Work Sampling and Value Stream Mapping of Lean Construction

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Abstract- ***Low productivity is the chronic problem in construction industry. One way to increase the productivity is to reduce non-value adding activities. A number of problems affecting productivity can be noted when the activities in progress on a typical construction site are closely observed. Productivity improvements achieve higher cost savings with minimal investment. Lean construction is relatively a new construction management philosophy which has evolved from Lean Manufacturing principles. Lean construction along with its various tools like Pull Approach, Just in Time (JIT), The Last Planner System (LPS), Total Quality Management (TQM), Work Sampling (WS) and Value Stream Mapping (VSM) etc. has gathered a lot of momentum in the developed nations. The challenge now lies in implementing it in the developing countries.***

Lean Construction is a philosophy based on the concepts of lean manufacturing. It is about managing and improving the construction process to profitably deliver what the customer needs. Because it is a philosophy, lean construction can be pursued through a number of different approaches. This Research thesis outlines the elements of lean manufacturing and suggests how these might be adapted to deliver lean construction in practice.

Indexed Terms- ***Lean Technology, Work Sampling, Value stream mapping,***

I. PRESENT SCENARIO

India has seen a tremendous growth in construction and infrastructure sector in the last decade. Such a growth opportunity can be leveraged for competitiveness, but can also breed wastage. Delays were rampant in construction earlier and now costs are often too high for quality that is given. With increasing competition from foreign players, market shares of domestic firms in key segments has been shrinking. There is also evidence that the problems have become greater in extent and severity in recent years.

Lean construction is a nascent philosophy introduced as recent in 1995 in the western world. The name is penetrating in the Indian Construction industry. It addresses mainly to the wastages prevailing in the construction. The wastages as it is today is as high as 50 to 60% (Source: Dr. Tariq Ahmed, University of Michigan, USA). 50% wastage is huge and colossal. Here definition of wastage is generic-overrun of time, costs, poor design, adversarial relationships etc.

II. NEED FOR STUDY

Since many years, the construction industry in India has suffered from not delivering the projects in time, within budget and with the quality demanded by the customer. Due to these problems, the loss of big projects to international companies is obvious. This study is concerned with the need to spread and apply The Lean Construction concepts and principles in the real world in order to contribute to the consolidation

of a theory. Also, to learn to discover and Reduce/Eliminate wastes in the organization. The Research thesis highlights the real issues confronting construction firms and explores the potential of Lean Construction concepts in construction industry in India.

Past research into the causes of waste in construction projects indicate that waste can arise at any stage of the construction process from inception, right through the design, construction and operation of the built facility. Waste in the construction industry has been the subject of several research projects around the world in recent years. It is commonly acknowledged that a very high level of waste exists in construction. The creation of this waste can be prevented by applying lean construction principles.

III. OBJECTIVES

1) To identify the amount of time spent by labours in different wasteful activities through implementation of work sampling.
2) To monitor and acquire the productivity of labours using daily progress report.
3) To identify wastes from the current process in construction by preparing the current state map and propose a future state map.

IV. METHODOLOGY

Objective 1:
Work sampling study will be carried out at the construction site for different RCC activities to achieve objective 1.

Objective 2:
The productivity of labours will be monitored through the daily progress reports for different RCC activities and analysed to achieve objective 2.

Objective 3:
Waste will be identified from the current state map and more efficient future state map will be proposed for the RCC works of a typical slab to achieve objective 3.

V. LEAN CONSTRUCTION TOOLS

The following are the key lean construction tools:
1) The Last Planner System (LPS),
2) Value Stream Mapping (VSM),
3) Work Sampling (WS),
4) Location Based Management System (LBMS),
5) 5s Housekeeping(5s),
6) Daily Progress Report (DPR).

VI. CONCEPTS OF LEAN CONSTRUCTION

Lean Construction is defined as the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream and the pursuit of perfection in the execution of a project. In the opinion of Mossman (2009), lean thinking is lean because it provides a way to do more and more with less and less – less human effort, less equipment, less time and less space – while coming closer and closer to providing customers with exactly what they want.

