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STUDY ON CONSTRUCTION LABOUR PRODUCTIVITY USING LEAN PRINCIPLES

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ABSTRACT

The construction laborers are the most dynamic element in the construction and plays an equal role in the success of a project especially in today's world of high labor expenses. Lean principles consider construction industry similar to production systems and aims to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value. Reducing construction times, increasing productivity and efficiently managing projects can all be achieved through successful implementation of lean principles. The eight major types of lean waste including defect, overproduction, waiting, non-utilizing talent, transport, inventory, motion and excess processing result in downtime. The purpose of this paper is to develop a tool to identify lean waste occurring due to internal resource flow at construction sites and guide in how to prioritize waste reduction activities at site. Lean tools such as Value Stream mapping and Work Sampling carried out at construction site along with information gathered from interviews were used for determining the proportion of time spent by workers in various defined categories of activity. For the purposes of this paper, the study objectives are twofold. (i) Actual labour productivity at site under different work categories: Direct work, essential contributory work and Non Value Added work and determining current labour utilization rate at construction site. How contributory activities and non value added activity contribute to lean waste. (ii) To develop and validate a suitable lean tool to prioritize waste reduction at site. Initial observation and interviews indicate unnecessary movement, waiting and Breaks are major waste at site. Initial labour utilization was only 38.97%. Few simple techniques such as pull approach between different workforce and 5S approach, can eliminate variation in the process leading to a more predictable workflow thereby improving labor productivity and Labour Utilization rate in construction site to 50% under current study.

Keywords*: *labour utilization rate, lean construction, pull approach, value stream, work sampling.

I.INTRODUCTION

Construction is a labour intensive industry. Labour productivity directly influences construction productivity. Internal resource flow within a construction site such as work crew, material handling procedure, availability of tools and equipments, construction procedures and sequences affects labour productivity rates. Lean

construction considers construction industry similar to a production industry. It is a way to design production system to optimize raw materials and maximize productivity. Lean principles aims to deliver a value stream by eliminating wastes involved in construction projects thereby helps in achieving continuous flow of work processes by reducing variation and making productivity a more predictable factor in construction industry. The eight major types of lean waste including defect, overproduction, waiting, non-utilizing talent, transport, inventory, motion and excess processing result in downtime. There are a number of tools, methods, and systems that have been developed in an attempt to translate lean thinking to construction. Last Planner System, Building Information Modeling, Integrated Project Delivery, Kaizen Event and 5s process are few of the tools and systems used in applying lean principles to construction.

1.1 OBJECTIVE

The main objective of this paper is to develop a combined tool in how to identify various lean waste at construction site and measure it, guide in how to prioritize eventual waste reduction activity. It also focuses on identifying potential effects of lean implementation at site.

1.2 LITERATURE REVIEW

Murodif.et.al(2015) measure labour productivity using work sampling technique for formwork reinforcement and concreting works. The Labour Utilization rate were 47.32%, 43.17% and 49.76% respectively. The overall LUR was 45.60% and productivity was relatively high. Relatively large part of worker time is spent on material handling, preparation, waiting, rework and motion that add no value. Pradeepkumar and Loganathan considers lean waste as potential waste in construction that hinder the flow of value. Minimizing waste would not only improve project performance but enhance value to individual customer. Idle time observed through work sampling was mainly due to lack of supervision and recoverable productivity was 36%. In a study conducted by Josephson and saukkorii(2005) , a group of workers were observed for 22 working days. 33.4% of activities were not adding any value due to rework, waiting, idle time and disruptions. It was suggested that improving flow of construction process and resource utilization would add economic benefits to the project. Doloi(2008) concluded that cost overruns and running behind schedule are due to poor worker productivity. If one third of the work carried out has no value then the project cost would increase by 25%. Modig(2004) in her research work found that one of the largest construction firm in Sweden paid extra to the logistics for on-time service since it was estimated that they saved money by having material just in time. Eriksson(2010) considers waste reduction, process flow in production planning, continuous improvement and cooperative relationships are the core elements of lean construction.he also suggests that waste reduction should be given priority than achieving flow in construction.Winch and Carr(2000) state that a process mapping tool is recognized as an important management tool for understanding how value is delivered for customers. It is a functional tool that helps in streamlining a construction company by adding value to each step in construction process.

