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Lean Construction - Approach Capable of Dealing with Complexity and Uncertainty

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ABSTRACT
The construction projects involve various risk factors which have various impacts on objective that may lead to low productivity and time-overrun. One way of contributing to the productivity improvement is to implement lean. Lean or lean thinking was implemented for the first time by the car manufacturer Toyota and has been used in the manufacturing industry for decades. In the construction sector, lean have not been implemented as much as in the manufacturing industry and therefore there is room to take lean further in construction projects. The aim with lean in construction projects is to utilize the resources as labor and material better to get less waste, fewer delays and lower costs or, in other words, to minimize the Non-Value adding Activities. The objectives of this paper are to provide with fundamental knowledge and benefits of Lean Construction and its capability to enhance performance in construction thus the quality of life for future Indian construction sector.
Keywords: Lean, Construction, Project, Management.

I. INTRODUCTION

Infrastructure sector is a key driver for the Indian economy. Construction sector is highly responsible for propelling India's overall development and enjoys intense focus from Government for initiating policies that would ensure time-bound creation of world class infrastructure in the country. India as a developing country faces many complex difficulties in construction business, such as inadequate details and documents of preceding data concern risks and lack of adapting modern techniques for minimizing the effect of risk factors on projects objectives. One way of contributing to improve performance and increase productivity is to implement lean construction. Lean concepts are implemented for the first time by the car manufacturer Toyota and have been used in the manufacturing industry for decades. In the Indian construction industry, lean have not been implemented as much as in the U.k, U.S.A, Sweden, Denmark etc. and therefore, there is room to take lean further in construction projects. Lean construction sets productive flows in motion in order to develop control systems with the aim of continuous improvement to eliminate waste by sorting out Value adding Activity (VA) and Non-Value adding Activity(NVA) [1]. The objective of Lean in construction is to utilize the value adding resources as labour and material better to get less waste, fewer delays and lower costs or, in other words, to minimize the NVA. In general sources for the NVA wastes in construction are Transportation, Inventory, Motion Waiting, Overproduction, Over processing and Defects. Elimination of these wastes is achieved through the successful implementation of lean elements [2]. The time spent on NVA varies though, significantly among construction projects. The average is that, just below 50% of the time in construction projects are spent on non-essential or wasteful activities as Non-Value adding Activity. The waste of material in Dutch construction industry is 09% by weight while the purchased material waste in Brazil is 20-30%. Koskela discussed the waste, VA and NVA in the construction by referring to several studies. The cost for waste by poor quality is between 5 % and 20 % of the total project cost while the cost for bad material management is around 11 % of labour cost and excess material usage is around 10 %. From the reviews of the literatures, Lean Construction is able to overcome the challenges highlighted previously. Koskela et al argues that Lean Construction is a system that will be able to work with the complexity in the site and still be able to minimize the wastage hence implement lean construction is possible only with the collaboration of the Owners (client), Architects, Engineers, Contractors, Facility Managers, and End-users for the project [3].The authors who researches in lean suggested

- That lean production is able to reduce the overall cost while maintaining the quality standards and reducing cycle time.
- That lean construction is different from other construction management due to its clear set of objectives. It's aimed for the delivery process, concurrent product design and process, and production control throughout the life of the project [4][5].

The foremost objective of this paper is to provide a basis knowledge and understanding on lean construction for Indian construction

stakeholders. An extensive literature review was conducted in order to achieve the objectives of this paper. This paper is also aimed at highlighting on how to incorporate the LCM concept in the construction industry to promote sustainable construction.

Problem Description

Up until now, researcher's attention has been paid in explaining lean as a philosophy of management, with its principles and objectives. Furthermore, it has been described the need to reform project management and how lean can be adapted from manufacturing to construction in order to enhance current project management practices. It is well known the increasing interest of companies in new project management methods that allow them to reduce duration, increase performance and avoid confrontational relations during project execution [5]. So far, lean project management practices are relatively new and few authors have explained its theoretical foundations as well as its convenience for different types of projects according to their complexity. On the contrary, researchers have focused on decreasing uncertainty instead of trying to deal with situations of uncertainty and complexity. In addition, since construction projects will continue to become more uncertain and complex over time, a change in investigation needs to be done. Thus, a study about lean construction management together with project risk management and its practices results necessary in order to enable managers to assess project complexity. Then, when the challenge presented by each project is established, it will be possible to choose the best approach to manage the project, traditional or lean [6-8]. So, in a complex construction identifying a optimum solution for any uncertain task is a high priority to avoid delays and cost-overruns, hence with-out the knowledge of lean construction, identify an optimum solution for uncertain task would be inadequate if the outlook is only limited to traditional management.

