A PRELIMINARY LITERATURE REVIEW INTO LEAN CONSTRUCTION IMPLEMENTATION

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ABSTRACT

Although all activities expend cost and consume time, Lean Principles state that only conversion activities add value and these should be made more efficient, whereas non value adding flow activities should be reduced or eliminated. Research into these lean principles in construction has found that considerable waste lies in flow processes of construction. By eliminating waste activities, processes can become 'lean' which provide 'more with less' resources. These flow wastes are recognised as a major weakness, which hinder performance and efficiency in the Construction Industry. Previous studies conclude that the construction industry workforce is ignorant of these flow activities that create waste and hinder construction performance.

However, the industry lacks an implementation framework to implement lean principles into the construction processes. This research aims to develop such an implementation framework through action research study for Sri Lankan construction contractors and achieve long-term sustainable benefits by becoming lean. The research is in its initial stage and the aim of this paper was to explore the literature on how LC is implemented in different contexts in construction industries in the world.

The findings reveal several benefits when applying lean principles in construction such as reduce sharing of non-value adding activities increase the output value through systematic construction of customer requirement and reduce process variability. The paper finally identifies the few barriers for implementing lean principles and provides some guidelines on how to overcome the identified barriers for effective implementation of lean principles.

Key words: *Implementation, Lean Principles, Construction Industry, Literature Review.*

1. INTRODUCTION

Construction project delivery system consists of three domains; the contract, the project organisation and the project operating system (Thomsen *et al*., 2010). Within the typical project structure the parties involved in a project such as Client, Contractor and Designer generally worry about their own interests and communication which usually occur along contractual lines. Singleton and Hamzeh (2011) stated that over the past 20 years, innovations have brought major changes to the project organisation and commercial terms, such as Design and Build and Partnering. However, these changes have done very little to improve construction in terms of efficient use of labour, equipment, and material. The project operating system has been largely neglected in construction. Thomas *et al*. (2010) revealed that this situation contributes significantly to inefficiency and waste and lead to construction's low productivity rates. In recent past, researches have put greater focus on developing ways in which a construction project operating system can be improved and one such method is known as Lean Construction (Singleton and Hamzeh, 2011).

First, the paper explains the implications of the lean principles, and how when taken together they result in different ways to manage construction activities. Second, the literature on lean construction

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implementations are explored in different construction settings. Third, their effectiveness together with benefits offered and implementation issues are investigated. Implementing lean in construction in any setting then becomes a matter of developing and acting on this already available knowledge and good practices. It is hoped that the key literature findings arising from this stage, will assist to develop a conceptual implementation framework using lean principles for the construction process.

2. LEAN CONSTRUCTION

Although all activities expend cost and consume time, Lean Principles state that only conversion activities add value and these should be made more efficient, whereas non value adding flow activities should be reduced or eliminated (Koskale, 1992). Similarly, Ballard and Howell (2003) stated that lean constriction is aimed to maximise value and to minimise waste of money, time and materials. Lean construction is a concept still new to many construction industries in the world (Senaratne and Wijesiri, 2008). All construction activities can be divided into two; *conversion activities* which produce tangible and flows activities which bind such conversion activities during the delivery process of the output. Research into these lean principles in construction has found that considerable waste lies in flow processes of construction. By eliminating waste activities, processes can become 'lean' which provide 'more with less' resources (Womack and Jones, 2003). Further, Salem and Zimmer (2005) defined that lean construction is a continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream and pursuing perfection in the execution of a constructed project.

2.1. UNDERSTANDING WASTE

When focusing on waste, attention is on what is not needed. So, it is easy to lose sight of value what the customer wants (Mossman, 2009). Further, he states that when there are more demanding problems or emerging waste, the initial waste that was aimed to eliminate can re-emerge. The waste emerging cycle demonstrated in Figure 1 illustrates when focused on waste elimination, how it gets into an oscillation in which the amount of waste increases and decreases. This pattern can be seen very clearly on construction sites. For example, when one trade falls behind, a special pressure is put on to catch up. Pressure is then reduced as attention shifts to another trade that is now more behind. Now in the first trade things slip again and the, pressure is increased again. Therefore, Mossman (2009) stressed that value should be focused rather than waste. Focusing on the value is more rewarding and more effective. Value is delivered and waste is eliminated or perhaps not even created in the process.