II. RESEARCH METHODOLOGY

The problem area was defined and research questions were formulated based on literature review on the construction industry and field of lean thinking. The literature review covered key concepts within the fields of lean, work sampling, value stream mapping and 5s processes. Interviews to field personnel, middle level management in construction industry, academicians and lean experts were conducted to gets idea on lean practices at site and information regarding successful implementation of lean in construction. A structured work sampling study and value stream mapping was carried out at construction site in Brick Masonry, Shuttering and formwork, Concreting work and Utility fixing activities to observe labour utilization rate and level of value adding and non value adding activity at the site. This thesis work focuses only on the internal resource flow at construction site and not on external resource flow as the paper focuses on waste reduction within the site. Based on observations and interviews, different lean wastes occurring at site were classified and their root cause were analysed. A combined lean tool was developed to identify and measure waste, prioritize waste reduction order and validate the potential effects of successful implementation of lean thinking at construction site.

III. DATA COLLECTION

3.1 WORK SAMPLING TO IDENTIFY LEAN WASTE

Work sampling is a statistical tool used for calculating the amount of time spent by workers under different work categories. It is a efficient tool to identify the flow of value in construction. No External flow of resources were considered. Assuming that the external resources were readily available, labour productivity with respect to internal flow of resources was studied. Sampling was carried out for Masonry, concreting, utility fixing and Shuttering activities. All the samples observed were classified under three heads: (i) Value Adding (ii) Essential Contributory (Necessary non value added waste) (iii) Non Value Adding. These three heads were further classified into various sub categories to understand the level of lean waste associated with each activity. Table 1 and figure 1, figure 2 and figure 3 gives the work sampling analysis result.

Table 1 Work sampling Analysis result

Activity	**Work Sampling activities type**		**No.of sample**	**Proportin (%)**	**Total (%)**	**LUR (%)**
Masonry	Direct Work	Brick Placing	46	24.21	35.95	**43.81**
		Applying Mortar Layer	22	11.58		
	Non Value added but Essential	Transporting Bricks	36	18.95	32.21	
		Helping in Checking levels	4	2.10		

Work (n= 190)		Assisting Brick work	21	11.05		
	Non Value added work	Travelling empty handed Viewing Work Tea Break	41 17 3	21.58 8.95 1.58	32.11	
Concreting (n=98)	Direct work	Pumping Concrete Spreading Pumped concrete	22 11	22.45 6.96	33.67	
	Essential Contributory	Helping in Pump alignment and movement	16	16.33	16.33	**37.75**
	Non Value Added work	Viewing the executed work	49	50	50	
Shuttering and formwork (n=160)	Value Added	Alignment of Panel	43	26.87	26.87	
	Essential Contributory	Panel Shifting .Holding Panel Panel Cleaning Receiving Instruction Assisting Fixing	5 14 7 3 4 14	3.12 8.75 4.37 1.87 2.5 8.75	29.36	**34.21**
	Non Value Added	Travelling empty handed Viewing Work Non availability of material	27 31 12	16.87 19.37 7.5	43.74	

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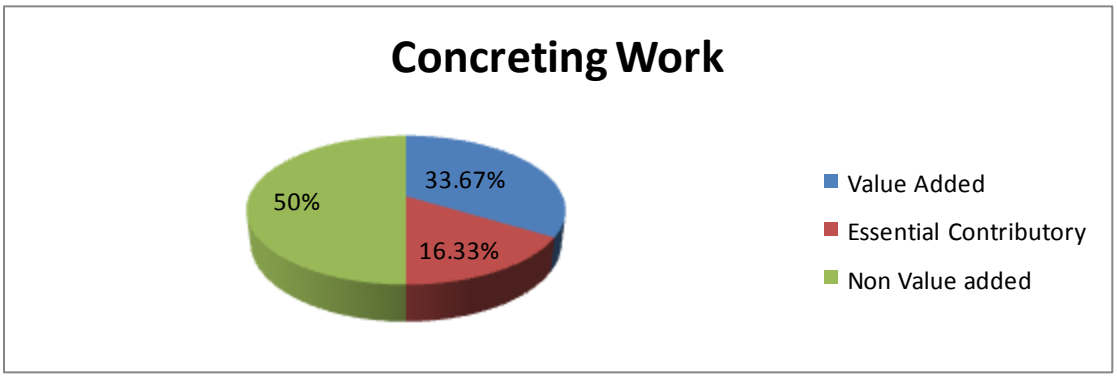

