated and implemented by Toyota. The adoption of lean at that time was fostered by several factors, including market size, market share and an organizational crisis within Toyota itself. This crisis was the catalyst for the adoption of lean principles in the company and, even today, a crisis is seen as essential for the adoption of lean.

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Definition

Lean is a buzz-word that has equally fascinated and startled managers around the globe. In manufacturing, the phenomenon of lean has been well-researched in the years since the publication of the book 'The Machine that Changed the World' (Womack *et al.*, 1990). Many firms have attempted to adopt the philosophy in order to improve their performance and competitiveness. Most of these attempts have failed due to problems with the transferability of theory into practice. For construction the issue is even more problematic. Differing procurement methods between the manufacturing and construction industries only compound the difficulty in attempts to implement lean methods. One problem that has contributed to this difficulty in the implementation of lean principles is the lack of a coherent definition of the term. Leanness has never been measured, and it would be difficult to quantify any performance improvement from the research studies undertaken to date.

Although there is no unified definition of lean construction, the Lean Construction Institute (LCI, 2000) provides their own version:

'Lean construction is a new way to design and build capital facilities. Lean theory, principles and techniques, taken together, provide the foundation for a new form of project management. From roots in production management, lean construction has produced significant improvements particularly on complex, uncertain, and quick projects.'

This of course is not a definition and their claim that lean methods can improve performance should be treated with caution. The LCI provides consultancy services to firms and therefore has a financial interest in promoting lean principles. Their objectivity needs to be questioned, as do their approaches to implementation and methods of evaluation.

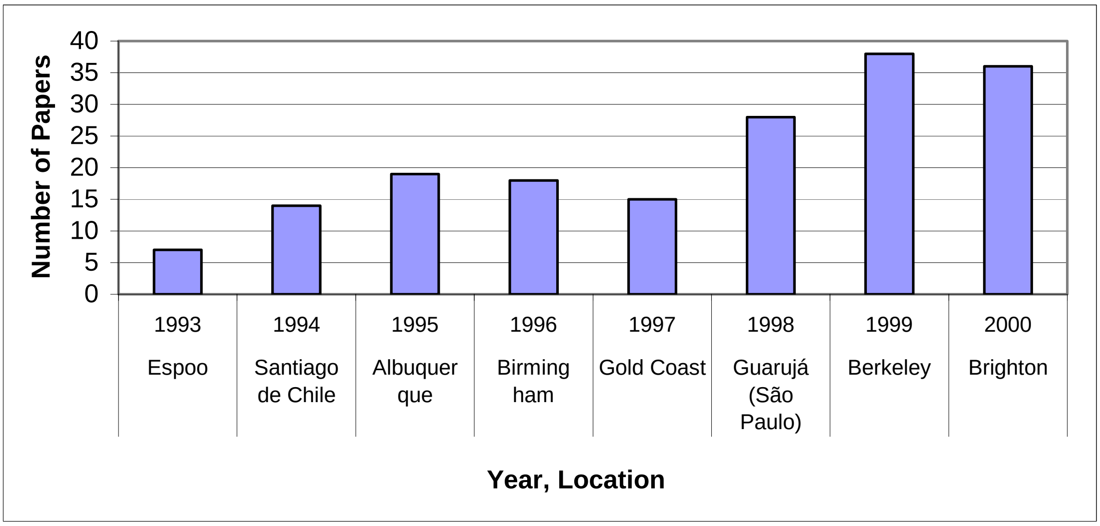

Figure 1: Number of Papers at the IGLC Conferences

In the academic arena, lean has been promoted through the International Group for Lean Construction (IGLC). The IGLC organizes an annual conference, at which researchers from around the world gather to share their knowledge and experience of lean theory and practice. There is no doubt that there is a growing interest in lean research as the increasing number of papers at the IGLC conferences show (Figure 1), however, critical voices are notable by their absence. The conferences often degenerate into rituals of confirmation and celebration led by gurus from the LCI.

Few have raised issues relating to lean implementation and its transferability in a critical manner. In too many cases lean has failed to deliver what it has promised - half the production time, half the production space and half the development time. The failure to deliver can be observed not only in construction but also in manufacturing, from where it originated. The big question is why? While in manufacturing the core problem relates to cultural issues, in construction the answer to the question lies in how the term lean is defined. This paper identifies how lean constructs can influence the implementation and application of the lean principles process. It will further clarify some of these issues and argues that there are two ways of approaching lean, both of which will shatter its image as a panacea for improving performance in the construction industry.

