ACHIEVING RAPID CONSTRUCTION USING LEAN PRINCIPLES

Muhamad Azani Yahya
Civil Engineering Faculty
University Technology of Malaysia
Johor, Malaysia.
Email: azani@upnm.edu.my

Mohamad Ibrahim Mohamad
Civil Engineering Faculty
University Technology of Malaysia
Johor, Malaysia.
Email: drm2i@yahoo.com

ABSTRACT

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 fulfilment 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.*

Theme: Innovation in construction.

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. 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. 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

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 behaviour 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.

3.0 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.

4.0 LITERATURE REVIEW

Delay and cost overruns are the rule rather than exception in the construction industry. Lack of constructability late in the construction phase generating the failure of handing over project due to ripple effect which create delay and disruption throughout the entire organization are the largest

contributors to the state rule. Because of that, there is a need for improved coordination and performance of the building construction process flow. Means to analyze plan and manage by minimizing the waste and maximizing value. The construction process involves many parties and thus, special focus should be on the interrelated tasks of the numerous parties such in communication and interfaces. In the building construction industry of increased competitiveness, demand from many companies continued effort to develop new methods and tools, in which the design for quality, cost, constructability and reliability play an important role. The planning and management of construction process flow has historically focused upon traditional methods of planning. Little effort is made to understand the complexities of the construction process. The main concern of this chapter covered the modelled of overall building construction process systematically creating a general state of art model that covers the construction from early stage till completion.

Lean construction has at least two distinguishable focuses that makes it crucial in achieving a successful construction (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 4.1), 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.

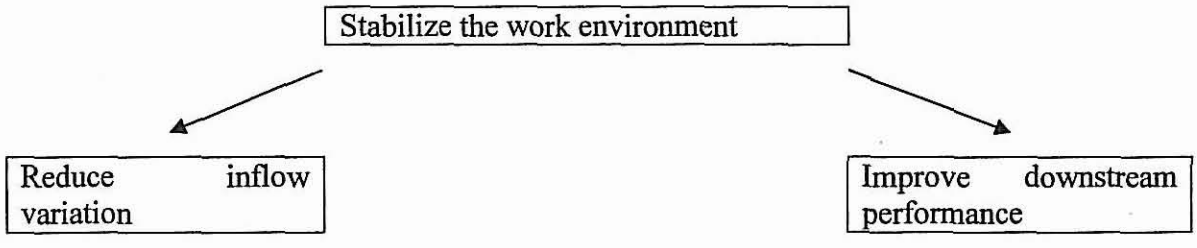

Figure 4.1: Stabilizing the work environment
Source: Lauri Koskela. "Application of the New Production Theory to Construction." (1992)

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 4.2.