Fig 1 Work Distribution for Masonry Work

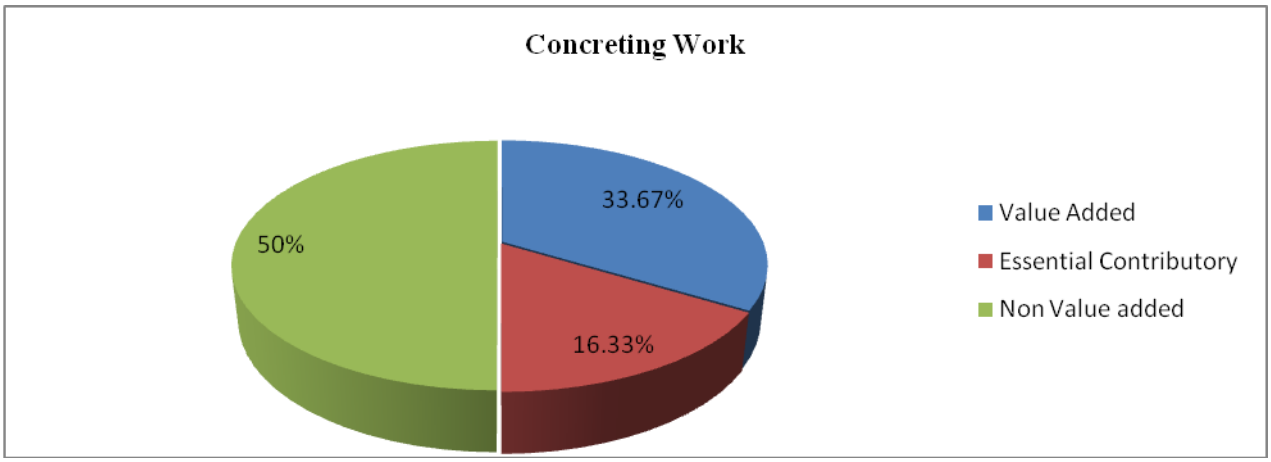

Fig 2 Work Distribution for Concreting work

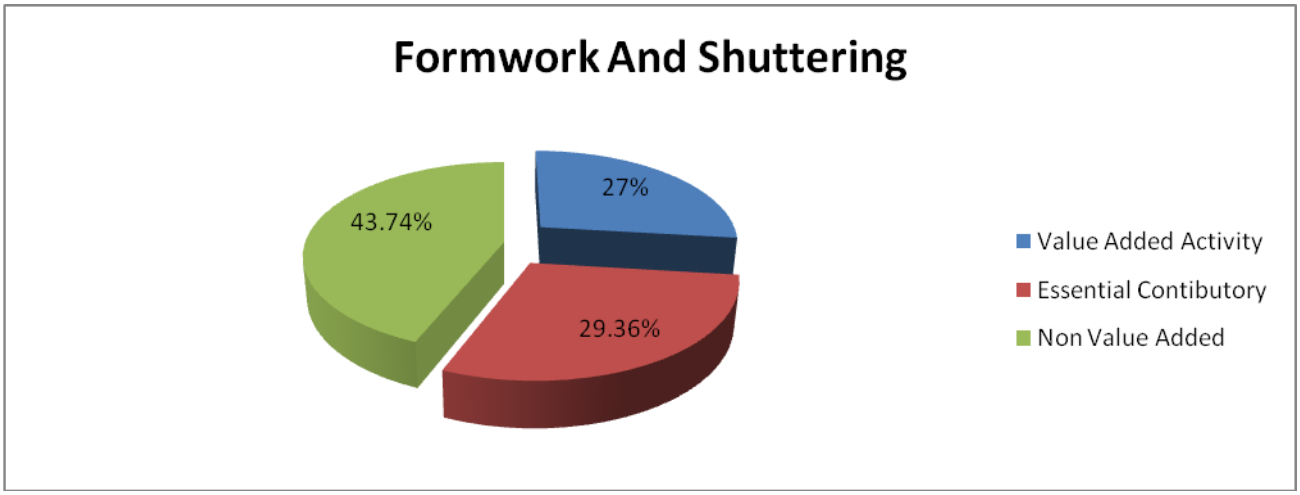

Fig 3 Work Distribution for Shuttering work

3.2 IDENTIFYING WASTE

By mapping the current state of flow within the construction site, it would be possible to frame a future state map to have a process approach eliminating the waste involved in current approach. Value Stream Mapping, Planning tools, Daily meetings, Last planner system and Look ahead planning were some of the significant lean tools identifies during interviews. Planning and daily meeting tools are used to optimize planning and identifying a better way to complete the task by utilizing the workers' intimate knowledge of their work. These were not used for the study but certainly holds a core place if the company plans for serious lean implementation in their work site. Value Stream Mapping was used in this study as the observers can directly experience the factors affecting flow in the process. Figure 4 gives the lean waste observed at site.

3.3 MEASURING WASTE

Lean wastes were calculated based on two measurements. (1) Measuring Time. (2) Measuring Coordination and flow. Unnecessary movement, waiting, over processing are the major lean waste observed at site. Often the worker had to move in search of material, tool, collegue, walking back and forth etc. The material need for the job was located in one place and job was performed at a different place. The workers were also miscalculative in assessing the material required. Over processing often lead to material waste. Workers sometimes had to stop performing their activity in order to help out colleagues in materials, tools or solving a problem. Waiting for an upstream colleague to finish their work before the downstream colleague could carry on with the activity that was under process. Extra processing of work was categorized as lean waste when reworks were carried out to compensate a mistake done earlier that were identified much later in the process underway. Unused employee talent and unnecessary transport were important parameters in interviews but were insignificant in field observations as only workers were focused and not material movement. Excess inventory was the last waste identified since better planning was done on inventory considering safety, damage and loss.