Lean theory and principles taken together provide the foundation for a new form of project management. Lean Construction has produced significant improvements particularly on complex, uncertain and quick projects. Managing construction under Lean Construction is different from typical contemporary practice because it:

- Has a clear set of objectives for the delivery process;
- Is aimed at maximizing performance for the customer at the project level;
- Designs concurrently product and process;
- Applies production control throughout the life of the project.

VII. THE LEAN WASTES

Womack et al. (1990) define waste as any human activity which absorbs resources but do not create value. Ohno defines waste into seven categories that are apparent in every manufacturing facility in the world:
1) Overproduction;
2) Waiting;
3) Unnecessary transport;
4) Inappropriate processing;

5) Unnecessary inventory;
6) Unnecessary motion;
7) Defects An eighth waste was added by Liker (2004) which is
8) Unused employee creativity.

VIII. LEAN CONSTRUCTION VERSUS TRADITIONAL CONSTRUCTION

Construction is considered to be one of the most change resistant industries in the world. Koskela (1992) claimed that the most general concept seems to be understanding construction as a simple process of transforming an input to an output. This conception is actually shared by both old and newer methods in construction. The traditional system of construction project focuses more on keeping track of time and cost. Time control is about looking at the progress in the production line, while cost control is primarily concerned with the budget. Cost control tracks if the project is under or over budget. Kim (2006) suggests that in traditional construction, control consists of monitoring against schedule and budget estimates; while in Lean construction control is defined as causing events to conform to plan. Kim (2006) continues to say that traditional construction focuses more on individual activities. In traditional construction, control begins with tracking cost and schedule, and therefore any effort to improve productivity leads to unreliable work flow due to sub-optimization. As a result, project performance is considerably reduced.

In Lean philosophy, the focus is on how one activity affects the next activity, as all activities are part of the whole system. It works first to assure the reliable flow of work between the tasks. In that perspective Koskela (2000) depicts construction as a continuous flow of materials and/or information instead of just conversion activities (from input to output).

The Most fundamental difference between traditional and Lean construction can be found in scheduling (Kim, 2006). In scheduling, Lean construction uses the “pull” work schedule while traditional construction uses the “push” work schedule. Pull systems schedule work based on demand as opposed to the push systems which schedule work based on system status.

IX. WORK SAMPLING – A LEAN CONSTRUCTION TOOL

Work sampling is an activity measurement technique that has received increased emphasis in recent years as managers struggle to control construction costs. The underlying theory of work sampling is that the percentage of observations recording a man or machine as idle, working or in any other condition reflects the percentage of time actually spent in that state or condition. If the observations are randomly distributed over a sufficiently long period of time, this theory is held to be true. Work Sampling has three main uses Activity and Delay Sampling: To measure the activities and delays of workers or machines (e.g., to measure the percentage of the day that a person is working or notworking). Performance Sampling: To measure working time and non-working time of a person on a manual task, and to establish a productivity of the person during his or her working time. Work Measurement: To establish a time standard for an operation.

X. DATA COLLECTION

Under the above heading data were collected from a construction site in Mumbai for following three lean construction tools. The three lean construction tools are: -

1. Work Sampling,
2. Daily Progress Report, and
3. Value Stream Mapping.

XI. WORK SAMPLING

There seems to be a misconception in the construction industry that if a worker is moving then they are being productive. The work sampling study helps in identifying the actual tasks being performed and can help identify wasteful activities within a process.

Work sampling is a management tool which consists of making a large number of random observations and using the theory of probability to identify the activities where waste exists. Work sampling groups the activities into one of three categories: value-added, non- value-added but necessary, and non-value-added. The value-added (VA) activity is anything that directly contributes to the construction, the Non-value added

but necessary (NVAN) activity is that which is necessary to be done, but does not directly add value to the construction and Non-value added (NVA) activity is any activity which does not add value to the project.

