THE SIGNIFICANCE OF LEAN PRINCIPLES TO ACHIEVE RAPID CONSTRUCTION

Muhamad Azani Yahya[1] and Associate Prof. Dr Mohamad Ibrahim Mohamad[2],

Civil Engineering Faculty,University Technology of Malaysia,81310 Skudai, Johor, Malaysia.

This research is conduct as an attempt to answer the question of adopting lean principles to achieve rapid construction. The general approach within lean construction is to make the construction process as it is normally undertaken on the construction site and leaner by reducing non-value generating activities. The reason on why the lean principles are used into rapid construction is to solve the chronicle and congested activities within the time frame of the rapid construction projects. Five principles of lean were made into comparison in the review of three case studies. In many applications of construction technology, the use of Rapid Construction method components significantly decreased the construction time required for the project. From this research, the lean principles signified that it can be adopted in rapid construction projects. The most significant benefit has been seen in areas where systems have been using it repeatedly. The sharing benefits from lean principles into rapid construction are the shorten of order fulfillment leading times, less project downtime, more innovation and true reduce the chronicle predecessor. This research has also identified eight critical factors of integrating lean with rapid construction that are proven successful which are; 1) planning it right, 2) understanding the whole life construction cycle in non price factor view,3) utilize knowledge and expertise,4) integrate the team by working with the end to end supply chain in an integrated manner,5) understand the end to end process, 6) measure performance to include reporting in your own performance, 7) training and 8) benchmarking.

Keywords: lean principles, rapid construction, significant, process flow, eliminate waste

INTRODUCTION

Many reasons are given as to why construction projects are often completed late. As a result on non price factors, increased emphasis is being placed on improving work zone safety and minimizing traffic disruption, while maintaining construction quality and reducing the life cycle of construction and environmental impact. The use of innovative prefabricated systems away

Email: [1]azani@upnm.edu.my, [2]drm2i@yahoo.com

from the work zone can be an efficient solution, which would address many of the challenges in building construction, rehabilitation and replacement, in terms of the systems design effort, on-site construction time, minimum lane closure time, and

minimum environmental impact. Simultaneously with the requirements and specification drive for **rapid construction**, this methodology in construction sector can provide changes in project delivery methods within the period defined in the contract. With the basic intention to enhance the speed of construction, this terminology will be focusing on injecting **Lean Principles** by eliminating waste as a focus to drive project delivery in chronicle time. These principles are commonly used in manufacturing industry and not widely used in construction. In construction sector, rapid construction is crucial in the construction physic itself to change the view of the industry. So, this research will elaborate on how the lean principles can be adopted in the construction process flow to make sure the chronically time constrain of the project could be overcome.

RESEARCH AIM

This research shows the significance of lean principles to achieve **Rapid Construction** process, whereby this technology shall acts as a form work to derive change in the construction methodology. This research requires literature review and gathering published and unpublished experiences from construction environment on these types of systems. There are needs to further develop research in construction concepts that are suitable for different applications. This research then studies and determines the behavior of rapid construction analytically and experimentally, and develops limitations and practical applications for each system. To produce an eligible method, **lean principles** will be added to integrate with the construction flow. The purpose of these principles to be integrated in this research is to make this research unique and valid to be practiced in this professional sector. The fundamental aim for this research is to solve major problem in delivering projects that have taken into consideration the rapid period in a contract. It also considers the modernizing practice that can be done with the benefits for all construction industry as well as clients. There are lots of construction problems that occur during the construction itself until the handing over time which is why we can see many rapid projects are unable to be completed on time. Another significance of this research is to promote the lean principle that has been used in the manufacturing industry for the rapid construction process. These principles will be the variables in aiming the success of this research. The results of this research would also help to develop the technologies in construction by providing the means for the betterment of construction technology and also to solve the related problems in the construction flow.