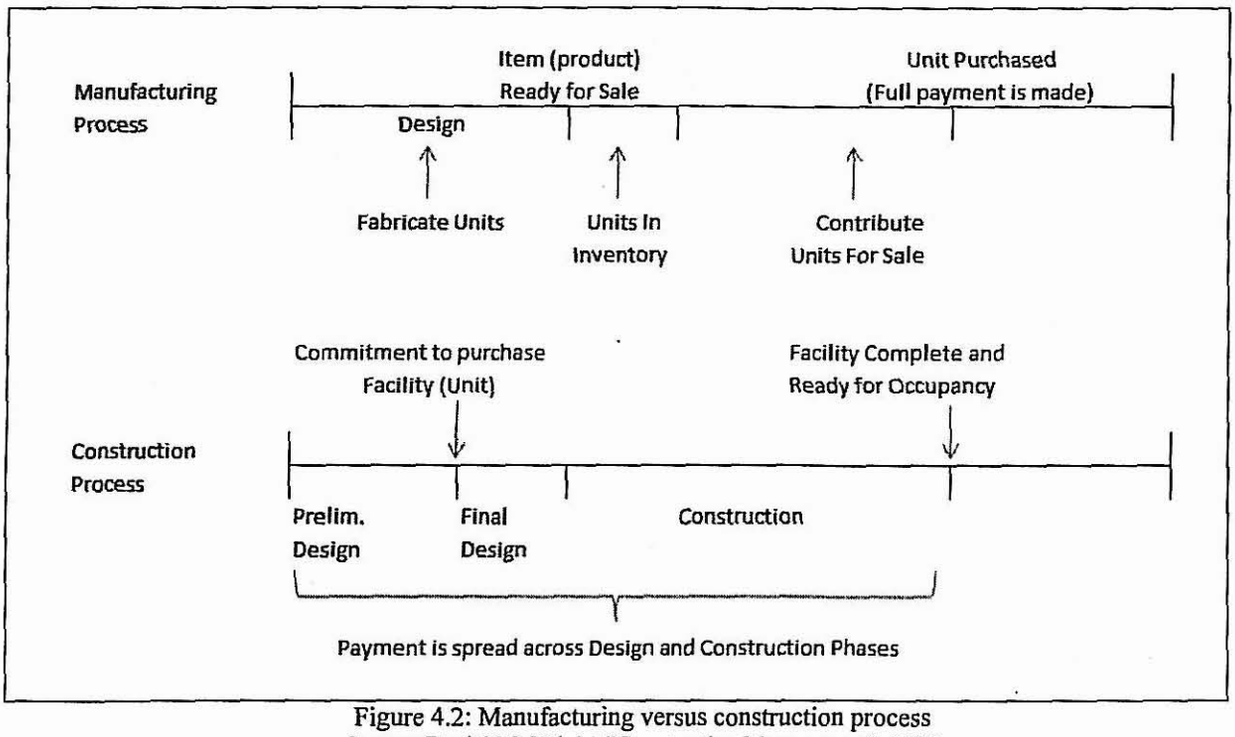

Figure 4.2: Manufacturing versus construction process
Source: Daniel W. Halpin. "Construction Management", 2006

According to 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 (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. It 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 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.

Rapid construction is a systematic approach in time reducing to deliver activities of one kind project with complexity in construction due to limited time schedule, contract agreement, approved construction method and meets client satisfaction. This definition seems comprehensive and it is cover on the construction physic itself. Koskela (1995) define rapid construction as the outcome of a continuous drive for construction time reduction. According to Chris Llewellyn Smith (2005) from UKAEA, rapid construction involving major step in the development of fusion as a potential large scale sources. Kentucky Transportation Center (2005), in their report of "Innovative Rapid Construction/ Reconstruction Methods" briefly describe that rapid construction is a construction project due to limited schedule by using such methodology of construction method and shorter time. Rapid construction is a terminology to enhance the construction process flow and to ensure the successes of project delivery in a chronicle time of contract. Major field of rapid construction are initiated by the contractor on project that contain unique design restrictions such as time constrains, project obligations or monetary provision. These factors encourage the construction players to develop innovative rapid construction methods especially when accurate project durations are established. From the definition of rapid construction, it is a process of stabilization and improvement of construction process flow. Koskela (2005) made observation that any construction work package (task) has seven precondition in order to be sound as construction project and delivered without any delay.

The preconditions are:

1. Construction design (information);
2. Components and materials;
3. Workers;
4. Equipment;
5. Space;
6. Connecting (previous) work; and
7. External conditions.

These precondition looks that the rapid construction projects have to have concentrated in the precondition to set up and launch the project. Another model of 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:

1. Directives;
2. Previous work; and
3. Resources.

Directives provide guidance according to which output is to be produced or assessed. 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, instruments of labour or conditions in which labour is exercised. Resources can bear load and have finite capacities. Consequently, labour, tools, equipments and space are resources (Ballard et. al., 2002).

5.0 ANALYSIS AND DISCUSSION

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 re-examination 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 fulfilment 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.

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. 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.

REFERENCES

Abdelhamid, T, (2004) "*Forum Minute: 4th Lean Construction Institute Academic Forum*", Atlanta, Ashley, David B, Lurie, Clive S. & Jaselskis, Edward J. (1987) " *Determinants of Construction Project Success*", Project Management Journal, Vol. XVIII, No. 2, pp. 69 - 79.

