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REVIEW ON LEAN PRINCIPLES FOR RAPID CONSTRUCTION

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Abstract. 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 concept, the use of rapid construction method components significantly decreased the construction time required for the project. The most significant benefit has been seen in areas where systems have been using it repeatedly. The 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 planning it right, understanding the whole life construction cycle in non price factor view, utilize knowledge and expertise, integrate the team by working with the end to end supply chain in an integrated manner, understand the end to end process, measure performance to include reporting in your own performance, training and benchmarking.

Keywords: Lean principles; rapid construction; significant; process flow; eliminate waste

Abstrak. Penggunaan prinsip "lean" di dalam proses pembinaan adalah untuk melancarkan perjalanan proses pembinaan terutamanya di tapak binaan dengan mengurangkan aktiviti-aktiviti yang tidak penting untuk melengkapkan kitaran pembinaan secara efektif. Tujuan prinsip ini diadaptasi di dalam pembinaan yang pantas adalah untuk menyelesaikan masalah yang kompleks disebabkan oleh susunan aktiviti yang padat di dalam proses pembinaan itu sendiri. Lima prinsip utama "lean" telah disesuaikan dengan kajian kes. Di dalam aplikasi pembinaan, penggunaan konsep pembinaan pantas adalah sesuai untuk mengurangkan masa aktiviti-aktiviti pembinaan dan memenuhi kehendak tempoh pembinaan. Kelebihan daripada penggunaan prinsip "lean" di dalam pembinaan pantas adalah ianya dapat mengurangkan keseluruhan masa pembinaan, memenuhi kehendak masa pembinaan, lebih berinovasi dan mengurangkan masalah kepadatan aktiviti pembinaan. Kajian ini juga mendapati lapan faktor kejayaan dalam mengaplikasi prinsip "lean" di dalam pembinaan pantas iaitu perancangan yang tepat, memahami keseluruhan kitaran pembinaan dari aspek faktor bukan harga, penggunaan kepakaran, kerja berpasukan yang baik, memahami setiap proses, pengukuran kemajuan, latihan dan penanda aras.

Kata kunci: Prinsip "lean"; pembinaan pantas; kesesuaian; proses pembinaan; pengurangan pembaziran

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1.0 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 (Kentucky Transportation Center, 2005). The use of innovative prefabricated systems away 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 (Koskela, 1999). 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.

2.0 RESEARCH AIM AND OBJECTIVES

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 considers the modernizing practice that can be done with the benefits for all construction industry as well as clients. This study promoted lean principles for rapid construction process. In achieving the aim of this study, the following objectives are identified:

(1) To identify the criteria of rapid construction project;
(2) To evaluate the principles of lean for rapid construction flow; and
(3) To identify the benefits and critical success factors of lean principles in the rapid construction flow.

3.0 LITERATURE REVIEW

Lean construction has at least two distinguishable focuses that makes it crucial in achieving a successful construction (Lecitia, 2007). One focus is on the reduction of waste. Breaking from the conversion process model and production processes in terms of Koskela's (1992) flow process model (Figure 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 or 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.

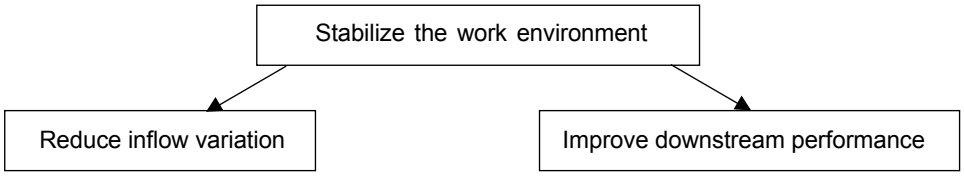

Figure 1 Stabilizing the work environment
Source: Koskela. "Application of the New Production Theory to Construction." (1992)

3.1 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 is bound by a contract. So, the perfect definition of lean construction and rapid construction are:

> "*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 a concept to enhance efficiency of construction process flow by time reduction to ensure the successes of project delivery in a chronicle time of contract and meets client satisfactions.*"

3.2 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* (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 Womack and Jones (2003) 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 (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 2.