RESEARCH OBJECTIVES

The need to place a greater emphasis on achieving a better construction technology which meets the needs of the end user at the earlier processes will make this research flow by the objective of:

1. Identifying the criteria of rapid construction project;
2. Integrating lean principles into rapid construction flow;
3. Identifying the benefits and critical success factors of lean principles in the rapid construction flow; and

4. Proving that these manufacturing principles of production can be effectively applied to achieve rapid construction.

METHODOLOGY

Research methodology as defined in the research method will be carried out in this study. The cost-effective usage of the revenue will only be achieved using the suitable method. Therefore, it is crucial to ensure data and information gathered to be exact and in line with the information and objectives of the study. This research methodology will touch on the aspects of procedure in the implementation of this study to ensure that the findings can be operated more orderly and effectively. This matter aims to ensure all data gathered are based upon valid sources and it is in accordance with objective of the study. The procedure will be starting by understanding the construction problem and the elements of rapid construction. Then the lean principles will be defined by conducting the literature review. All of these procedures will be conducted in the first phase of the study. In the second stage, the principles of lean will be compared to few case studies in order to get the suitability in approaching the rapid construction. These principles will be used to observe a construction process starting from the earthwork until the handing over process. The scope and the objective of this research will be the baseline in prducing the outcome.

LITERATURE REVIEW

Lean construction has at least two distinguishable focuses that makes it crucial in achieving a successful construction (S. Leticia, 2007). One focus is on the reduction of waste. Breaking from the conversion process model and production processes in terms of Koskela's flow process model (figure 5.1), it revealed that the time and money are wasted when materials and information are defective or idle. Instead of simply improving the efficiency of conversion processes, the task is extended to the management of flows between conversions. Secondly, in addition to its focus on waste, lean construction also focuses on managing flows and in order to do so, management systems and processes are put into the spotlight along with production processes. The flow management of the project is a much more difficult aspect in a complexity of rapid construction projects such as civil and structural. These projects are normally bound by time constrain, complicated supply chains and many players that are typically under pressure to get the final product and are subject to multiple, extensive process design changes motivated by the opportunity to make much more profit than its lost through disruption of construction. In this condition, traditional approaches to the management of construction usually fail miserably. The conversion process model conceals everything that needs to be revealed, particularly the design of systems and processes to manage work and work flow.

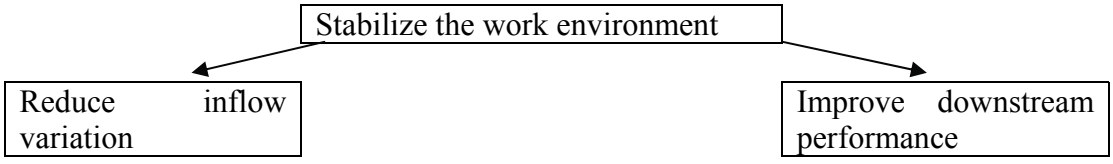

Figure 5.1: Stabilizing the work environment
Source: Lauri Koskela. "Application of the New Production Theory to Construction." (1992)

Definition

There are many definitions of lean construction and rapid construction found in literature. The summary of these definitions provide the new definition which is very suitable with the construction phase. This is because the construction term itself is bound by a contract. So, the perfect definition of lean construction and rapid construction are by Yahya M.A. (2008):

"*Lean construction is about managing and improving the construction process to profitability deliver what the customer needs by eliminating waste in the construction flow due to construction contract, specification and agreement between client and other parties by using the right principle, resources and measure to deliver things right first time."*

"Rapid construction is an activity of one kind project with complexity in construction due to limited time schedule, contract agreement, approved construction method and meets client satisfaction."

The term of rapid construction also given by the players in construction around the world such as below:

1. Method of construction technology to solve the chronic congestion which decrease construction time. (Kobayashi Osamu, Development of Two-level Crossing Rapid Construction Technology "Suisui-mop Method of Construction"(Part 2) -Test for Confirming the Performance of the Pier Pillar Precedence Build Method of Construction, 2005).
2. Construction due to limited schedule by using such methodology of construction method and shorter time of in the development of fusion as a potential large scale sources. (Chris Llewellyn Smith, United Kingdom Atomic Energy Authority, UKAEA, 2005).