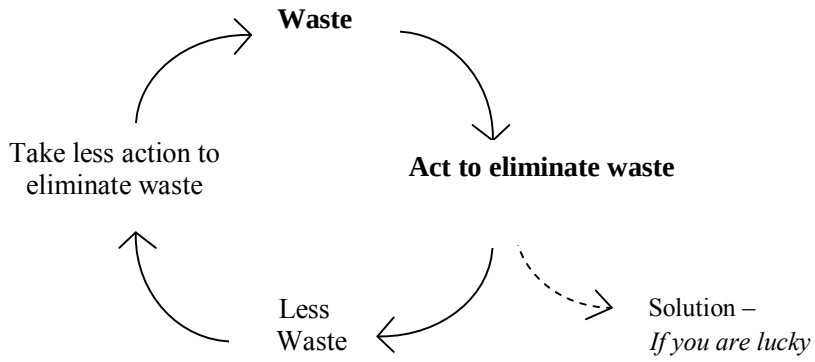

Figure 1: Waste Elimination Cycle (Source: Mossman, 2009)

Waste that generate in flow activities are recognised as major weakness, which hinder performance and efficiency in constriction activities. Several authors including Cornick (1991), Austin *et al*. (1994), and Koskela *et al*. (2001) have discussed the main causes for the poor performance of building design process are poor communication; Lack of adequate documentation; Deficient or missing allocation; Lack of co-operation between disciplines; Unbalanced resource allocation; and, Erratic decision making. Lean principles argue that waste could be eliminated by certain techniques which provide more value with

fewer resources. These are discussed in the next section.

2.2. LEAN TECHNIQUES AND THEIR IMPLEMENTATION IN CONSTRUCTION

Several lean techniques were developed for Manufacturing Industry by many authors. These are summarised in Table 1 and their implementation in construction industry is discussed next.

Table 1: Lean Construction Techniques

Lean Techniques	Definition	Application
Last Planner (LP)	Production Planning and Control system implemented on construction projects to improve planning and production performance (Hamzeh, 2009)	LP has been created to maximise reliability of the work /material / information flow to minimise waste in time / money in project processes and to maximise customer value (Ballard and Kim, 2006)
Just In Time	JIT is a Japanese management philosophy which has been applied in practice since the early 1970s in many Japanese manufacturing organisations. It was first developed and perfected within the Toyota manufacturing plants by Taiichi Ohno as a means of meeting consumer demands with minimum delays (Monden, 1993)	JIT manufacturing has the capacity, when properly adapted to the organisation, to strengthen the organisation's competitiveness in the marketplace substantially by reducing wastes and improving product quality and efficiency of production. (Cheng and Podolsky, 1993)
3D Models	3D modelling is the process of developing a mathematical representation of any three-dimensional surface of object via specialised software. The model can also be physically created	The use of 3D models for improving constructability has typically included model based design and coordination by combining multiple models into one and running clash detection (Staub-French and Khanzode, 2003)
Increased Visualisation	The increased visualisation lean tool is about communicating key information effectively to the workforce through posting various signs and labels around the construction site. Workers can remember elements such as workflow, performance targets, and specific required actions if they visualise them (Moser and Santos 2003).	This includes signs related to safety, schedule, and quality. This tool is similar to the lean manufacturing tool, Visual Controls, which is a continuous improvement activity that relates to the process control
Value stream mapping	A value stream map is a comprehensive model of the project that reveals issues hidden in current approaches (Howell and Ballard, 1998)	Value stream maps can be identified as Process Flow Charts that identify what action releases work to the next operation.
Stopping the line	Stopping the line in manufacturing prevents the release of defective work down stream	Planning at the assignment level is the place to “stop the line” in construction to assure a reliable flow of work and no defective assignments are released downstream (Howell and Ballard, 1998)
Reverse Phase Scheduling (RPS)	RPS is a pull technique is used to develop a schedule that works backwards from the completion date by team planning (Ballard and Howell, 2003)	Phase scheduling is the link between work structuring and production control, and the purpose of the phase schedule is to produce a plan for the integration and coordination of various specialists’ operations.