CLASSICAL LEAN CONSTRUCTS

Classical lean constructs originated from the work of the MIT research team. Their findings were subsequently published in the book ‘The Machine that Changed the World’ (Womack *et al.*, 1990). In their initial work, the team examined the differences between global car industries in terms of quality and productivity. These studies provided the basis for further research, and the development of lean concepts, which were first described in the book ‘Lean Thinking’ (Womack *et al.*, 1996), and include:

- Value,
- Value Stream,
- Flow,
- Pull,
- Perfection.

The section below examines each these principles in terms of their applicability to the construction industry.

THE FIVE LEAN PRINCIPLES

Value, as a classical lean construct, should be specified by the end-user. In construction, value is specified more by the customer than it is in manufacturing, as an overwhelming percentage of projects are bespoke. However, clients will not only interfere in the design but will also set some of the specifications. Furthermore, as construction is a long process (from a few months to several years) the clients’ values might change during the construction process.

However, there is a more significant problem in construction with value and its definition. While in manufacturing the producer usually can produce a prototype (whose costs would be spread over many units) to demonstrate features and thus value, construction’s most common language to convey value is drawings, models and specifications, which are sometimes inadequate and difficult to understand for clients.

Womack and Jones (1996) illustrate the concept of value on the case of a house builder. In their example, the question was how to get a first-time buyer a house in a short time, hassle free. However, the design stage was already excluded as there were standard designs, and the rest of the interior design (being similar to the choices from a catalogue) was in the hands of the constructor. Interfaces were therefore eliminated. Because the designs were not very different from each other, customers could actually see and 'try' the product before purchase and only had to imagine different interior colour schemes. This example from the construction industry is really not very different from manufacturing and thus conversion to a lean model was much easier.

The classical construct of **the value stream** is the flow of a product throughout its life, from design to after sales service. The elimination of waste in the value stream is something that occurs between companies and/or departments. This waste is primarily attributed to a lack of communication between parties and to lead times, which originate from the batch and queue method commonly used in manufacturing.

The authors impressively illustrate the waste that occurs through 'batch and queue' in the value stream by using the example of a can of beverage. However, as argued before, construction is generally a tailor made product, thus batch and queue does not occur in the process. It can only occur further down the supply chain when sub-contractors and suppliers store bulk-bought products.

On the other hand, in construction plenty of waste certainly does occur between the involved parties. The authors illustrate this problem using the example from the aerospace industry where certain parts were double-processed in the supply chain due to a lack of information and communication between the parties concerned. However, unlike manufacturing, there is an additional complex factor in the construction process. While a manufacturing company can solve the problem by getting the project team together to openly discuss it (contracts are usually relatively long term), in construction it would be necessary to change the attitude of the industry as a whole. There is the possibility to change the attitude of the clients so that they are willing to use the same contractors and sub-contractors over and over again (even single project clients). Alternatively, the attitude of all contractors could be changed so that an exchange of any contractors or sub-contractors would not result in inefficient communication, as all would have the same understanding of the general process. Either way, ensuring effective and efficient communication in the project team is both beneficial and important, but it is more complex than in manufacturing.

In the classical lean theory, **flow** is concerned with the flow of products through the system. The notion of flow is again very different between manufacturing and construction industries. A straight transfer of principles to the construction industry is possible, but the emphasis needs to be shifted, as the two systems are almost contrary. In manufacturing the resources are static and the product is dynamic, while construction has a static product and dynamic resources, therefore manufacturing should place an emphasis on the products, while construction should recognize the importance of the resources. This leads to a different approach to tackle waste. In manufacturing managers will seek to eliminate waste, while in construction a more complex optimization problem will have to be addressed. For a detailed discussion of the flow philosophy and the problems related to it see Dauber *et al.* (2001).

A **pull** system, as understood in lean manufacturing, means that an element or product is produced just as it is required by the next process; thus each element or product is drawn by its successor at the right time, in the right quantity and at the right quality.

Most construction projects are custom-made for a particular customer. Therefore, when a customer orders a product the whole pull machinery will be set in motion; the architect will prepare the conceptual design and the plans, then the contractor will put in a tender for the project. However, when the contractor prepares his project execution plan, the pull system somehow suddenly changes to a push system. Tasks will be scheduled for the earliest possible starting date, and as soon as something can be done, a push procedure will start to push this process down the line to the finished product. Naturally this is only valid for processes which are not on the critical path, as they are already pulling the project through.