Construction versus manufacturing process in Lean Principles

Lean principle or lean thinking got its name from a 1990's best seller call *The Machine That Changed the World: The Story of Lean Production* (J.Womack et. al., 1990). This book chronicles the movement of manufacturing from craft production to mass production until lean production. It tells the story of how Henry Ford standardized automobile parts and assembly techniques, so that low skilled workers and specialized machines could make cheap cars for the masses. The book goes on to describe how mass production provided cheaper cars than the craft production, but resulted an explosion of indirect labour: production planning, engineering and management. It shows how a small company set its sights set on manufacturing cars for Japan, but it could not afford the enormous investment in single purpose machines that seemed to be required. James P. Womack and Daniel T. Jones further distilled lean thinking into five principles:

1. Specify the value desires by the customer;
2. Identify the value stream for each product provided that that the value and challenge all of the wasted steps necessary to provide it;
3. Make the product flow continuously through the remaining and value added steps;
4. Introduce pull between all steps where continuous flow is possible; and
5. Manage toward perfection so that the number of steps and the amount of time and information needed to serve the customer continually falls.

In construction, projects are sold to the client in a different way. The process of purchase begins with a client who has need for a facility. The purchaser typically approaches a design professional to more specifically define the nature of the project. This leads to a conceptual definition of the scope of work required to build the desired facility (W. Halpin, 2006). Prior to the age of mass production, purchasers presented plans of the end object (e.g., price of furniture) to craftsman/contractor for manufacture. The craftsman then proceeded to produce the desired object. A chronological diagram of the event involved in the manufacturing process versus those in the construction process is shown schematically in figure 5.2.

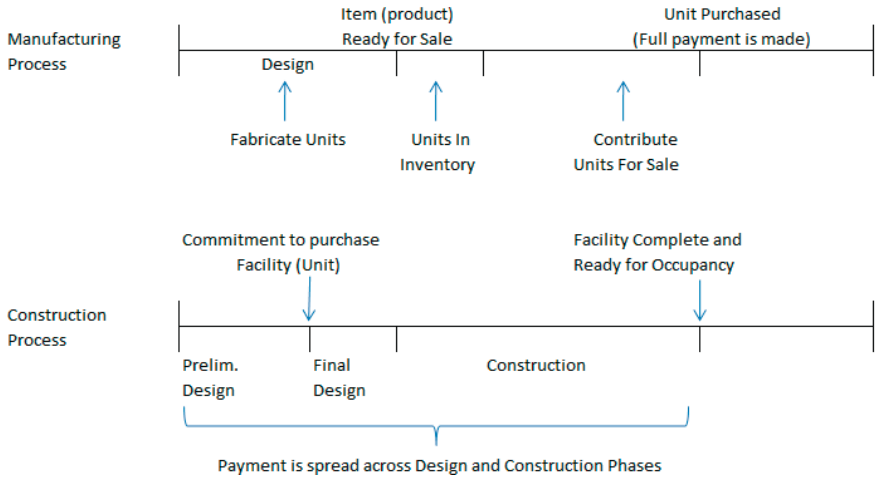

Figure 5.2: Manufacturing versus construction process
Source: Daniel W. Halpin. "Construction Management", 2006

According to J. Strickland (1997) in his paper called "*Applying lean Production principles to the construction industry*", lean construction is a planning and control system designed to improve project performance by improving the short term planning process. The words "short term" shows that these principles can be adopted in rapid construction. This lean concept is based on deceivingly simple ideas. Based on the paper, few argued that a construction crew will be able to accomplish greater work with less effort if:

1. Everyone in a team of project understand what they need to do and how their work need to be coordinated with other crew;
2. Everyone is able to comply on the schedules provided by other parties;
3. They have what they need to complete their task before they actually try to start it; and

4. The task has been scheduled so that it flows among crews smoothly.

To conclude this statement, making these thing happened is actually the goal of Lean Construction. To achieve a rapid construction, understanding and managing the construction process as a flow have been a key issue (S. Bertelsen et. al., 1999). A fundamental issue in construction physic is to understand the underlying causes of time and flow variability mainly caused by non-transformation stages of production (e.g. waiting, moving and inspection) and to characterize the effects of this variability in the overall production process (Gilbreth, 1992). The idea for the work on rapid construction is similar to the production of project, focusing not only at the main flow of the process of the product, but also verifying the statement that there might be more than one flow of determining the performance of the process. When discussing about rapid construction, all variations and customizations are foreseen and included in the project for real improvisation in the process features at the most limited time constrain.