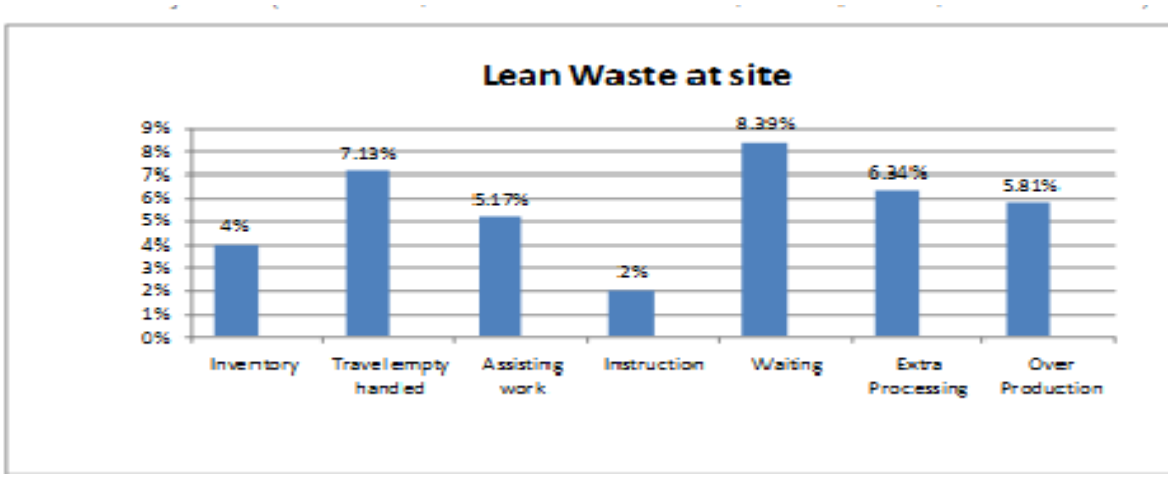

Fig 4 Lean waste observed at site

IV.ANALYSIS AND RESULT

4.1. WASTE PRIORITIZATION

Although it was possible to identify all the types of lean waste occurring at site, it was important to rank the waste based on the frequency of occurrence. Waste can be prioritized based on importance, urgency and tendency. Since the main scope of this paper is waste reduction at site and achieving coordination in workflow, first priority was given to those factors that affect flow. A noticeable change is required in order to gain acceptance of lean approach. In this study priorities were given to achieve improved work environment, process stability, better flow, coordination and material handling to reduce lead times and increase production rate. Interviews and suggestions from field level supervisors and site engineers were considered. It was highly recommended during interviews that conducting a root cause analysis would be the first step in prioritizing waste reduction activities. Pareto analysis and Ishikawa diagrams were efficient lean tools to structure waste elimination activity. The lean tool that has been constructed as seen in figure 5, is built upon different aspects collected from theory, field observations and interviews from experts to identify and reduce the lean wastes occurring at site.

