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Identification and Analysis of Lean Techniques inIndian Construction Projects

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Abstract:*Currently several construction companies in USA, UK, Australia, Brazil, and Singapore have started to implement the lean construction to obtain better productivity in their current project. There are many challenges to implement the lean concept in construction industry. Due to lack of attention and illiteracy towards the lean management principle the owner, contractor, engineers etc. are still in developing stage to implement this principle in their project. This study has been carried out to explore the impact of lean construction practices and their applicabilityin the Indian construction industry. A detailed literature review was done to study the conventional practices and the influence of lean approach in the projects. A questionnaire, based on factors of lean construction techniques was used to survey and gather the data for the analysis. Various factors derived from lean techniques were ranked on the basis Relative Importance Index (RII). From the ranking obtained, the key lean techniques prioritized are value stream mapping, standardization, huddle meetings, just in time. These techniques can be effectively implemented in construction projects to reduced wastes and improve productivity.*

Keywords-*Buildings, India,Lean construction*

I. Introduction

In India, the construction industry is second largest industry after agriculture. Under the increasingly competitive environment, it has become imperative for construction companies to improve the quality of their work, increase work effectiveness, reduce waste and costs, and increase profit. It is urgent to improve the enterprises competitiveness, meet the clients' requirements and increase the usage efficiency of resources. This is particularly more pressing under the current financial crisis and economic recession. Most construction managers agree that the industry is susceptible to multiple wastes, overruns, delays, errors, and inefficiency. As a result, construction projects seldom finish on time, within budget, and at a quality level accepted by the customer (Al-Aomar, 2012). Thus, several project management approaches have emerged to improve construction performance including lean construction, lean project management, and value-engineering. Lean construction has been introduced as a new management approach to improve the productivity, eliminate waste and increase profit in construction industry and the similarities between the construction processes and manufacturing make lean production theory very applicable to construction. Lean construction is one of the fastest growing trends in the construction industry. (Alves et al., 2010)Lean practices applied to the construction industry promise not only to improve productivity, but also to improve the overall project management process (Howell et al., 2011). Construction companies, using production processes established to build large quantities of cheap housing, are faced with the challenge of providing customized apartments for increasingly sophisticated homeowners.

Residential construction is a prime candidate for lean construction study, both theoretical and applied, for a number of reasons. First, it forms a major part of the construction industry. Second, cost and schedule overruns and rework are common. Third, construction management practices in residential construction are largely conventional, and traditional critical path scheduling and work structuring practices are relatively inflexible. Large production homebuilders construct very similar homes in great numbers. The tools used for production planning and control by large production builders, however, are similar to those developed for traditional construction management applications rather than tools designed specifically for the unique characteristics of the residential construction industry (Howard et al., 2005). Hence residential construction area has been focused for this study; however influence of lean has been analyzed in other divisions also.

During the life cycle of construction projects, most of contractors are striving to reduce their losses and maximize their profits overall stages in the project life cycle. But they still rely upon fundamental theories and traditional construction project management practices and tools which are already obsolete. Most of them are

unaware about new management methods and models that are emerging. Currently several construction companies from other countries are started to implementing the lean construction with nebulous hopes of obtaining better result from their current projects (Chandrasekar and Logesh, 2014). In India, the implementation of lean management in construction industry is a major task. Hence Indian construction industry has to familiarize lean practices and adopt them into application. The lean management principles in the construction industry will increase the profit and quality of project in reasonable time.

II. History Of Lean Construction

2.2 The 1990's Evolution of Lean Construction

Lean Production (LP) was developed by Toyota production system in the 1950s led by Engineer Ohno who was committed to eliminate waste in production process. The term "lean" was invented by the research team working on international auto production. (Womack et al., 1991)The term "Lean Construction" was introduced in 1993 by the International Group for Lean Construction in its first meeting that was hosted by Lauri Koskela in Finland, who is a pioneer in introducing lean construction, used the lean thinking approach. The traditional thinking of construction management focuses on conversion activities and does not pay attention to flow and value. The wastes associated with the construction process was assumed to be the waste of materials and non-value added activities that may lead to waste such as delays, transportation of materials and others. Essential features of lean construction include a set of objectives for the delivery process to maximize performance for the customer at the project level, efficient design of product and process, and the application of production control throughout the life of the product from design to delivery. Significant research remains to complete the translation to construction of lean thinking. (Howell, 1999)

