

LEAN AND GREEN CONSTRUCTION

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Abstract— Today, the construction industry is facing a number of problems which include cost overrun, completion delay, low productivity, poor quality. These inherent problems need to be solved and taken care of in order to bring an overall change and improvement in the current scenario of the construction industries. The need for the change can only be resolved by the Lean construction and Lean project management approach. Today, people have started to be concerned about the 4 R's i.e. Reduce, Recycle, Reuse and Regulate. In the recent years, eliminating the 'concept of waste' and creating a healthier environment through design and management has become a prime goal, thus involving the issues of sustainability in construction. The paper would bring out the deep connections of the lean and green philosophies, both seeking to reduce waste. It would explore as to how the lean strategy in the construction industries help to bring out a green and sustainable built environment.

Index Terms— Lean Construction, green, Sustainable construction, sustainability, environment, sustainable development, lean principles.



1. INTRODUCTION

The construction industry plays a significant role in economic growth, both directly through its activities, and indirectly through the provision of buildings and infrastructures for the smooth functioning of businesses. However, the construction industry is highly challenged as a 3D's industry - dirty, dangerous and demanding.

Lean production focuses on eliminating waste and maximizing productivity through the pull system, employee involvement, continuous improvement, etc. Much has been discussed about the waste elimination and productivity improvement that can be achieved by applying the lean concept. However, as the consideration of the environment is becoming an increasingly important part of the construction culture, there is a need to investigate the applicability of the lean concept to achieve environmental sustainability, which is often used interchangeably with the term "green".

2. THE PRACTICAL RELATIONSHIP BETWEEN LEAN METHODS AND SUSTAINABLE IMPACTS- THE LEAN DELIVERY PHASES-

The Lean Project Delivery system consists of four interconnecting phases extending from Project definition to Design, supply and assembly. (Fig.1)

The Project Definition consists of three different modules: Needs and Value Determination, Design Criteria and Conceptual design. Defining value and waste is critical

in Lean production. Value management aims to maximize value and eliminate waste. Recently more studies have introduced the environment as an additional "customer" for sustainable facilities (Horman et al., 2004; Lapinski et al., 2005). Minimal building impact, maximum building system efficiency, energy efficiency, waste reduction, and a healthy, productive environment for occupants are the key features of the lean and green construction. The social impact of facilities has been one of the critical concerns in the architecture industry. It is hard to measure the social impacts of facilities on humans and communities. Together with the economic and environmental bottom lines, the social bottom lines also included in Sustainability. Lean construction needs to identify sustainable values including economic, environmental and social values as important factors in implementing sustainable construction.

Lean Design

It is a process that includes various construction techniques and materials to produce value to an owner. This process is very important considering the impacts to the overall life of a facility. The green facilities can only be applied to its best in a design contributing to sustainable construction only if the use of green materials, resources and the construction technologies is comprehensively coordinated with each other. The impacts of this green facility phase on the Operation and Management phase are remarkable. One researcher suggests that a mere one percent of the initial costs in the early phase of a project address seventy percent of its life cycle costs (Romm, 1994).

In order to minimize environmental impacts and energy consumption during construction of sustainable facilities, several Lean design methods could be implemented: Integrated Design (Whole system design), Design for Maintainability (DFM), Set-based Design, Target Costing, and 3D Modeling.

Integrated Design is one of the most critical methods for sustainable construction (Hawken et al., 1999;

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Riley, 2004; Horman et al., 2004; Lapinski et al., 2005). The most important feature of the Integrated Design method is to integrate various green materials and construction technologies by encouraging stakeholders in the design phase for maximizing the sustainability of a facility while reducing the need for energy, equipment, or resources.

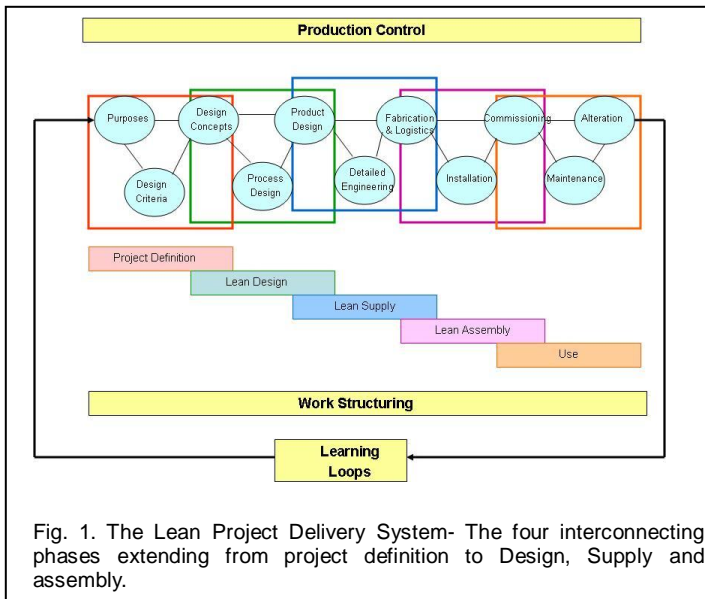


Fig. 1. The Lean Project Delivery System- The four interconnecting phases extending from project definition to Design, Supply and assembly.