To successfully conduct a work sampling study the following steps must be followed:

1. Establish the study objective;
2. Define the population to be studied;
3. Define the study period;
4. Formulate the activity categories
5. (VA, NVAN and NVA)
6. Establish number of observations; and
7. Develop random observation times.

The steps were followed with the help of the site engineers to successfully conduct the work sampling study.

- Objective of the study: To identify the amount of time spent by workers in different wasteful activities and to improve productivity by reducing wasteful activities.

- Population to be studied: A gang of workers including 20 members for RCC work activities.

- Study Period: One month

- Activity categories: were formulated with the help and suggestions of site engineers, contactors, site supervisors.

- No. of Observations per day: 5 to 10Observations

- Duration of Observation: Minimum 20 minutes to Maximum 60 minutes per observation.

The work sampling study was conducted by physically going to the construction site and observing the workflow of the contractor. Observations were taken periodically and identified the work being done as: value-added, non-value-added but necessary, and non-value-added. Further, workers, the site engineer, and the project manager were interviewed during the process to help aid in the understanding of the project. Table 3.1 shows the pre-defined activity categories formulated for RCC work activities.

Table 3.2 Pre-defined activity categories for RCC works

REINFORCEMENT		
Value added	**Non value added but necessary**	**Non value added**
Cutting of bars	First shifting of materials	Late start/Early Quit/ Unavailability of Labours
Bending of bars	Shifting of tools	Break
Fixing of bars	Cleaning of bars	Personal/Talking
Cover blocks	Reading Plans	Waiting
SHUTTERING		
Value added	**Non value added but necessary**	**Non value added**
Placing of Materials	First Shifting of materials	Late start/Early Quit/ Unavailability of Labours
Shifting of Materials	Cleaning of Surface	Break
Erecting the Materials	Making/ Cutting of wood (Ply)	Personal/Talking
Supporting/Staging	Oiling	Waiting
	Levelling (Verticality Check)	
CONCRETING (RMC)		
Value added	**Non value added but necessary**	**Non value added**
Concreting	Transportation of Materials	Late start/Early Quit/ Unavailability of Labours
Curing	Slump Test	Break
	Filling Cubes for test	Personal/Talking
	Vibrating	Waiting
	Cleaning of Aluminium Formwork	

After the thorough brainstorming, the list of different activities was prepared which include all the major tasks for RCC works and categorised them into VA, NVAN and NVA as per its contribution to the final product.

The observation sheet for work sampling study can be found in the appendix 1, are as: -

APPENDIX - I

OBSERVATION SHEET

WORK SAMPLING SHEET					
ACTIVITY: RCC Works					
PROJECT NAME: GODREJ Platinum					
DATE:				OBSERVER NAME: Maharshi J.Shelat	
Observation No.	VA	NVAN	NVA	Time	Remarks
TOTAL					

REINFORCEMENT		
VA	**NVAN**	**NVA**
Cutting of bars	First shifting of materials	Late start/Early Quit/ Unavailability of Labours
Bending of bars	Shifting of tools	Break
Fixing of bars	Cleaning of bars	Personal/Talking
Cover blocks	Reading Plans	Waiting
SHUTTERING		
VA	**NVAN**	**NVA**
Placing of Materials	First Shifting of materials	Late start/Early Quit/ Unavailability of Labours
Shifting of Materials	Cleaning of Surface	Break
Erecting the Materials	Making/ Cutting of wood (Ply)	Personal/Talking
Supporting/Staging	Oiling	Waiting
	Levelling (Verticality Check)	
CONCRETING (RMC)		
VA	**NVAN**	**NVA**
Concreting	Transportation of Materials	Late start/Early Quit/ Unavailability of Labours
Curing	Slump Test	Break
	Filling Cubes for test	Personal/Talking
	Vibrating	Waiting
	Cleaning of Aluminium Formwork	

XII. VALUE STREAM MAPPING

Value stream mapping (VSM) is an important tool of the lean approach and is used to identify value-adding activities and those considered wasteful of materials and the flow of information and people. The purpose of studying this tool is to understand how Value stream mapping (VSM) is helpful in lean implementation and to develop the road map to tackle improvement areas to bridge the gap between the existing state and the proposed state of different construction activities.