Huddle Meetings	Two-way communication is the key of the daily huddle meeting process in order to achieve employee involvement.	As part of the improvement cycle, a brief daily start-up meeting was conducted where team members quickly give the status of what they had been working on since the previous day's meeting, especially if an issue might prevent the completion of an assignment (Schwaber, 1995).
Make it flow	Product components should be in constant motion, that is without stopping	In construction, this may mean repackaging work so that parts of the project can proceed without completion of others (Howell and Ballard, 1998)
Kaizen	Kaizen is a system of continuous improvement in quality, technology, processes, company culture, productivity, safety and leadership	Kaizen implicates cost reduction and zero defects in Final Product
Five S	5S is a set of techniques providing a standard approach to housekeeping within Lean (Kobayashi ,1989; Hirano, 1998)	Visual work place: a place for everything and everything in its place It has five levels of housekeeping that can help in eliminating wasteful resources
Fail Safe Quality	Shingo (1986) introduced Poka-yoke devices as new elements that prevent defective parts from flowing through the process. Generation of ideas that alert for potential defects.	Fail safe for quality relies on the generation of ideas that alert for potential defects. This approach is opposed to the traditional concept of quality control, in which only a sample size is inspected and decisions are taken after defective parts have already been processed
Off site manufacturing (OSM) **Prefabrication**	OSM is largely seen as offering the ability to produce high-volume, high-quality products based on the efficiencies of general manufacturing principles common to many industries (Cooperative Research Centre for Construction Innovation, 2007)	Manufacturing and assembling process, whereby, construction components are made at a location different from the place of final assembly, under specialised facilities with different materials. May lead to better control of the inherent complexity within the construction process
Target Value design	TVD is a management practice that seeks to make customer constraints drivers of design for the sake of value delivery (Ballard, 2011)	TVD is a method that assures customers get what they need (where it is valued by customers) and also a method for continuous improvement and waste reduction (Ballard, 2011)

Last Planner is a lean technique that has four main processes: Master Schedule, Phase Schedule, Look ahead plan, and Weekly plan (Hamzeh, 2009). Many researchers have proved reducing plan variability helps increase productivity. Alarcon *et al*. (2006) suggested a regression line between plan reliability and production and Alarcon *et al*. (2006) showed difference in productivity after implementing Last Planner. In construction, the effective point of intervention has proven to be the Weekly Work Plan, because that is where work is selected and commitments are made, and the key to reduction of uncertainty is improving the ability to keep commitments through better selection of work to be done (Howell, 1994).

With **the pull approach**, the concept of **just in time** is utilised in construction wherein the inventories are kept to the bare minimum and new inventories are ordered based on the current demand (Ballard and Howell, 1998). Stocking of material is wasteful. Its implementation requires good relationship with suppliers.

According to Egan (1998), Pacific Contracting of San Francisco, a specialist cladding and roofing

contractor have used the principle of lean thinking to increase their annual turnover by 20% in 18 months. The key to this success was improvement of the design and procurement process in order to facilitate the construction site. They used a computerised ***3D design*** system to provide better, faster information provides isometric drawings of components and interfaces, fit co-ordination, planning of construction methods, motivation of the work crews through ***visualisation***. Further Khanzode *et al*. (2005) states that having a constructible design, reduces the amount of contractors' requests for information and change orders related to field changes. Additionally, MEP (Mechanical, Electrical and Plumbing) contractors are able to use more prefabrication which improves productivity on site and improved safety. And also, Staub-French *et al*. (2003) revealed that 3D models can be used for accurate quantity takeoff. When quantities are taken off manually there is lot of waste in construction process because quantity takeoff needs to be performed each time the design is updated. **3D models** can produce quantities automatically based on a means and methods database.