Lean Production

Lean production beat mass production in several ways. [10]. The time is cut, defects are reduced, inventories and manufacturing space are reduced and in lean production it is possible to change from one product to another much faster than in the mass production system. Products produced in lean production process are replaced more frequently and the variety of models is higher than in mass production. Lean production, as a system with the aim of producing more with higher quality and less space, time, material and labor than the mass and craft production systems. Which are archived by using tools as just-in time deliveries, pull mechanism, reduced batch size by reduced set-up times and increased transparency where everybody is involved in the production system. [10] [11] The lean system that was developed in Toyota could be seen as a pyramid with different levels of lean implementation [12]. The pyramid with lean principles, is presented in Fig. 1 below.

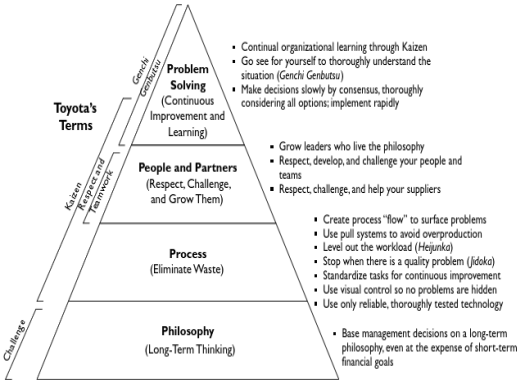

Fig 1 - Different stages of implementation of lean [12]

Basically, lean construction is a big scale of adaptation from the Japanese manufacturing principles and the concept is implemented to the construction process [13]. Cullen et al. stated that the principles of lean construction, which arose from adapting the concepts of lean production, had been developed by leadership of Taiichi Ohno. Starting from efforts to reduce machine set up time and influenced by total quality management, he developed a simple set of objectives for the design of the production system, which is to produce a car to the requirements of a specific customer, deliver it instantly, and maintain no inventories or intermediate stores [14] [15].

II. LEAN CONSTRUCTION

Despite lean was originally developed or defined from the car manufacturing industry and Toyota, Womack et al. argued that lean production could be used with benefits in all industries. Such an industry could be the construction industry. Lean production is today used in several others industries than the manufacturing industry, e.g. healthcare, service and construction [16]. Lean in construction projects has been promoted in countries as USA, United Kingdom and Denmark while different kinds of lean construction institute have been founded in several countries, e.g. Lean Forum Bygg and Lean Construction Institute. Lean in construction projects has also been discussed and promoted in professional press and among lean construction networks, but not that much in articles and papers in peer-reviewed journals [17]. Researchers as Koskela have discussed lean in construction for over two

decades. Construction companies have discussed implementation of lean the recent decade to create competitive benefits of cost and time predictability, quality, supply chain relationship and flexibility, and also stronger relationship to the client. The formulation lean construction got its name by Lauri Koskela at a conference with a few researchers in Finland 1993 [3] [18] [11].

Lean Construction has been introduced as a new management approach to the construction industry by Koskela and Howell. It is hoped the successful adaptation of this concept will not only be beneficial to the clients but also to the communities and environment itself. There were barriers in their implementing lean concepts in the construction fields[19]. This point of view is affirmed by Separate and Wijesiri, which stated that if a company successfully implements the concept of Lean Construction, it would be able to gain significant cost advantage by eliminating cost-consuming flow activities and become a cost leader. [20] Furthermore, construction industries all over the world such as Australia, Brazil, Denmark, Ecuador, Finland, Peru, Singapore, United Kingdom, United States of America and Venezuela have implemented the lean concepts within the industry and have earned its benefits [21]. Moreover, the Lean Construction approach is different from the normal practices as lean construction is based on production management principles and it gained better results in complex, uncertain and quick projects [22]. The characteristics that could define complexity are summarized and are presented below.