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Design for Maintainability (DFM) is a design strategy focusing on the reliability and ease of maintenance of a facility (Dahl et al., 2005). These methods increase the importance of O&M in the design phase of a facility. Operations & maintenance (O&M) costs are the largest portion of the total expenditures over the life of the facility, typically accounting for 60-85% of the life cycle cost. The safety and wellbeing of the occupants and of a community can be ensured by addressing social issues during the design phase in a sustainable construction project. Moreover, these social benefits may improve external images of the sustainable construction project.

Lean Supply

Just-in-time (JIT) could also be regarded either as an environmentally-friendly method or the opposite. Just-in-time reduces damage and materials (Riley et al., 2005). Moreover, this method may reduce the various sources of extra inventory but at the same time, however, the frequent transportation of inventory and materials may cause volatile organic compounds and CO₂ emissions. Several Lean plants have recognized that a Just-In-Time strategy has caused more air emissions of volatile organic compounds in the plants, while contributing flexibility of operations and reducing inventory level (Rothenberg et al., 2001). Therefore, the plants have reconfigured some of their Lean management principles to reduce their air pollution emissions. Even though applications in the manufacturing industry and construction industry are not exactly the same, we need to notice the probabilities and possibilities of bad environmental impacts from Lean adaptation. The consideration from the holistic perspective is required to increase the sustainability of a construction project.

Lean Assembly

One of the most successful procurement methods that can be adopted to achieve sustainability is the Prefabrication. Economic, social, and environmental indicators from (Horman et al, 2005) examined the impacts of prefabrication for purposes of sustainability using these indicators (Horman et al., 2005 in Luo et al., 2005). The features of prefabrication on sustainable constructions include:

- Increased potential of improved supply chain integration of green materials
- Safer working conditions
- Reduced environmental impact due to transferring workers, machines, staked materials, temporary structures and onsite activities to a prefabrication plant
- Easier recycling of materials in an off-site environment
- Enhanced flexibility and adaptability
- Reduced overall life cycle cost
- Reduced economic impact in local communities.

Prefabrication may have both sustainable benefits and disadvantages depending on the exact conditions of a project. These impacts fall into three categories: economic, social, and environmental. Thus, economically, one advantage is the reduced cost of prefabricated units as opposed to on-site units. Socially the working conditions are safer and more stable in prefabricated construction than they are on-site. Environmentally, this method may improve the supply chain for green materials, one aspect of green facilities. Yet, there are some problems as well. Economically, and socially, less local labour is needed, thus the salaries of the workers do not contribute to the local economy. Environmentally, this process may consume more energy for transportation of prefabricated products and emit more air pollution.

A contractor implementing sustainable construction should identify both benefits and disadvantages of prefabrication and reference them for the selection of the best procurement method using a holistic view over the life cycle of a project.

Kaizen, which means continuous improvement in Japanese, is a core component of Lean production not only for economic purposes, but also for social and environmental purposes in sustainable construction. Kaizen plays a key role in improving the current status for sustainable construction. All sustainable indicators may be improved through Kaizen.

Another potential tool for sustainable perfection is Kaikaku. Kaikaku (Kaizen events), means a rapid process of improvement, is a team activity designed to eliminate waste and make rapid changes for product and process improvement in the workplace. This strategy is employed to get workers with multiple organizational functions on different levels to unite in improving processes and addressing problems. When implementing chosen improvements, the team rapidly employs inexpensive solutions usually within three days. Kaikaku can create reduced pollution and material waste. Environmental Health and Safety staff must participate in Kaizen events due to the possibility of non-compliance and exposure of workers to hazards. Suggestions may be made by EHS staff to facilitate the process (US EPA, 2006).

the sustainable construction of a facility, while several Lean construction practices reveal no relationship or negative relationships.