In a system designed in accordance with the lean production philosophy, every process should start on the latest possible date or at least with a minimum buffer. This would have a catastrophic effect when first introduced on site. Not only would a project suffer unforeseen and unmanageable interruptions, but all the existing bad management practices would be revealed. Similarly, performance initially suffered in Toyota's system where every single operative could stop the line, with the effect that whenever a defective part came down the line or a part was missing or delayed, the whole process was halted. This meant that there was a lot of pressure on the people to get it right first time, as the company could not afford to stop the line too often or they would go out of business. Therefore, there are arguments in favour of this system, which eradicates safety cushions and reveals problems.

Contractors argue that it is necessary to schedule and execute all their processes as early as possible as an insurance against any unforeseen and uncontrollable influences, such as the weather and the variances of the multi-project environment. Further the higher variability will require backlogs of tasks to be executed in case of unforeseen events influencing the planned schedule. However, it was argued earlier that in construction emphasis needs to be placed on resources rather than on products and therefore a pull system of products might do more harm than good.

There is no good reason why the construction industry should fail to strive for **perfection**. However, there are several barriers that prevent the construction industry from innovating at its full potential (Tatum, 1986). This is partly due to the separation of the design and construction stages in a project. There are principally four groups that can bring innovations into the construction process – the contractor, the client, the supplier/sub-contractor and the designers.

The contractor has little incentive to try radical new or risky methods if only the client benefits from it. The majority of projects are different (few possibilities for repetition), therefore there is little motivation for contractors to invest in innovation, other than the optimization of their own process (Pries and Janszen, 1995). For the client, on the other hand, it is very difficult to choose a new process or product for construction. Since construction is usually the largest fixed investment made by individuals, corporations and public authorities, it is not surprising that most risk-aware decision-makers feel more comfortable investing in structures built using mainstream, established designs, materials and techniques, rather than using some new and innovative approaches that may not live up to their promises in the long run (Rosenfeld, 1994). The most innovative group are the suppliers. They will directly gain from their innovations, and hence have a higher commitment to investment in them. However, of all those involved the suppliers are closest to the manufacturing industry, thus not the best example of how perfection could work in construction. Finally, the designers are eager to innovate, but they have least to lose should the new method fail. Should there be a cost overrun, they would be rewarded with higher fees. However, this is a short term strategy and future clients might avoid these designers, so they will find themselves with a conflict of interest.

For these reasons the culture in construction would need to change radically to make any lean approach of perfection work.

A WORD OF CAUTION!

There are still major problems in lean implementation. When Womack *et al.* (1990) published ‘The machine that changed the world’ they were very vague about what made those well performing companies in Japan so different. In their second book, they tried to specify these differences, but still kept their explanation very general. Later Rother and Shook (1998) developed a booklet that attempted to help practitioners in manufacturing to implement flow and examine the value stream in their company. However, these are only parts of lean production and a clear implementation structure is still missing. One argument is that lean will only sustain itself if it is fully implemented, but without a definition and measurements it is very difficult to asses whether a company has done enough to ensure it has a self sustaining lean system. Lean ideas are far better understood and their effects better researched in manufacturing than in construction but still many problems arose when it was implemented. In construction, researchers and practitioners have tried to implement lean in organizations without any definitions and even without clear transition ideas.

The authors claimed in their first book that lean producers use only half the production time, are three times as accurate and 40% more efficient in terms of production space, with their inventories being only a fraction of that of ‘mass producers’. However, there has never been any productivity data to show where lean producers reduced labour to become so productive (Williams *et al.*, 1992). Furthermore in the comparisons of different plants, the authors used adjustment factors and compared selected activities of production only (Kieser, 1993). Kieser argues that the comparison and their adjustment factors do not compare like with like. This is backed up by Williams *et al.* (1992) with their statement:

‘Worse still, the crucial process comparisons undertaken by a staff researcher, John Krafcik, raise large problems about method and conclusions which do not seem to have been recognized by the principal researchers who use this work in ways that create further problems.’ (p 323)

By equalizing all measurements to ‘the standard car’ too much information about the process gets lost and, when taking into account the level of technology used, their revolutionary statement of half the production time becomes even less convincing. Both of these references seriously question the accuracy of Womack *et al.*’s study and, thus, their conclusions.

Nevertheless, that is not to say that the movement of lean construction needs to be condemned totally. The section to follow will examine lean constructs in an abstract form.

LEAN, THE OPPOSITE TO FAT

Keeping in mind that the difference in performance between mass production and lean production (if those systems exist anywhere in purity) is not so spectacular, it was shown that a direct translation to construction is hardly possible. However, if the lean philosophy is abstracted enough there might still be the possibility of gaining something from it.