- Large number of elements where the interaction is non-linear and dynamic, and the system changes over time.
- The elements are different; the variability is high and the relations among the elements vary.
- Unanticipated variability and uncertainty.
- The resilience of the system and the system's ability to adjust the functioning to changes and disturbance.

The characteristics are applicable to construction projects and therefore construction projects are complex systems. Saurin et al. concluded that lean prescriptions are compatible with complex systems and that lean helps to reduce the unnecessary complexity [23]. The below comparison can differentiate the processes between lean and traditional construction process.

Lean construction process	**Traditional construction process**
Focus is on production system.	Focus is on transaction and contracts.
Transformation, flow and value goals.	Transformation goal.
Downstream players are involved in upstream decisions.	Decisions are made sequentially by specialists without downstream players input.
Product and process are designed together.	Product design is completed, then process design begins
All product life cycle stages are considered in design.	Not all product life cycle stages are considered in design.
Activities are performed at the last responsible moment.	Activities are performed as soon as possible.
Systematic efforts are made to reduce supply-chain lead times.	Separate organizations link together through the market and take what the market offers.
Learning is incorporated into project, firm and supply chain management.	Learning occurs occasionally.
Stakeholder interests are aligned.	Stakeholders interest are not aligned.
Buffers are sized and located to perform their function of absorbing system variability.	Buffers are sized and located for local optimization.

Table 1 - Summary between lean construction processes and traditional construction processes [11]

Today's construction projects, particular the larger ones, have a numerous sub-contractor. Even though the negotiated price between the main contractor and the client is fair and includes opportunities for a qualitative work, the contract between the main contractor and the subcontracted entrepreneurs might be less fair. [24]. This lead to the sub-contractors adjusts their own profits with a high possibility low qualitative work instead of contributing to the total value of the construction process. Because of the complexity and uncertainty in a construction process, it is important to have responsibilities and relationships between the actors that reduce the complexity and uncertainty, and enable the possibility to deliver a lean project.

III. LEAN CONSTRUCTION PRINCIPLE

The traditional project management practices treat all the activities in construction as value adding activities (those which cannot be removed) and accordingly the construction process is a conversion based process in which one value adding activity leads to another. Uncertainty in work flow places great demand on communication channels as people attempt to find some way to keep the project or their crew moving in the face of uncertainty. But flexibility defined in this way

requires slack resources and injects more uncertainty into the flow of work. This states that as soon as one activity is finished the other should start irrespective of the fact whether the other pre-requisites of the activity like materials, labor and equipment are available. This model pressurizes the available resources to act fast thereby resulting in a compromise in the quality of the construction. On the other hand, lean construction is a flow and conversion based model where a construction process is a collection of conversion processes involving flows of information and materials from one process to the other as depicted in managing and improving the construction process to profitably deliver what the customer needs [25].

Key Principles

Womack and Jones (2003) established five key aspects in lean methodology that are necessary to avoid waste. Lean thinking provides a method to specify value, align the actions that create value according to the optimal sequence, carry out these activities without interruption when someone requests them, and perform them with increasingly effectiveness. Figure 2 shows the key principles of lean management. [25].

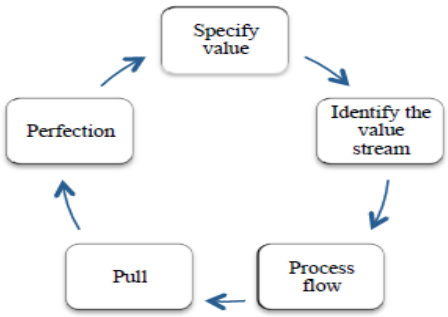

Fig 2: Lean principles

- **Specify value**

Value in construction is like value in any business: it is a return of investment. So, value needs to be defined from the perspective of this client, which meets the client's needs at a specific price at a specific time. It is defined according to the end consumer and is expressed in terms of a specific product that meets customer's needs with a concrete Specify Value Identify the value stream. In order to achieve this, it is necessary to redefine the concept of value in companies, the main objectives of stakeholders and managers exceed the concept of creating and specify value to the consumer or client[25].