2.2 The New Millennium- Arrival of New Lean Approaches

After developing lean construction concepts from lean production development, the lean project delivery system was developed by the Lean Construction Institute (LCI). The basic idea or domain of LPDS is the project-based production systems. On further studies in 2000's various benefits and positives outcomes of lean construction were observed. Ballard classified the LPDS into four interconnected modules: project definition, lean design, lean supply, and lean assembly (Ballard and Glenn, 2000). Following is some of the lean production techniques as introduced in the literature: Flow Variability, Process Variability, Continuous Improvement, and Transparency (O. Salem et al., 2006). Several countries started to use and incorporate lean concepts and techniques in the construction industry such as USA, UK, Finland, Denmark, Singapore, Korea, Australia, Brazil, Chile, Peru, Ecuador and Venezuela (Ballard and Howell, 2003). The adoption of Lean manufacturing principles to the construction is an innovative approach for managing and improving construction processes by reducing cost and maximizing value considering customer demands (Koskela, 2002).

Same as manufacturing principles, minimizing waste at early stages lead to a better quality and thus successful project in terms of time and cost. The manufacturing process has seen noticeable improvements and development after applying lean principles to the industry. Traditional project management methods are more adequate for simple projects. These traditional methods will not be able to comply with the sophisticated projects requirements' due to the various interactions between activities. Although there are many common elements between Lean manufacturing and lean construction techniques, not all lean production theories can fully be implemented in the construction industry. There are obvious differences between Manufacturing plants and construction sites (O. Salem et al., 2006). From the literature, lean principles were found to be affecting the construction process efficiently. The construction process has seen intrinsic improvements in terms of quality and cost by addressing lean principles. The project is said to be "lean" when it is delivered with minimum waste and maximum value. The overall outlook says that Lean construction is moving towards new agenda. Even though there is still much to be learned about how to minimize waste and focuses on the area of value generation, on which project management principles focused on.

2.3 The Post 2010's – Implementation of lean practices

Post 2010's various researchers focused onto theory to implementation of lean techniques. Even though various techniques were derived out of production principles, the case study and studies based on implementation gave a better outlook towards lean construction. (Vieira et al., 2012) used in their study the Rapid Lean Construction-Quality Rating Model to evaluate the application of Lean Construction principles of two construction companies in the State of Goiás (Vieira et al., 2012). The performance level of these companies was obtained in respect of applying and understanding lean principles & thinking. After the evaluation was done, recommendations

and suggestions were introduced to help the companies implement lean thinking in a more efficient way (Vieira et al., 2012). To ensure that the expected benefits of applying lean thinking to construction projects are actually being delivered, evidence should be provided to the concerned stakeholders to encourage them continue applying this new approach. Lean construction is in the stage of development and some of its tool are tested in the field and refine over last decade, such as Last Planner, but some tools such as daily huddle meetings, visualization and 5s are in testing stage and all procedures for their implementation are being developed.

III. Methodology

This study involves identifying various lean construction tools and techniques that are prevalent in construction industry from literature survey. The factors of some popular lean techniques are derived and a questionnaire was formulated. The construction industry experts are asked to rate the factors with five point scale in the questionnaire. The most rated factors where ranked on the basis Relative Importance Index (RII) and key lean techniques where identified.

The procedure followed in this study is as follows:

- Various lean techniques were identified from literature survey
- The factors for each technique have been derived based on lean principles.
- A questionnaire has been developed with these factors
- The various construction professionals are asked to rate the questions on five point scale for level of impact. The scale ratings are as follows, 0-Not at all 1-Extremely high 2-Very high 3-Average 4-Low
- The collected data is analyzed by using statistical tool.
- The most rated factors where ranked on the basis Relative Importance Index (RII)

3.1 Questionnaire Design

The questionnaire was designed in such a way that the factors of various lean techniques were derived and formulated into questions and it includes:

- Details about respondents and company,
- Generally 4 questions about impact of lean construction in the projects.
- The approach to new techniques and influence of traditional conventional construction practices are comprised into 5 questions.
- The factors of various lean techniques are formulated into 19 questions.
- Finally, 1 question is about timely information given by clients

The various lean techniques which are identified from literature survey have been analyzed and their factors are formulated into questions. The Table 1 below shows how the questions are formulated based on lean technique and its benefits.