ABSTRACTION

'Abstraction is the act, process of leaving out of consideration one or more properties of a complex object so as to attend to others; analysis. Abstraction is necessary to classification, by which things are arranged in genera and species' (Gove, 1971).

Abstraction can take place on several levels. For example the former section, where lean principles were directly translated to construction, is some kind of abstraction on a very low level. However, it has already been demonstrated that this implementation is bound to fail. In the following section, lean principles will be abstracted to a degree where they are transferable to construction. If lean is abstracted to the most basic level possible the crucial driver and driving equation in the business environment is found.

$$\text{Profit} = \text{Price} - \text{Cost}$$

Long term profit is the most fundamental reason for the establishment of a business (Goldratt and Cox, 1993). Clients and designers might have some other motives, e.g. to build a memorable monument, however, without profit even their business will perish.

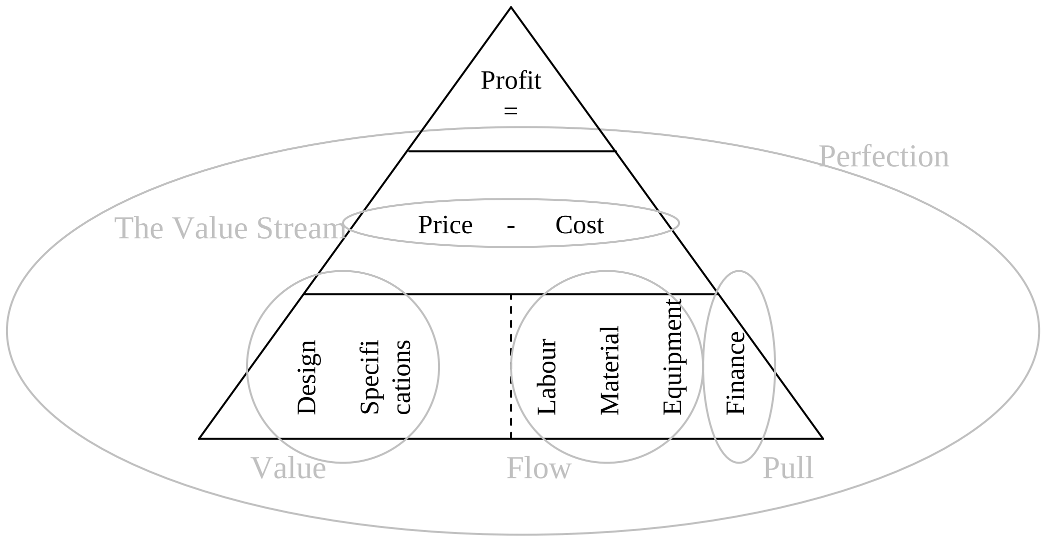

Figure 2: Level of Hierarchy where Lean Principles operate

Figure 2 illustrates that the five lean principles are targeted on different segments of the general equation. While value, flow and pull are operating on the lowest level with influence mainly on organizational structures, the value stream takes a more holistic approach with cross-boundary emphasis. Perfection on the highest level is not associated with any particular course of action but rather drives the others. However, the 'boundaries' displayed here are not as rigorous in reality.

In the abstraction process those segments are still targeted but by leaving out some considerations, that were necessary for manufacturing, the lean concepts will better suit construction. The abstraction of the five lean principles will be tackled in turn in the following section.

Fat or waste in **value** occurs if the client does not get the right product, at the right price and at the right time. Value does mainly influence the price of any project rather than cost, thus is less related to the contractor's side of the project. A majority of 80% of the cost is fixed in the design stage of a project, thus most of the waste in construction with regard to value can occur in the design stage of a project (Salisbury, 1990). Therefore, it is of paramount importance to convey the client's needs and ideas to the architect and contractor. This problem is a very old one and architects have tried to overcome it since the very early days of construction. Building models of construction was an attempt to visualize the projects to the client. However, this proved very cost and time consuming and was not viable for smaller projects. Today, technology makes it easier to achieve better understanding between clients and the parties involved. Even small projects are drawn in CAD and it is not very difficult to transfer these initial drawings into virtual reality. Many researchers and practitioners have struggled to find better ways of conveying value to clients and to solve the problems of the client/designer interface. A good discussion of these problems can be found in Lawson (1980).