Like most industrial processes, current construction practices are linear. They use energy and natural resources, convert them to the built environment, and discharge waste. The large quantities of debris left over from demolished buildings are examples of waste from a linear process. Experts recommend a cyclical construction process that puts a greater emphasis on recycled, renewed, and reused resources. This cyclical construction approach should be accompanied by reductions in energy and resource use. The cyclical method could conceivably reuse much of a discarded building to erect a new one in its place. The adoption of this concept is likely in developing nations only if industry, academia, and government join forces and address it as a long-term goal, but with a plan for gradual, measurable progress towards its attainment.

The Lean principles emphasise on eliminating process and material wastes and which can further result to the green construction which emphasise on the energy efficiency and the cost efficiency. The Lean and green Construction philosophy can tremendously improve the needs and result in high productivity of the construction industry. The lean and green theories both compliment each other.

Lean construction is all about removing waste from the construction process, thus making it most efficient. Green construction also emphasises and focuses on the removal of waste from the construction process but also adds an environmental dimension to lean construction. The green construction in addition to the theories of lean construction also focuses on the recycling, reusing of the resources thus making the process and the project cost efficient and most productive.

Lean Project Delivery Phases	Methods/Tools	Sustainable Impacts		
		Economic	Social	Environmental
Lean Project Definition	Integrated Product Teams	O	O	O
	Performance-based Contracting	O	O/X	O/X
	DBOM	O	O	O
Lean Design	Target Costing	O	O	O
	Integrated Design	O	O	O
	Design for Maintainability	O	O	O
	Set-based Design	O	-	O
Lean Supply	JIT	O	-	O/X
Lean Assembly	Prefabrication	O/X	O/X	O/X
	5Ss/6Ss	O	O	O
Over Whole Delivery Process	Value Stream Mapping	O	O	O
	Kaizen	O	O	O
	Kaikaku (Kaizen events)	O	O	O

O: positive impacts; X: negative impacts; O/X: Both positive and negative impacts; -: no impact

Fig. 2. Lean Methods and Sustainable Impacts – The quantitative assessment on the sustainability of a construction project.

Figure 2 illustrates a quantitative assessment of the previously discussed methods on the sustainability of a construction project. Most lean construction methods provide positive economic impacts for sustainable facilities while showing several no-impacts or negative impacts on social and environmental aspects. The table shows concrete relationships between the Lean construction methods and

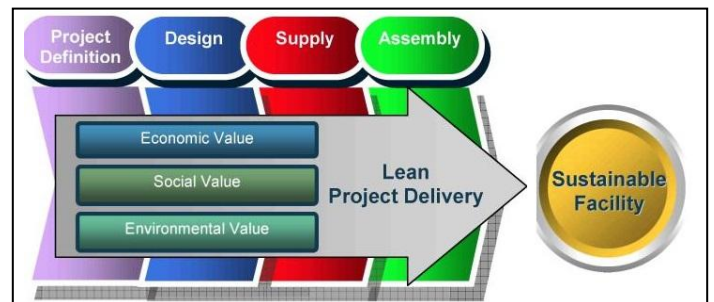


Fig. 3. Relationship between sustainable development and Lean production – The four interconnecting phases of Lean Project delivery System.

In the figure 3, the four interconnecting phases of the Lean Project Delivery System (LPDS) extending from project definition to design, supply, and assembly are used to illustrate the Lean construction process (Ballard, 2000).

Addressing sustainable issues, such as economic, social, and environmental values as the requirements of an owner, Lean may act from the project definition to the construction phase for a sustainable facility.

Lean principles can be implemented in the design phase of the project to attain cost reduction and enhance sustainability. Value Stream mapping is a good example of making a project most efficient from the design phase to the construction phase. The value stream mapping (VSM) is a tool created by the lean production movement for redesigning the productive systems. A value stream map is a complete model of the project that reveals issues hidden in current approaches. Value stream maps can be understood as process flow charts that identify what action releases work to the next operation.

3. CONCLUSION AND RECOMMENDATION

The research tries to bring out the need for the implementation of lean philosophy in the construction industry. The values and the principles of the Lean construction and clearly discussed and compared with the present scenario of the industry. The main reason for the evolution of Lean Construction is the incompleteness of the typical construction followed today. Lean Construction should be adapted and considered as it can solve many problems of the construction industry and the project management as the cost over run, poor quality and the delays.

The importance of environmental aspects cannot be separated from the lean construction as they add value to each other when combined and used correctly. The methods of lean construction should be extended to environmental planning to help improving the efficiency of the production management process.

In this paper, most of the lean construction methods and the green construction methods are studied and examined. Although there are many other lean construction methods which are not been examined for sustainability, but if studied in future, will surely have a possibility for sustainable purpose.

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