- **Identify the value stream**

The value stream is the set of all the specific activities required to produce a specific product. Value-stream mapping is a process of identifying all the VA and NVA of any process. The objective is to find a process to eliminate those wasteful activities. At a top management level, it offers a perspective on defining what is to be done and how the systems are to be designed, supplied and constructed, offers a different way of organizing for construction. At a operational level, the value stream map can identify where NVA of a particular process is present. This process analysis shows how value stream can be achieved more effectively. The value stream is composed by all the necessary tasks that should be completed in order to deliver the product or service to the ultimate customer. Those activities that do not add value are considered waste and can be removed from the value stream. However, it can be distinguished between activities that are partially without value but needed in order to complete the tasks and all the activities that do not have any value and therefore should be eliminated [25].

- **Process flow**

Flows are characterized by time, cost and value. The flow of resources and information is the most vital units of analysis in lean construction management. It can be divided as controllable flows and uncontrollable flows. Controllable flows are effortlessly manageable aspects like materials from the warehouse or instructions from management respectively. Uncontrollable flows are complex to manage and not dependable such as supplier's provisions of resources and controlled design information. Only after specifying value and mapping the stream in relation to a process, value-creating steps of flow can be devised. Hence under lean thinking, improvement is possible by reducing uncertainties in workflow which eliminate a possibility time delays and cost-over runs. Furthermore, it should be achieved a continuous movement of the product through the value stream. Doing this at the beginning of the project, will allow to Release spaces, Discover the inventory excess, Avoid and change an inefficient process, understand that employees cannot be multifunctional [25].

- **Pull**

At operational level, pull identifies the need to deliver the product to the client within a specified time. The principle of pull suggests a decision where the ability to define quickly what the client needs from a building in relation to client business and subsequently customizing and deliver them more predictably when the client requires them. So, the management avoids producing a irrelevant product or service until the client downstream requests. Applying the pull system in a construction management implies to acquire the ability to design,

program and do exactly what the client requests. This should be done at the time that the client orders and with a reasonable cost. Project teams should allow their customers to be involved in the design process in order to extract value from them.by this way, companies allow their clients to establish their agendas and tell them what should be done [25].

- **Perfection**

A lean project requires constant vigilance to maintain and improve its operation. It requires team discipline and zero tolerance towards the waste of resources. Many obstacles appear when trying to achieve a lean environment. However, it is necessary to get over them to permanently remove all the waste of the value stream. With continuous improvement done and with waste eliminated along the flow process, perfection is the ultimate reward that companies can achieve. In essence, lean construction is a project delivery system founded on the reliability and speedy delivery of value to the client. it is important to remember lean is not a static system and requires constant effort and vigilance to perfect. Every employee should be involved in implementing lean. Lean experts often say that a process is not truly lean until it has been through value-stream mapping at least half a dozen times[25].

IV. APPLICATION CHANNELS OF LEAN CONSTRUCTION

Though many applications tools have been developed this study focus on the following two in relevance to future work.

Lean Project Delivery System

Close related to the design-build delivery method or design-bid-build with collaboration project delivery method, is the lean project delivery method. One of the key differences between a project delivery adopting lean and project delivered in a traditional way is the variation in phases [11]. Namely the definition of the phases as well as the relation between them and the participants within the phases. The different stages in a construction process where lean is implemented, or as they call it, a lean project delivery method. The main phases or processes are the project's definition phase, design phase, supply phase, assembly phase, and the usage of the construction [11].

In the project's definition phase, the importance is to take the client's and stakeholders' requirements into account, including involving the representatives from the other phases to share their knowledge to allow smoother further phases. The design stage takes over the values, concepts and design criteria from the project definition. The way lean design differs from traditional is that lean design tries to postpone the design as much possible, i.e. last responsible moment, to have more time to enveloping and exploring new alternatives and solutions.