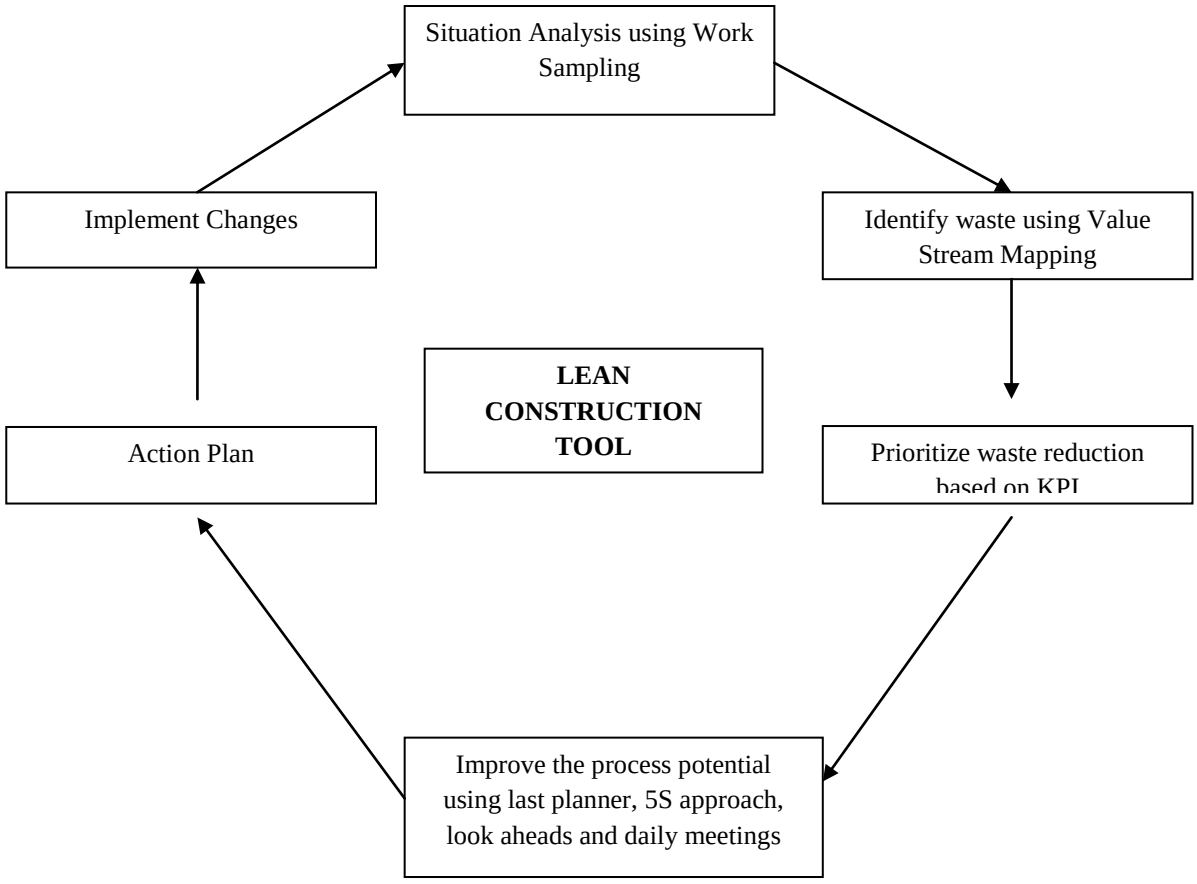

Fig 5 Lean Construction Tool

4.2. VALIDATION OF RESULTS

To validate the lean tool formulated it was tried out on a construction process at a medium sized construction company based in Chennai carrying out Construction of hospital buildings at two different locations within the state of Tamilnadu. The first step was carrying out a work sampling study of various activities in the site and the results are represented in table. Based on work sampling results, different waste have been identified using value stream mapping and grouped according to the earlier mentioned construction site wastes. Initial sampling carried out during brick masonry activity showed that 32.11% of the work carried out contribute to lean waste. The main reason for non value added activities in this category is variation in amount of work performed by value added workers and non value added workers. Unit rate of production by direct workers is less and rate of production by non value added workers is high. Work in progress for direct workers is high leading to excess processing by non value added workers. Four labourers were observed for every 1.25 cu.m of masonry work. Supporting labours contributing to masonry work from outside the work area were also considered. Based on the lean waste observed during Sampling, a looped process approach was formulated to minimize lean waste observed in brick masonry activity. The crew size was reduced to three labourers for 1.25cu.m. Bricks required for the next day was placed close to 10m from the work area