TABLE 1 Formulation of questions

Lean technique	Benefit	Questions	No. of qns.
Reduce Cycle Times	Waste Reduction	• What is the range of material waste produced in site? • Whether the employees are aware about waste elimination in the project?	2
Value Stream Mapping	Reduce Variability	• Do you standardize the construction processes at any stage of construction? • Do you thoroughly review the design drawings at early stages to avoid late variations?	2
Visual Manage-ment	Transparency	• Do you use visual management system at site such as electronic status board, mobile signs or safety signs? • Do you explain the whole method of construction to employees on project site?	2
Just In Time	Flow Variability	• Do you rely on the schedule look-ahead to improve the work flow? • Do you ensure that the information flows smoothly between all the departments on the project? • Do you procure materials just before the requirement during process to decrease the volume of inventory on site? • Do you consider the importance of the smooth and efficient flow of information, materials and equipment on site? • Do you prefer work flexibility on site (eg. Assigning of multi-skilled labor to different activities on site)?	5

Huddle meetings	Continuous Improvement	• Is there a measurement system to quantify the unused ordered material on site? • Do you share your previous experience with employees on the project? • To what extent are the employees contributing in the process enhancement? • What about the willingness of the workers to learn new techniques? • To what extent do you consider the customer feedback to improve the process? • Is there any need of training for different levels of management to improve overall efficiency?	6
Standardization	Customer Focus	• How about the flexibility to meet the customer changes & requirements? • Whether there is a communication between the contractor and the customer?	2

3.2 Data Collection

The questionnaire was collected from various construction professionals by direct survey and by online survey. Through online survey it was able to approach professionals from various parts of India. The total numbers of respondents are 35 of which 12 are through direct survey and 23 are through online survey as shown in Fig. 1.

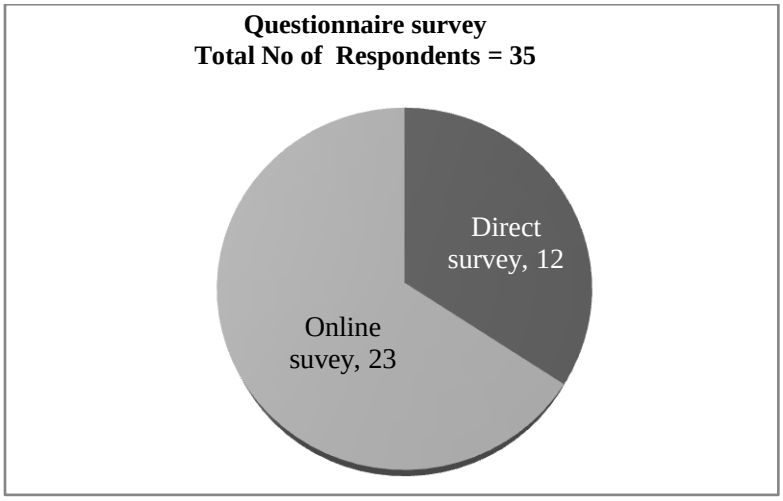

Fig.1 Total no. of respondents

IV. Data Analysis

The survey is conducted by asking the construction professionals to rate the factors on five point scale. Number of experts participated in the survey is thirty five. Based on the ratings given by the professionals the rating is analyzed using MS Excel 2010 and the following steps are done:

- Each factor is aggregated based on the rating
- Mean value for each factor is found out and each factor is then ranked in ascending order