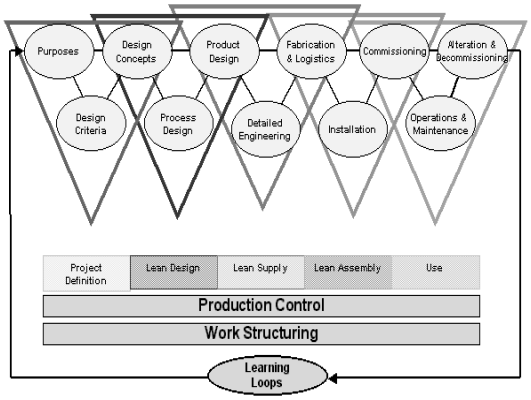

Fig.3 Different phases and their collaboration in a lean project delivery system [11]

Traditionally the design tasks are made as soon as possible which leads to reworks and disruptions Next phase is the supply phase where the detailed engineering, fabrication and delivery are included. This phase prerequisites a product and process system that are design to meet the requirements about what has to be detailed and fabricated and also when it has to be delivered to perform it in a lean and efficient way. The next phase is the assembly phase where the delivered products are constructed and installed. The last is the usage phase where the operations and maintenances take place and are important for the life cycle perspective. In lean delivery process illustrated in Figure 3 above, the production control and work structuring are important tools to support the process. [11].

Last Planner System

The last planner system (LPS) is a crucial method of lean project management, which is inspired by the lean production philosophy. The elaboration of this system shows the adaptation of lean principles and methods to the project area [26]. It consists of work flow control and production unit control. Work flow control is accomplished primarily through the look-ahead process, while production unit control is accomplished primarily through weekly work planning [27]. The LSP is based on a traditional planning system, the condition of (SHOULD-CAN-WILL-DID) is implemented. Figs. 5A and 5B represented the diagram of the Last Planner System. A reliable assignment, one that gets done at the required time, determines what WILL be done, after considering both what SHOULD from higher-level schedules and what CAN be done based on the situation at hand. Assignments are likely to get done when they are well defined, resource sound,

in the right sequence, and within the capacity of the crew. The last planner's job is to make certain task in the assignment that meets these criteria and to reject assignments that do not. Last planners can reasonably commit to completing the tasks on weekly work plans that meet these criteria. To be effective, production management systems must tell what should be done, what can be done, and what will be done; then, they compare what was done to improve planning [27].

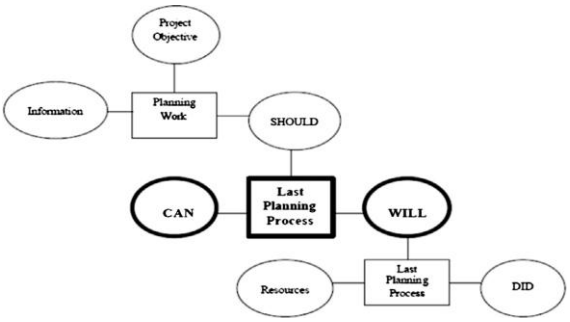

Fig.4 Last Planner System. [27]

Fig. 4 illustrates the possible relationships among SHOULD, CAN, and WILL. Referring to Fig. 5A, a reliable assignment determines what WILL be done, after considering what SHOULD and CAN get done based on the situation at hand. [27].

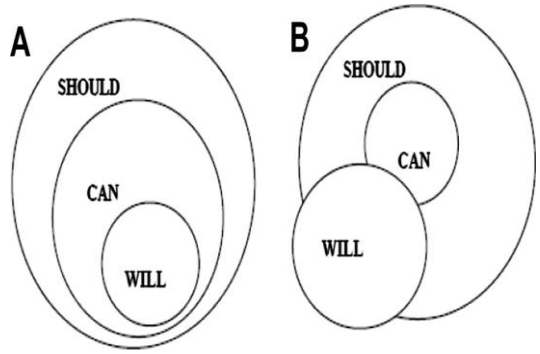

Fig.5 A-Philosophy of lean planning B-Philosophy of traditional planning

In general Construction projects require planning by different people, in different positions, possibly at different organization and during different moments of the life cycle of the work. The LPS defines definite standards of obligation that are requires advanced commitments of production in order to protect the productive units from uncertainty and variability. One of the founders of lean construction UK, Mossman [28] explains about five key conversations of the Last Planner System. When all are working together they reinforce each other and the overall benefits are greater. The conversations are:

- **Collaborative Programming**

Creating and agreeing the production sequence. This helps the project team get to know each other, identify issues with the project and agree how to resolve them and design and plan handovers [27-28].