and productivity of downstream worker was made equal to the capacity of upstream worker and new samples were taken to identify potential effects of lean implementation. Percentage og direct work was increased from 35.95% to 40.31% and essential contributory activities were increased from 32.21% to 38.28% and non value added activities was decreased to 21.27% from 32.11%. The Labour Utilization was 50% show a successful trend when lean principles and implemented. The various categories of lean waste observed after implementation of lean tool is shown in figure 6 and 7.

4.3. KEY LEARNINGS FROM VALIDATION CASE

The validation case showed that the formulated Lean Construction tool worked well for the processes taken for the study and could detect and visualize different kind of waste occurring within a construction site. During the validation study, it was not necessary to use all the lean approaches because required information were obtained without using certain methods (Ishikawa diagrams were not used for analyzing waste). Getting to the root cause of the problem was of significant importance since one type of waste easily caused other types of problems disturbing the flow in the process. As in this validation case, unnecessary movement was mainly due to unorganized work environment , miscalculative in material requirements to carry out a particular task and waiting for a upstream worker to complete their work due to uneven distribution of work within the same crew.

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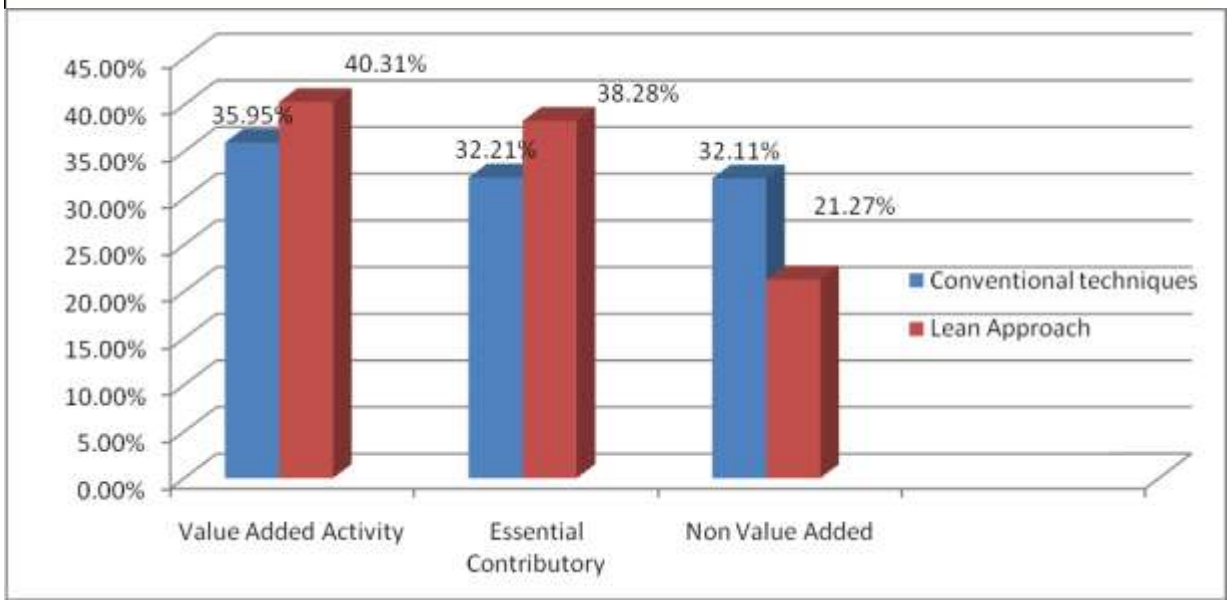