Once value is communicated correctly and specifications have been fixed, waste in value can still occur if the contractor has to re-work parts of the work because of failure to comply with specifications in the first place. There is certainly room for improvement in the field of re-work in the construction industry and the area has already been identified by researchers (Borcherding and Sebastian, 1980).

In manufacturing, the **pull** idea derived from the huge waste that occurred in companies when they produced products on forecasts rather than on demand. However most traditional construction projects are started only on demand. During the construction process there are other more important issues that affect waste than early production of parts of the works. Furthermore, the construction industry has established different payment methods; finished parts of the work and sometimes, work in progress is paid for. For these reasons, it is seen as not very beneficial to introduce a pull-process into the process of the construction phase. Naturally there are construction projects which are more closely related to manufacturing, e.g. housing developments, where a pull-process for construction will be viable.

Another part in the construction process where a pull approach would be feasible is material delivery to site. Again there will be an optimization problem of how frequently it is feasible to deliver material and goods on site. The main argument for this, however, is not so much the waste in finance that occurs but rather that products delivered early might get damaged or lost. This is similar to a Just in Time approach or earlier material controlling and can be dated back as far as the 1960's (Oxley and Poskitt, 1968).

Many construction companies have a poor performance because their short term planning is either not very good or non-existent (Borcherding and Oglesby, 1975). This in turn will lead to major deficits in the **flow** of work.

Most companies produce a detailed programme for each project at the beginning of the construction phase but neglect to up-date or re-think it after construction has started. It is known that highly detailed planning for a period of more than a couple of weeks in advance is in vain, as too many variables influence the plan. Research currently undertaken at the University of Dundee suggests that the best time scope for detailed planning is within an one to two week window. Flow might be manageable in manufacturing by standard procedures where a reasonable degree of complication but not complexity appears. Construction can not rely on standard procedures but will need innovative problem solving.

Therefore, the abstraction of flow is the planning, controlling and coordination of all resources involved in the construction process. Naturally, the optimization of one of them is not consistent with the holistic optima, thus a manager will have to optimize between them. Resource optimization and levelling is a well researched principle in construction management (Oxley and Poskitt, 1968).

The value stream is essentially not very different from the flow principle. However, acting on a higher level, it should not just take one managerial sector into account but keep track of the project. The value stream needs to take care of a product during its whole life. Therefore, it brings together design, construction and after sales care and maintenance. Amongst the areas that have been researched are:

- Changing clients' attitude towards whole life cost;
- Incentives for designers to minimize whole life cost;
- New form of organizations (prime contracting) and contracts (design and build).

Whole life costing as a sole discipline emerged in the mid 1970's, but can be traced back to its origins in the engineering economy (Flanagan and Norman, 1984).

Perfection is already quite an abstract concept and thus will not be abstracted here any further. Any system, aimed at improving or sustaining performance, that is set in place needs to be checked and maintained. Once this control or maintenance is missing, the system and thus performance, will deteriorate. Perfection is a very good way of keeping the members of an organization thinking about improving performance as it is an impossible goal to achieve. Perfection can be seen as the motor that keeps everything going once it has been started.

TRANSFERABILITY OF LEAN – NO NEW CONCEPTS

In this section it was demonstrated that it is possible to transfer the ideas of lean production into the construction industry. On a very high level of abstraction lean production is trying to eliminate waste in the manufacturing industry. Abstraction of lean principles can benefit construction, however in construction an optimization problem rather than an elimination dilemma has to be solved. Efforts to optimize the construction process have been made long before the lean philosophy emerged. Some of those methods have been around for many years. Nevertheless lean might have brought them together in an orderly manner for the first time.

CONCLUSION

All the above arguments demonstrate that classical lean constructs are not transferable to the construction industry. Manufacturing is, in too many aspects, very different from construction. The influence of weather, the clients' attitude, diversification, conflict of interest, and the complexity of construction projects are just a few examples. Therefore, very different approaches are needed to improve performance in construction.

In the second part of the paper it was shown that there is the possibility to gain from the lean movement. On a very high level of abstraction lean thinking can benefit construction. Nevertheless, on such a high level of abstraction, the principles and ideas do not have much to do with lean any more. The ideas and 'innovations' that can be extracted from lean thinking have been around for a long time and are nothing new. If lean is abstracted enough to make it work in the construction industry, then it is just about selling old wine in new bottles. However that should not necessarily lead to a complete condemnation of lean. The quest for better performance slows down occasionally and there is a need to give it a push again. This is exactly what lean and the discussion of lean can supply, the right momentum to get moving again.

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