- **Make Ready**

Making tasks in the Look Ahead period ready (i.e. constraint free). This ensures that the work can be done when they want to do it[27-28].

- **Production Planning**

Collaboratively agreeing production tasks for the next day or week. First Run Studies are an opportunity to rehearse critical handovers and understand where failures might occur so that they can be planned to counteract [27-28].

- **Production Management**

Collaboratively monitoring production to keep activities on track. Weekly or daily production planning meetings lets team check for interdependencies before they promise[27-28].

- **Measurement, learning and continual improvement**

Learning together about and improving project, planning and production processes. It helps them adjust plans in the light of new information, & the learning element encourages learning from success & reduces repeated failures [27-28].The reliability of the last planner system is measured in terms of the percentage of planned completed (PPC) as planned at the end of each week. The causes of failures of fulfilment are identified and also investigated each week in order to avoid them in the future. The planning reliability is directly related to productivity [26].

Kim and Ballard investigated the theories implicit in two prevalent project control systems: (1) Earned Value Method (EVM) and (2) Last Planner System (LPS). They introduced two fundamental and competing conceptualizations of management: (1) Managing By Means (MBM) and (2) Managing By Results (MBR) The EVM is found to be based on MBR. However, project control based on MBR is argued to be inappropriate for managing at the operational level where tasks are highly interdependent. The LPS is found to be based on the MBM view. The empirical evidence from case study suggested that the MBM view is more appropriate to manage works when it is applied to the operation level where each task is highly interdependent [29].The LPS is not only a tool to replace or compete with traditional practices as critical chain, but it accompaniments and enhances them by

improving variability and workflows. In addition, it tries to increase reliability of planning which in turns increase the performance and productivity. The LPS is specifically designed to enhance control in the uncertainty and complexity. Fig 7 illustrates the impact of implementation of the Last Planner System on a construction project, it is evident that Last planner system have a positive impact of the system on budget and productivity [30]

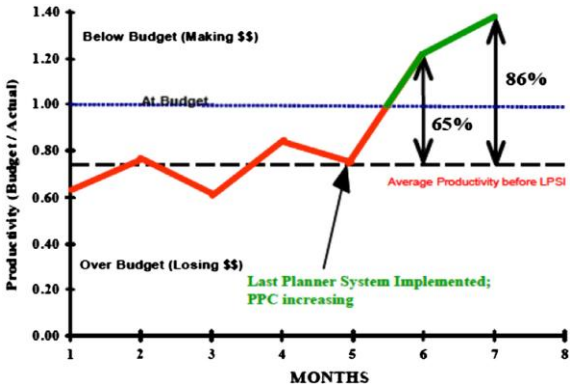

Fig6. Productivity improvement using LPS [30]

V. CONCLUSION

Traditional project management, which includes methods such as Critical Chain Project Management, Critical Path and Program Evaluation and Review Technique, has entailed several problems, for complex projects, since it is not able to deal with uncertainty, since managing uncertainty and workflow in projects are crucial aspects in construction, production management theories have shown to be the best appropriate to reform project management. They include the management of activities, workflow between activities and the creation of value. Of all the theories of production, lean production is which best fits for construction management, as it adds the value and flow view to the transformation view in projects, in which projects are only seen as the transformation of inputs into outputs. With these new points of view, constructions stakeholders try to deal with uncertainty instead of avoid it, and to achieve the best value form the customer perspective. These new approaches give rise to the new project management method, named lean Construction management, which is organized by lean applications tools in order to maximize value and minimize waste.

Despite all these achievements, traditional project management has proved to be successful for simple projects, where the problems that arise from the interactions between activities can be resolved without difficulty. Therefore, lean Construction is appropriate for complex and uncertain projects, where the management of the workflow and the value perspective focused on customer's specifications can allow managers to deal with uncertainty. Thus, to decide which method should be applied, it results necessary to evaluate the uncertainty and risks of each project before their beginning. In order to do that, Lean Construction management appears as the perfect way to evaluate risks and complexity in projects.

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