To assess the likelihood of each identified factor of various techniques of lean five point likert-scale of 0-4 was used, where scale of 0-Not at all;1-Extremely high; 2-Very high; 3-Average; 4-Low. All the respondents were asked to rank each factor as per degree of importance. The identified factors were then ranked on the basis of Relative Importance Index (RII). (Zeba et al., 2015) The equation used for RII is:

$$RII = \Sigma (Pi*Ui)/ (N*n) \quad (1)$$

Where,

P_i = Respondent's rating

U_i = Number of respondents placing identical rating

N = Sample size

n = Highest value on Likert scale

The RII for all factors was calculated by above shown formula (1). Apart from ranking lean techniques the impact of lean construction in the construction industry was assessed using a set of questions and it is observed that the RII obtained is low. Hence it is evident that influence of lean construction is poor in Indian construction

industry. The influence of traditional conventional construction practices was assessed using a set of questions and it is observed that the RII obtained is high for these questions. Hence it is evident that influences of traditional construction practices are high in Indian construction industry .i.e. still construction industry relies upon conventional practices.Finally a comparison of lean construction vs traditional methods of construction practices were done as shown in Fig.2. From the Fig.2 it is analyzed impact of lean construction in the construction industry 4 questions were asked and their RII (0.36) found to be less compared to RII (0.71) of 5 questions related to influence of existing traditional methods present in current scenario.

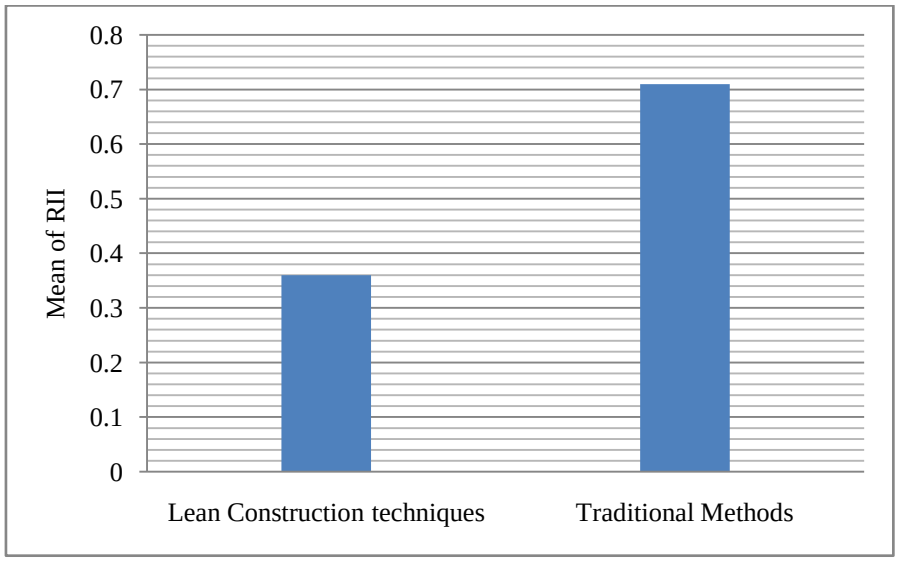

Fig.2 Comparison of influence of lean construction techniques vs traditional methods

The RII for all factors was calculated by above shown formula. The mean of RII of various factors leading to each technique where calculated as shown in Table 2,3,4,5,6,7.

TABLE 2 Mean of RII for factors of lean technique Reduced Cycle time

Lean Technique : Reduce Cycle Times			
Qn. No.	QUESTIONS	RII	Mean
10	What is the range of material waste produced in site?	0.529	0.557
11	Whether the employees are aware about waste elimination in the project?	0.586	

From the Table 2 shown above it is observed that the mean of RII obtained is 0.577 for the questions derived from factors of reduced cycle time technique. Cycle time can be progressively reduced through elimination of non-valueaddingactivities and variability reduction. The shorter the cycle time, the morecycles are affordable.For the point of view of improvement, the cycle time from becoming conscious of a problemor an opportunity to the implementation of a solution is crucial. (Lauri Koskela , 1992) In traditional organizations, this cycle time sometimes goes infinite due to lack of communication where no message is passed, or in case long channel of communication where the message gets distorted.

TABLE 3 Mean of RII for factors of lean technique Value Stream Mapping

Lean Technique : Value Stream Mapping			
Qn. No.	QUESTIONS	RII	Mean
12	Do you standardize the construction processes at any stage of construction?	0.643	0.717
13	Do you thoroughly review the design drawings at early stages to avoid late variations?	0.793	

From the Table 3 shown above it is observed that the mean of RII obtained is 0.717 for the questions derived from factors of value stream mapping technique. The ultimate goal of VSM is to identify all types of waste in the value stream and to take steps to try and eliminate these (Vilasini and Gamage, 2010).Waste is anything that creates no value for the parties involved in the process namely owner, customer, and consumer. Therefore waste is defined in terms of value and there is no absolute definition of waste, it is all relative. Therefore the definition of

value stream map should be extended as a tool which uses to identify the waste and waste causes exist in current process and find appropriate process design for removal of wastes which only add value to the process. Value stream map is identified as an essential tool because it helps to visualize the process, waste and its sources, information and material flow.