Fig 6 Comparison of Work Sampling Categories

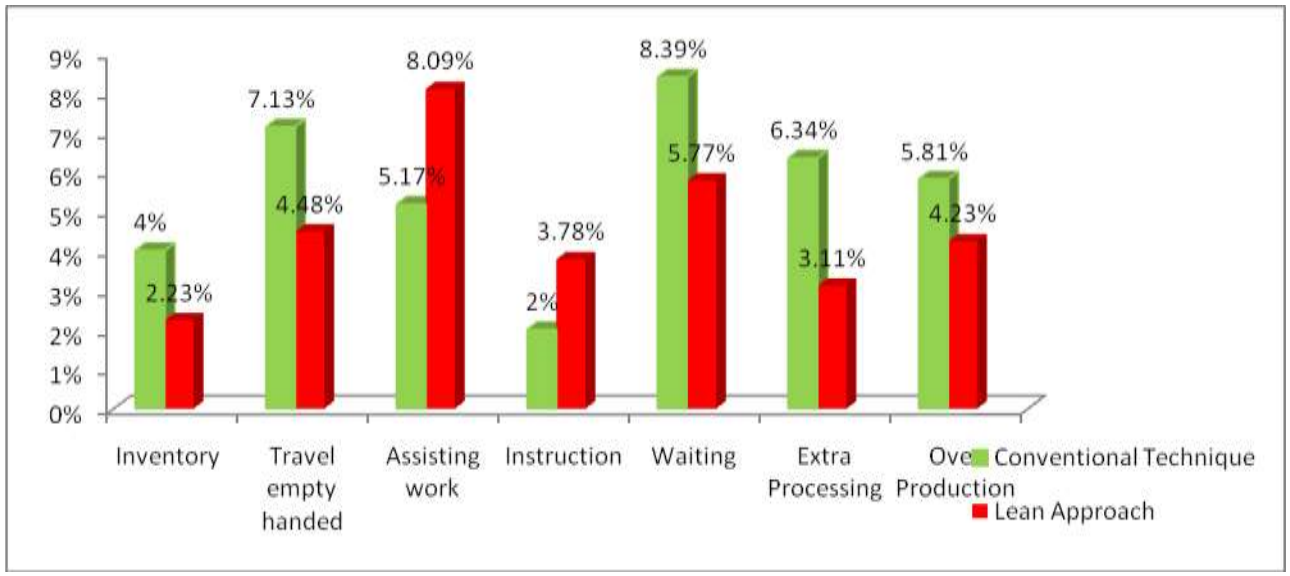

Fig 7 Comparison of lean waste observed at site.

V. CONCLUSION

The average Labour Utilizatiom rate observed at site initially was 38.59%. The major lean waste affecting productivity rates at site includes unnecessary motion, breaks, extra processing and waiting time. Also the contributory activity and non value added activity directly affects productivity rates. The main reason of these

waste is variability of work distribution within the same work force work, unorganised work environment and poor look aheads of labourers.Therefore it is essential to reduce the variations in the process by optimizing the work sequence & work crew so as to have a predictable and continuous work flow. Also the process should aim at reducing the work in progress of the downstream worker. The productivity of upstream worker and downstream worker should be equal so that the labours at site are always under production. Lean tools and process have been validated and has shown successful trends in improving productivity rates in construction. These lean tools are simple and efficient and can be implemented at least cost with a little extra effort and support from middle and upper level management. It also improves the value of all the stakeholders involved in the project leading to a stabilized and predictable work flow.

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