From the physic of construction (Koskela, 2000), rapid construction is actually a process. This is because any constructions work package has conditions to be fulfilled without any delay, which is an important issue mentioned in the Last Planner System (Ballard, 2000). Koskela suggested that the precondition to that are construction design (information), components and materials, workers, equipment, space and external condition. Yahya M.A. (2008) reviewed that the external condition includes time and contract. Another model of the flows in the construction process was introduced by Ballard et. Al. (2002), who looked at the nature of the prerequisites for the process and found three types which are directives, previous work and resources. Directives provide guidance according to which output is to be produced or assesses. Examples are assignments, design criteria and specifications. Previous work is the substrate on which work is done or to which work is added. Examples include materials, whether raw or work-in-process, information that is input to a calculation or decision. Resources are either labour, instrument of labour or conditions in which labour is exercised. According to S. Lecitia (2007), lean principles can reduce the wastage and achieved rapid construction by reducing activities of:

1. Rework; and
2. Non-value adding activities and workflow such as waiting, moving, inspecting, accident and minimized variation order.

Review

Case study 1: (Source: Constructing Excellence, 2004)
Pacific Contracting of San Francisco, a specialist cladding and roofing contractor, had used the principles of lean thinking to increase their annual turnover by 20% in 18 months with the same number of staff. The key to this success was improvement of the design and procurement processes in order to facilitate construction on site by investing in the front end of projects to reduce costs and construction times. They identified two major problems to achieving flow the whole construction process – inefficient supply of materials which prevented site operations from flowing smoothly, and poor design information from the prime contractor, which frequently resulted in a large amount of redesign work. To tackle these problems Pacific Contracting combined more efficient use of technology with tools for improving

planning of construction processes. They use a computerized 3D design system to provide a better, faster method of redesign that leads to better construction information. Their design system provides a range of benefits, including isometric drawings of components and interfaces, fit co-ordination, planning of construction methods, motivation of work crews through visualization, first run tests of construction sequences and virtual walk through of the product. They also use a process planning tool known as Last Planner, developed by Glen Ballard of the Lean Construction Institute, to improve the flow of work on site through reducing constraints such as lack of materials or labour.

Case study 2: (Source: Constructing Excellence, 2004)
The Neenan Company, a design and build firm is one of the most successful and fastest growing construction companies in Colorado. The firm has worked to understand the principles of lean thinking and look for applications to its business, using 'Study Action Teams' of employees to rethink the way they work. Neenan's have reduced project times by up to 30%, through developments such as:

1. Improving the flow of work on site by defining units of production and using tools such as visual control of processes;
2. Using dedicated design teams working exclusively on one design from beginning to end and developing a tool known as 'Schematic Design in a Day' to dramatically speed up the design process;
3. Innovating in design and assembly, for example through the use of pre-fabricated brick infill panels manufactured off site and pre-assembled atrium roofs lifted into place; and
4. Supporting sub-contractors in developing tools for improving processes.

Case study 3: (Source: Construction in Fortaleza, Brazil by José and Alves, 2007)
In the early years of the 21 century, a construction company in Fortaleza (Ceará State, Brazil) decided to innovate by adopting concepts and tools based on the work of the Lean Institute Brazil. The initial phase of the implementation of Lean practices was supported by the work of academics and experienced consultants. The experience was successful as the company experienced fast and large productivity gains. Based on this experience, a group of academics, engineers, and consultants organized two international events about Lean Construction (International Seminar on Lean Construction – CONENX 2004 and 2006) and a set of classes on the topic as part of a larger program on innovative practices in construction (INOVACON). These events and the classes raised the interest of local and national construction companies for Lean Construction. As time passed, it became clear that companies that had adopted lean principles start moving forward in terms of sustaining the practices that had been implemented and implementing new ones. This phenomenon called some academics attention, and raised a discussion on the role of strategy definition and deployment when new practices are implemented to improve construction processes. It believe that some companies implement lean tools and practices from an operational stand point, but are not able to sustain their use because the implementation was not grounded on a solid basis, i.e., company business strategy. Some companies lack a vision of future to define which goals they want to achieve by implementing lean and which path they should take to achieve them.