TABLE 4 Mean of RII for factors of lean technique Visual Management

Lean Technique : Visual Management			
Qn. No.	QUESTIONS	RII	RII Mean
14	Do you use visual management system at site such as electronic status board, mobile signs or safety signs?	0.500	0.6
15	Do you explain the whole method of construction to employees on project site?	0.700	

From the Table 4 shown above it is observed that the mean of RII obtained is 0.6 for the questions derived from factors of visual management technique. Visualization in general, and particularly in construction projects, is a convenient and intuitive way of conveying project information among various project parties. One of the major causes of accidents is unsafe site conditions, which basically is due to inadequate supervision with poor visualization. The increased visualization lean tool is about communicating key information effectively to the workforce through posting various signs and labels around the construction site. (Enshassi and Zaiter, 2014)

TABLE 5 Mean of RII for factors of lean technique Just In Time

Lean Technique : Just In Time			
Qn. No.	QUESTIONS	RII	RII Mean
16	Do you rely on the schedule look-ahead to improve the work flow?	0.636	0.635
17	Do you ensure that the information flows smoothly between all the departments on the project?	0.643	
18	Do you procure materials just before the requirement during process to decrease the volume of inventory on site?	0.550	
19	Do you consider the importance of the smooth and efficient flow of information, materials and equipment on site?	0.721	
20	Do you prefer work flexibility on site (eg. Assigning of multi-skilled labor to different activities on site)?	0.629	

From the Table 5 shown above it is observed that the mean of RII obtained is 0.635 for the questions derived from factors of just in time technique. Construction JIT will be advanced by implementing demonstrated techniques and industry research to test theories and develop new tools and techniques. (Lauri Koskela , 1992) Construction and manufacturing are different types of production; nonetheless a form of JIT is applicable to construction, in which physical buffers may ultimately be replaced by better managing uncertainty and eliminating the causes of flow variation. As the implementation of plan buffers propagates certainty throughout projects, productivity will improve from better matching labor to work flow, and project durations will shorten as physical buffers shrink with the flow variation they are designed to absorb. (Lauri Koskela , 1992) A new way of conceiving the tasks and tools of construction project management has been proposed. Instead of relying simply on schedule-push, managers are advised to systematically employ plan-pull as a means of adjusting to uncertainty and insuring that resources are employed to maximum advantage at each point in time. (Bertelsen and Sven, 2002)

TABLE 6 Mean of RII for factors of lean technique Huddle meetings

Lean Technique : Huddle meetings			
Qn. No.	QUESTIONS	RII	RII Mean
21	Is there a measurement system to quantify the unused ordered material on site?	0.551	0.698
22	Do you share your previous experience with employees on the project?	0.771	
23	To what extent are the employees contributing in the process enhancement?	0.707	
24	What about the willingness of the workers to learn new techniques?	0.699	
25	To what extent do you consider the customer feedback to improve the process?	0.736	
28	Is there any need of training for different levels of management to improve overall efficiency?	0.729	

From the Table 6 shown above it is observed that the mean of RII obtained is 0.698 for the questions derived from factors of huddle meetings technique.(Antonio, 2002) believed this tool is similar to the lean manufacturing concept of employee involvement, which ensures rapid response to problems through empowerment of workers, and continuous open communication through the tool box meetings. (Abdelhamid and Salem, 2005)

concluded that two-way communication is the key of the daily huddle meeting process in order to achieve employee involvement. With awareness of the project and problem solving involvement along with some training that is provided by other tools, employee satisfaction will increase.