In the building sector, it has been customary for architects to work with customers to understand what they want, then produce facility designs intended to deliver what's wanted (Ballrad, 2011). The cost of those designs has then been estimated and too often, found to be greater than the customer is willing or able to bear, requiring designs to be revised, then re- estimated. This cycle of design – estimate – rework is wasteful and reduces the value customers get for their money. Cho and Ballard (2011) further stressed that cost, time, location and other constraints are conditions that must be met in order to deliver value to customers and implementation of ***Target Value Design*** has also consistently resulted in the delivery of projects faster and under budget, both market benchmarks and project targets.

Current practice in construction generally ignores or accepts large inventories or backlogs as the natural consequence of the commercial situation. According to Howell and Ballard (1998), lean works to eliminate those places where value adding work on material or information is interrupted. The Lean principle ***Make it Flow*** says that value development and therefore product components should be in constant motion that is without stopping. In construction this may mean repackaging work so that parts of the project can proceed without completion of others and / or assure that resources are delivered in order required directly to the installation location.

According to Kobayashi (1998); Hirano (1989) Seiri (Sort) refers to separate needed tools / parts and remove unneeded materials (trash). Seiton (Straighten or set in order) is to neatly arrange tools and materials for ease of use (stacks/bundles). Seiso (shine) means to clean up. Seiketsu (standardise) is to maintain the first 3Ss and develop a standard ***5S's*** work process with expectation for the system improvement. Shitsuke (sustain) refers to create the habit of conforming to the rules. Spoore (2003) indicates that 5S is an area-based system of control and improvement. The benefits from implementation of 5S include improved safety, productivity, quality, and set-up-times improvement, creation of space, reduced lead times, cycle times, increased machine uptime, improved morale, teamwork, and continuous improvement (kaizen activities).

Howell and Ballard (1998) revealed that ***Value stream mapping*** brings choices to the surface and raises the possibility of maximising performance at the project level. Normally maps are prepared at the project level and then decomposed to better understand how the design of planning, logistics and operations systems work together to support the customer value.

According to Koskela (1992), a specialist who transforms his/her perception on the client requirements i to Design Decision Previous researches confirm that the adoption of lean principles facilitate manufacturing through increasing productivity, reduction of manufacturing space, improving quality and safety, reducing lead time, reduce human effort, reduce investments in tools, reduce engineering hours to develop a new product and ultimately increasing of sustainability values. Vilashini *et al*. (2010) argued that many problems persistent with ***Prefabrication*** Production Process can be solved or reduced by adopting lean principles.

Terry and Smith (2011) state that taking a construction company, lean involves two significant paths; best people and the systems in place to control them. Figure 2 illustrates theses two paths.

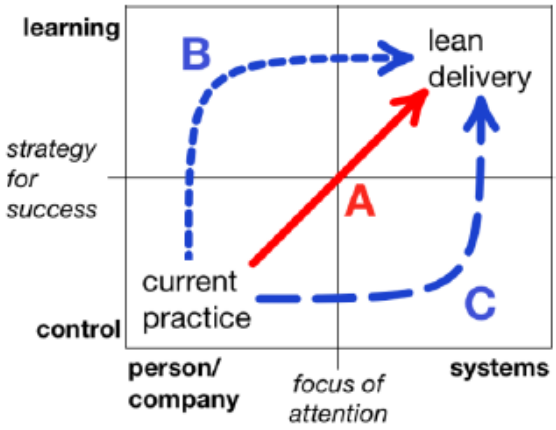

Figure 2: Paths to Implementation (Terry and Smith, 2011)

However, Howell (2011) argues that "successful transformations in my experience begin with action and study and lean construction focused on improving systems instead of individual motivation and training rather than control". According to Howell and Ballard (1998), both construction and manufacturing require prototyping that is the design of both product and process. Thus, implementing lean production does not require making construction manufacturing by standardising products, rather implementation starts by accepting the ideal of perfection offered by lean and understanding the application of each principle and technique to construction. Implementation of lean means adopting a "project-as-production-system" approach to construction.