ANALYSIS

Based on the case studies mentioned, the lean approaches definitely can shorten the time of construction. So, for the rapid construction, this approach is suitable to be integrated with the chronicle of construction flow which is the main element of rapid construction. For the use of this principle to run the rapid construction process, these principles are summarized as:

1. Value - Most organizations have probably analyzed processes, conducted customer surveys, and used audit to determine what customers want. Yet these techniques are not enough. Overall the stated techniques still departmentalize the value concept. A more holistic view of value that stretches beyond organizational boundaries and streams from manufacturer to supplier is to producer with an analysis of time and cost most effective in defining value. This is consistent with the Lean Thinking inclusion of "at a specific time". The timing of when a product reaches market has a strong influence over the perceived value of the product. One can associate this with the value you get from the measurement against perfection seems to be the most appropriate when focused on the "Price" portion of the value equation. Since the "ideal" is based on non-price attributes, such as "quality" and "time", value must be defined with a specific product with specific capabilities offered at specific time.

2. The Value Stream - The most effective process is achieved by performing the minimum number of non–value added steps. The method to maximize value-added steps in lean practice is through value stream mapping. The value stream is "specific activities required to design, order and provide a specific product from concept to launch and order to delivery of raw material into the hands of the customer". Performing a value stream analysis distinguishes three types of activities which are activities which unambiguously create value, activities which create not value but are unavailable with current technologies and production assets and activities which create no value and can be eliminated immediately.

3. Flow - The third principle is flow, once all the wasteful activities are eliminated the remaining value-creating steps need to 'flow'. Conceptually companies have a difficult time applying beyond internal departments. True integration of functions and departs in a company into product teams organized along the value stream enable and promote flow of information and materials.

4. Pull - Pull is defined as "a system of cascading production and delivery instructions from downstream to upstream activities in which nothing is produce by the upstream supplier until the downstream customer signals a need". The following three characteristics are necessary conditions for pull.

i. *Synchronization (Timing)*
Synchronization refers to aligning take times of interconnected process such that proper timing is in place, thus enabling flow and allowing for pull to be successful.

ii. *Alignment (Position)*
Alignment describes proper positioning that is necessary for pull to occur. In a manufacturing sense this could mean physical position, in a development point of view this could mean proper file format and location.

iii. *Transparency*
Transparency describes the ability to see the process totally and without obstruction as a means for identifying problems quickly and efficiently.

5. Perfection - Perfection is the continuous improvement aspect of Lean. Understanding that a process today is imperfect and that there is a need for continuous reexamination of the process or product is necessary to remain competitive and lean.

In many applications of construction technology, the use of Rapid Construction method components significantly decreased the construction time required for the project. From this research, the lean principles are significantly adopted in rapid construction projects. The largest benefits have been seen in areas where systems have been used repeatedly. The sharing benefits from lean principles and rapid construction are:

1. Shorten order fulfillment lead times;
2. Less project downtime;
3. More innovation; and
4. True reduce the chronicle predecessor.

The critical factors that are crucial in order to achieve success in this study are:

1. Planning it right;
2. Understanding the whole life construction cycle in non price factor view;
3. Utilize knowledge and expertise;
4. Integrate the team by working with the end to end supply chain in an integrated manner;
5. Understand the end to end process;
6. Measure performance to include reporting in your own performance;
7. Training; and
8. Benchmarking.

CONCLUSION

Based on the analysis, the rapid construction can be achieved through the basic principle which focusing on eliminating waste. The criteria of stabilizing the work flow can be achieved by injecting the lean manufacturing principles into the construction process flow. Lean construction is a new way to manage construction. The objective, principles and techniques of lean construction taken together form the basis for a rapid project delivery process. Unlike current approaches to managing construction (including design-build) and programmatic improvement efforts (partnering), lean construction provides the foundation for an operations based rapid construction project delivery system. While the transformation-flow-value theory broadens the understanding of project management, the perception of construction as a complex phenomenon opens up for the introduction of completely new approaches to project management. The ordered approach which gave rise to what can be called management-as-planning and management-as organizing should be reinterpreted and supplemented in future project management. Management as co-operation and as learning comes into focus. In this research hope, the consultant and contractor's

familiarity with the system led to significant reductions in construction time and improvements in overall economy. The use of material and workflow in this technology is to provide rapid construction, decrease environmental impacts, increase durability, and reduce on-site labour, resulting in better work zone safety. The elements of lean hopefully can give the logical practices in the construction industry as well in the successful of this research.

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