TABLE 7 Mean of RII for factors of lean technique Standardization

Lean Technique : Standardization			
Qn. No.	QUESTIONS	RII	RII Mean
26	How about the flexibility to meet the customer changes & requirements?	0.729	0.721
27	Whether there is a communication between the contractor and the customer?	0.714	

From the Table 7 shown above it is observed that the mean of RII obtained is 0.721 for the questions derived from factors of standardization technique.Standardization is one of the main features of lean construction since it adopts the philosophy of keeping things consistent for the workers. A clean, organized, and logical jobsite will lead to shorter cycle times and increased productivity. It systemizes operations and materials so that movements between operations and needed resources are efficiently used. The overall construction cost decreased as well as construction time on-site. (Simonsson et al., 2012).

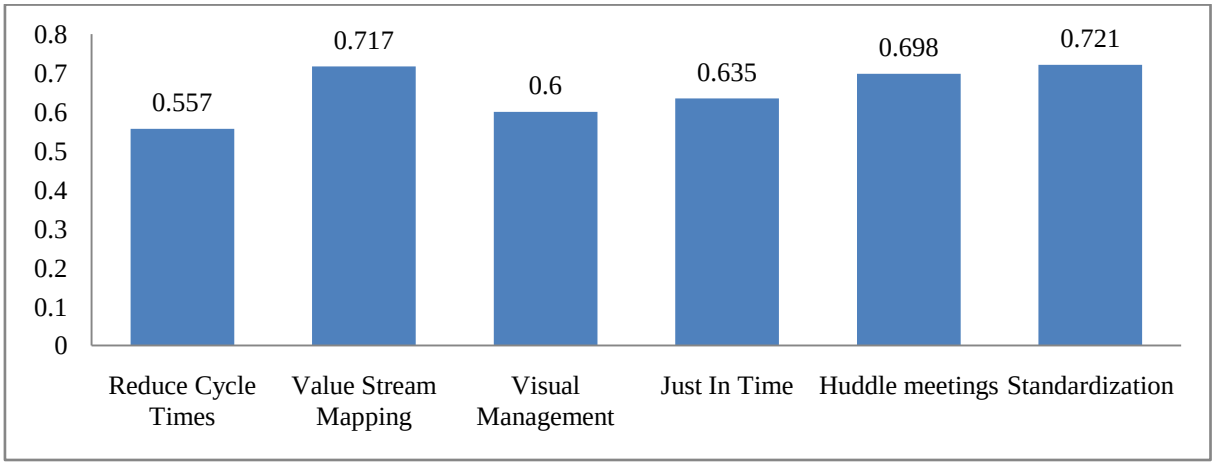

Fig.3 Various lean techniques and their mean of RII

TABLE 8 Prioritizing various lean techniques based on RII Mean

METHODS	Reduce Cycle Times	Value Stream Mapping	Visual Management	Just In Time	Huddle meetings	Standardization
Factors	2	2	2	5	6	2
RII Mean	0.557	0.717	0.60	0.635	0.698	0.721
Rank	VI	II	V	IV	III	I

From the Table 8it can be observed that the technique standardization is of key priority and other techniques in the order of ranking are visual stream mapping, huddle meetings, just in time, visual management and reduce cycle times.

V. Conclusion

Based on the work carried out it is found that lean construction has influenced Indian construction industry meagerly and on comparing the traditional methods and lean construction techniques, still construction industries rely upon traditional methods for various processes in the implementation stage. The available conventional management model in the construction industry is now obsolete. Hence there is need for new techniques for better project output. A detailed literature review was done to study the conventional practices and the influence of lean approach in the industry. A questionnaire, based on factors of lean construction techniques is used to survey and the data was gathered for analysis. Various factors derived from lean techniques were ranked on the basis Relative Importance Index (RII). The factors with higher RII value were identified and the respective lean techniques were determined. From the ranking obtained the key lean techniques prioritized are Value Stream Mapping, Standardization, Huddle meetings, Just in Time.In actual implementation processes of construction, site operations

are rather poorly systematized; only a handful of companies havestandard methods for various site operations. However, only through standard methods, the variability can be decreased and the rapid involvement of improvements beensured. VSM as a tool, used to visually map theflow of production. It shows the current and futurestate of processes in a way that highlights opportunitiesfor improvement of productivity and project output.Minimizing all forms of wastes andmaximizing the value added has become the great challenge for all stakeholders inconstruction industry.Hence these techniques can be effectively implemented in construction industry to reduce wastes and improve productivity of project in Indian construction industry.

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