On the whole, there is sufficient evidence on implementation of above discussed lean techniques in construction. However, some are implemented without the awareness on 'lean philosophy' and as a requirement of a quality assurance procedure. Hence, it is important that construction companies rethink about implementing lean techniques consciously to reap the real benefits of lean applications by avoiding general construction issues as discussed next.

3. BENEFITS AND BARRIERS OF LEAN CONSTRUCTION IMPLEMENTATION

Significant variations generally occur at every stage of construction process. Plans change and materials are late. Howell and Ballard (1998) stated that in compressed circumstances, variation becomes more apparent and critical as it exposes the interdependence between activities. When lean construction is implemented and the work environment is stabilised through modifying the planning system, it becomes possible to reduce variation in flows that improve the downstream operations. However, many researchers concluded that there is lack of interest among construction parties to sit for a weekly review meeting to solve the problems causing the plan failures (Salem *et al*., 2005 and Tzortzopoulos and Formoso, 1998). The other major problem which lies in the way is to make people change their mindset and be open to new ideas about managing construction projects. Salem *et al*. (2005) revealed that changing mindsets and behaviour with lean thinking become a challenge and to eliminate this barrier contractor need to offer training and recognition.

Howell and Ballard (1998) believed that lean production is a new way to coordinate action that rests on a new mental model and as problems are solved by "lean" the non-value adding flows would be recognised as problems in construction. Tzortzopoulos and Formoso (1998) stated that some clients have their needs which are not explicitly represented and some important aspects of design are abstracted away in the conceptualisation. Further, persisting problems in conversion may be identified as: not all requirements are identified at the beginning of the project, design errors are detected in later phases leading to costly rework and time delays. Lean thinking can address these problems.

Formoso *et al*.(1999), identified other general benefits when applying lean principles in construction; i) Reduce sharing of non-value adding activities, ii) Increase the output value through systematic construction of customer requirement, iii) Reduce process variability, iv) Reduce cycle times, v) Simplify

by minimising the number of steps parts and linkages, vi) Increase output flexibility, vii) Increase process transparency, viii) Focus on complete process, ix) Build continuous implement into the process, x) Balance flow improvement with conversion improvement, xi) Benchmarking.

However, Alarcon *et al*. (2006) revealed that there are barriers in implementation the lean construction. These barriers are; ***Time***: The main difficulty is lack of time for implementing new practices in the projects, ***Training***: Lack of Training, ***Organisation:*** Challenge to create organisational elements, ***Self Criticism***: Lack of self criticism to learn from errors, respond to some deficiencies, ***Low understanding*** of the concepts, Low use of Different elements, Inadequate administration, Weak Communication and transparency and ***Lack of integration*** of the construction chain.

Further, Koskela *et al*. (2010) stressed that the application of lean construction principles offer ***key benefits*** to prefabrication such as increase productivity, increase quality, increase sustainable values, provide better value to the customer and reduce human effort. On the other hand, Koskela *et al*. (2010) concluded that there are issues in implementing lean construction techniques, especially in prefabrication such as: waiting times, inventorying, moving, high quality controlling, requirement of efficient testing, stock keeping, less flexibility to varying design, standardisation and requirement of well trained people and resources.

Further, some researchers have attempted to apply lean principles in different construction delivery methods to get higher benefits. For example, Singleton and Hamzeh (2011) and Eagan (2004) have attempted to apply lean principles play a crucial to integrated project delivery (IPD) approaches such as in partnering and strategic alliances in order to maximise value and minimise waste on such projects. Further, Lamming (1996) relates lean principles to construction supply chain and Howell and Ballard (1998) to design process protocol and showed how benefits such as reduce variation in flows that improve the downstream operations and change people's attitudes could be achieved. Next section discusses suggestions offered by researchers in implementing lean principles in different construction contexts.