According to Strickland and Kirkendall (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.

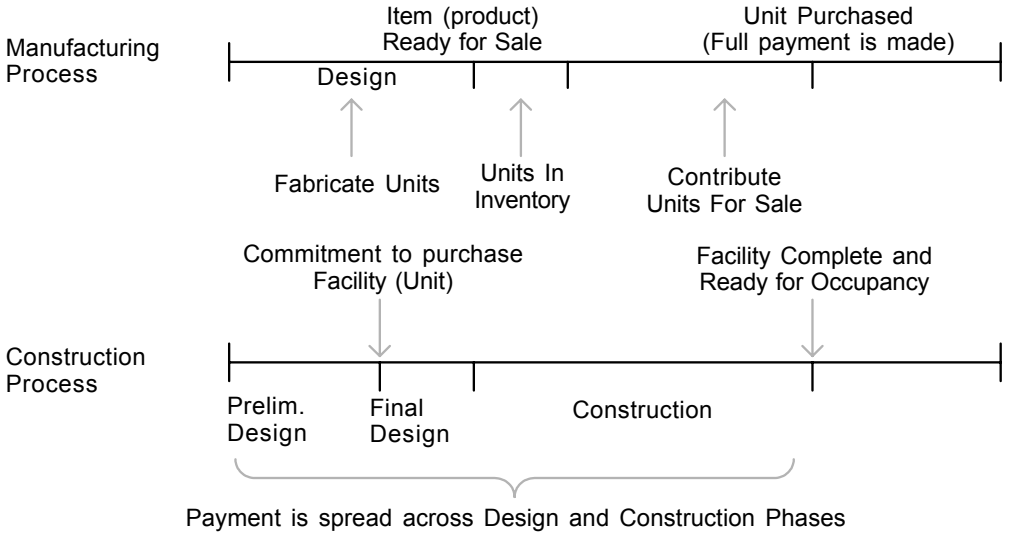

Figure 2 Manufacturing versus construction process
Source: Halpin. "Construction Management", 2006

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 (Bertelsen, 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 (Bertelsen *et. al*., 2007), 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 (2004) suggested that the precondition to that are construction design (information), components and materials, workers, equipment, space and external condition. 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 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.

3.3 Case review

Case study 1: (Source: Constructing Excellence by Watson, 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 of 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 and 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 Ballard (2000) 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 by Watson, 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 2004 and 2006) and a set of classes on the topic as part of a larger program on innovative practices in construction. 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.

4.0 METHODOLOGY

The goal of study in this context is analytic generalizations and thus cases research makes a contribution to adopt lean principles into construction process flow in time constraint. With this in mind, it was decided to review three cases in developing as rich a data set as possible to allow development of the principles along the areas and questions described in the objectives. This study will be starting by understanding the construction problem and the elements of rapid construction. Then, the area of lean including its principles will be explored and defined through 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. Last, the benefits and critical success factors within the context of study were defined. Contributions were summarized at the end of the chapter.

5.0 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 that 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 but 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 process, 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 as review in case studies. The largest benefits have been seen in areas where systems have been used repeatedly. The sharing benefits from lean principles and rapid construction are:

(i) Shorten order fulfillment lead times;
(ii) Less project downtime;
(iii) More innovation; and
(iv) True reduce the chronicle predecessor.

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

(i) Planning it right;
(ii) Understanding the whole life construction cycle in non price factor view;
(iii) Utilize knowledge and expertise;
(iv) Integrate the team by working with the end to end supply chain in an integrated manner;

(v) Understand the end to end process;
(vi) Measure performance to include reporting in your own performance;
(vii) Training; and
(viii) Benchmarking.

6.0 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. 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 concept is to provide rapid construction, decrease environmental impacts, increase durability, and reduce on-site labour, resulting in better work zone safety. Benefits from this integration can change the paradigm of current construction process by enhancing the efficiency. Critical success factors should be a growing interest by all construction players for improvement aspects. 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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