Austin, S., Baldwin, A., and Newton, A. (1994) "*Manipulating the Flow of Design Information to Improve the Programming of Building Design*", Construction Management and Economics, London, pp 445-455.

Ballard, Glenn. (2000) "*The Last Planner System of Production Control*", University of Birmingham, Doctoral Thesis.

Ballard, Glenn. (1999) "*Improving Work Flow Reliability*", Proceeding: Seventh Annual Conference of International Group for Lean Construction (IGLC-7), Berkeley, pp. 101-110.

Bourn, J. (2001) "*Modernizing Construction*", Report of the Controller and Auditor General, National Audit Office, London.

Brown, Kevin. "Re-*Architecting the Do Acquisition Process: A Transition to the Information Age*", MIT Master's Thesis, February 2006.

Daniel W. Halpin (2006) "*Construction Management*", Third Edition, John Wiley and Sons Inc, United State.

Koskela, L. (1995) "*Rapid Construction as a Change Driver in Construction Companies*" Proceeding: 3rd Workshop on a Lean Construction, Albuquerque, pp. 223-235.

Koskela, L. (1999) "Management *of Production in Construction; a Theoretical View*", Proceeding:
Seventh Annual Conference of the International Group for Lean Construction (IGLC-7), Berkeley, pp. 241-252.

Leticia S., (2007) *"Construction Design as a Process for Flow: Applying Lean Principles to Construction Design"*, Master Thesis of Engineering and Management, Massachusetts Institute of Technology.

Levitt, R.E., Cohen, G.P., Kunz, J.C., Nass, C.I., Christiansen, T., and Jin, Y. (1999) "*The Virtual Design Team: Simulating How Organization Structure and Information Processing Tools Affect Team Performance*", Computational Organization Theory. Lawrence Erlbaum Assoc. Pubs., Hillsdale, N.J.

Paul M. et. al., (2005) *"Innovative Rapid Construction/Reconstruction Methods"*, Kentucky Transportation Center, 2005.

Pixlery, David. (2006) "Applying *Lean Principles to Healthcare Construction*", LCI Symposium 2006, pp-10-11.

Tan W. L., (2004) *"The Application of Lean Construction to Reduce Wastes in Construction Process Flow"*, Master Thesis of Project Management, University Science of Malaysia.

Tzortzopoulous, P., and Formoso, C.T. (1999) "*Considerations on Application of Lean Construction Principles to Design Management*", Proceeding: Seventh Annual Conference of the International Group for Lean Construction (IGLC-7), Berkeley, pp. 335-344.

Kartu V., (1997) *"Construction Process Model"*, Technical Research Centre of Finland.

Womack, James P.,Daniel T.Jones and Daniel Roos, (1990) "*The Machine That Changed the World: The Story of Lean Production*", New York: Rawson and Associates.

Womack, James P., Jones Daniel T., (2003) "*Lean Thinking*", New York: Free Press.

Yahya M. A. and Mohamad M.I., (2009) "The Significance of Lean Principles to Achieve Rapid Construction", Proceeding: National Postgraduate Conference on Engineering, Science and Technology, Malaysia, pp 61.

Yahya M. A. and Mohamad M.I., (2009) "*Rapid Construction Criteria and Its Implementation in Construction Industry*", Proceeding: The Management in Construction Researchers Association 2009, Malaysia, pp 122-128.

Authors's Biography

***Muhamad Azani Yahya** has been awarded the bachelor degree in Civil Engineering in 2002. He has 7 years working experience as a civil engineer with contractors and consultant firm. In 2006, he was awarded the master of science in Project Management. In 2007, he joint Universiti Pertahanan Nasional Malaysia as a lecturer and currently doing PhD. in civil engineering. Current research area is in rapid construction concept.*

***Mohamad Ibrahim Mohamad** is the Head of Construction Technology and Management Centre (CTMC), Faculty of Civil Engineering at Universiti Teknologi Malaysia. He earned his Doctoral degree from Loughborough University, UK in the area of Construction Management. Current research area are in Collaborative Working Environment in Construction, Rapid Construction and Managing Structural Failures.*