4. SUGGESTIONS OFFERED BY RESEARCHES ON SUCCESSFUL LEAN IMPLEMENTATION

Koskela and Siriwardena (2009) founded out that changes are needed in terms of the proper implementation of lean principles such as top management commitment to the implementation, sufficient technical experts regarding the lean production, a quest for a culture of continuous improvement the company, fullest dedication of workers towards the implementation, awareness of employees regarding the lean principles, change people's attitudes and sufficient management expertise to induce the changes in the production flow process. Further Salem *et al*. (2005) stress that the commitment of the top management of the construction firms for implementation of these lean tools may prove to be most important factor in successful implementation.

Some other studies offer guidelines for effective implementation of lean approaches. For example, Singleton and Hamzeh (2009) offer the following guidelines when implementation Integrated Project Delivery linking lean.

(1) Avoid a segmented and rigid sequence of design activities

(2) Explicit internal Client supplier relationships between sub processes

(3) Involve designers in joint solutions

(4) Work with a set of design alternatives

(5) Introduce control focus on flow activities

Further, Ballard and Kim (2006) offer guidelines for implementing lean;

(1) Select partners or suppliers who are willing and able to adopt lean project delivery

(2) Structure the project organisation to engage downstream players in upstream processes and vice-versa, and to allow money to move across organisational boundaries in pursuit of the best project – level returns

(3) Do target costing: define and align project scope, budget and schedule to deliver customer and stakeholders value

(4) Encourage thoughtful experimentation; explore adaptation and development of methods for perusing the lean ideal

(5) Celebrate breakdowns as opportunities for learning rather than occasions for punishing the guilty

(6) Do set based design: make design decision at the last responsible moment, with explicit generation of alternatives, and documented evaluation of those alternatives against stated criteria

(7) Practice production control; in accordance with lean principles such as making work flow predictable and using pull system to avoid over production

(8) Build quality and safety in to the projects by placing primary reliance by acting to prevent breakdowns

(9) Implement Just In Time and other multi organisational processes

(10) Use 3D modelling to integrate product and process design

These lean implementations and guidelines on different context could be useful in exploring lean implementation in Sri Lankan construction industry. Next section discusses Lean construction approach in Sri Lanka and the research problem of the study.

5. CONCLUSIONS AND WAY FORWARD

The aim of this paper was to explore the literature on how lean construction is implemented in different contexts in construction industries in the world.

The findings revealed several benefits when applying lean principles in construction such as;

- Reduce sharing of non-value adding activities
- Increase the output value through systematic construction of customer requirement
- Reduce process variability
- Reduce cycle times
- Simplify by minimising the number of steps parts and linkages
- Increase output flexibility
- Increase process transparency
- Focus on complete process
- Build continuous implement into the process
- Balance flow improvement with conversion improvement and benchmarking

The paper identified few barriers for implementing lean principles as ***Time***: The main difficulty is lack of time for implementing new practices in the projects, ***Training***: Lack of Training, ***Organisation:*** Challenge to create organisational elements, ***Self Criticism***: Lack of self criticism to learn from errors, respond to some deficiencies, ***Low understanding*** of the concepts, Low use of Different elements, Inadequate administration, Weak Communication and transparency and ***Lack of integration*** of the construction chain. Finally, the paper provided some guidelines on how to overcome the identified barriers for effective implementation of lean principles. These lean implementations and guidelines on different context could be useful in exploring lean implementation in Sri Lankan construction industry.

There are few studies conducted in Sri Lanka on lean construction. For example, through an opinion survey of construction workforce, Senaratne and Wijesiri (2008) establish that lean construction is suitable and acceptable in the Sri Lankan context. Further, Ekanayaka and Senaratne (2011) and Vilashini *et al*. (2011) have applied lean to Sri Lankan prefabrication production processes. Also, Ekanayake and

Senaratna (2010) discussed the sustainable benefits in application of lean in prefabrication production process. All these studies show that the Sri Lankan industry is behind in effectively implementing lean in construction processes. The industry lacks an implementation framework to implement lean principles into the construction processes. This research aims to develop such an implementation framework through action research study for Sri Lankan construction contractors and achieve long-term sustainable benefits by becoming lean. It is expected that the key literature findings arising from this stage, will assist to develop a conceptual implementation framework using lean principles for the construction process.

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