Through this case study, the existing process of a slab cycle is mapped with the help of VSM process symbols and the biggest improvement areas like transportation materials, cutting of steel, fixing of reinforcement etc. are identified. Some modifications in current state map are suggested and with these modifications future state map is prepared. We have considered RCC activities for service floor slab (Part-1).

XIII. CURRENT STATEMAP

The goal of current state mapping is to create the clear picture of an existing process and to identify waste. For mapping the current state map, the information for different RCC activities for slab preparation was collected from the contractor, site engineer, site supervisors and workers. The data like, types of activities, its quantity for a typical slab, no. of days and resources required for RCC activities are gathered. It is shown in the table3.3.

Table 3.3 Resources required for each activity

Activity	Quantity	Resources Required					Days
		Carpenter	Fitter	Helper	Mason + MC	Total	
Starters fixing & Shuttering	17 nos.	3	2	1	-	6	2
Columns fixing & Shuttering	17 nos.	4	3	2	-	9	4
Beam bottom & Slab Shuttering	265 SQMT.	11	-	9	2	22	4
Slab Reinforcement Fixing	5.5 T	-	19	4	-	23	4
Concreting	265 SQMT.	4	1	8	19	32	1

According to current practice, a single slab takes 15 days to complete. This process is put in the graphical form to understand the value stream and identify waste from it. Consider activities in blue colour as pre-activities, Green as main activities and red as post-activities.

The graphical chart is prepared based on the information and data gathered from the contractors, engineers, supervisors and workers. According to the current state map, the steel for slab reinforcement is ordered 11 days before the execution of work. The raw steel provider provides the steel within 7 days. It arrives at steel yard on the 7th day of indent. Here, for Service floor slab (Part-1) of 265 SQMT, the quantity of steel required is 5.5 T. It requires 2 days for 5 labours to cut and bend the steel according to the bar bending schedule (BBS). After cutting the steel, it is required to shift to the site where it is to be fixed. Shifting takes 2 days for 2 labours to shift 5.5 T of steel to site.

It is assumed that the steel for starters, columns and beam bottom are used from the safety stock (Inventory). Fixing and shuttering of 17 starters take 2 days for 6 labours, fixing and shuttering of 17 columns take 4 days for 9 labours, Fixing and shuttering of beam bottom and fixing of slab shuttering of area 265

SQMT take 4 days for 22 labours, Fixing of Slab reinforcement of 5.5 Ton take 4 days for 23 labours, concreting of as lab is completed in a single day using ready mix concrete. It takes 32 labours for the slab area of 265 SQMT.

Concrete is ordered 2 days before the day of concreting by the management. And after concreting, curing is done for at least 7 days by 2 labours.

In the current state map, waste is identified from the process. If there is no such waste found in the current processes, then an innovative technology should be think of which can substitute any process and give more efficient results.

CONCLUSSION

This Paper described the work sampling & value srtream mapping for the lean technology, using this methodology, the considerable results were achieved. The slab cycle time for a typical slab, Service floor slab (Part-1) was reduced to 13 days from 15. The additional cost required for applying innovations should be considered. For this case study, the off-site column fixing saves 2 days in the cycle time but, for erecting the cage of column a tower crane is required. The rental of tower crane should be considered. It should not exceed the amount saved for two days. Applied Innovation has to get savings in comparison with the current practice on construction site. It should be considered that the readymade steel is 8 to 10% costlier than the normal steel. And the scrap value of waste cut pieces of steel should also be considered before taking decisions.

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