Identification And Quantification of Waste In Construction Sites Based on Lean Construction Principles

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Abstract- *Indian construction industry characterized major challenges like low productivity, lack of skilled labour, time and cost overruns etc. associated with considerable waste present in the construction sites. while a few larger construction companies have starts to look into waste reduction and process improvement issues through concepts like lean construction most organizations are yet to address this issue. as a prerequisite to implementing lean principles, in which a major factor focus is on elimination of waste, it is important to understand and quantifying the amount of waste actually present in Indian construction sites. Critical waste and waste causes were identified and categorized by disseminating a questionnaire survey.*

Keywords- Construction sites, New Lean visual management.

I. INTRODUCTION

Construction is the second largest economic activity after agriculture in India, and it makes significant contribution to the national economy. Construction activity being labour intensive has generated employment for about 33 million people in the country (Singh 2008). There are mainly three segments in the construction industry like real estate construction which includes residential and commercial construction; infrastructure building which includes roads, railways, power etc. and industrial construction that consists of oil and gas refineries, pipelines, textiles etc. Indian construction industry saw a large-scale boom in the past two decades till the recent global economic crisis.

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). 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.

Most construction companies were forced to slow down some of their ongoing projects because of the economic meltdown. One of the major challenges facing this sector is the lack of skilled and quality human resources and the limited ability of capital equipment suppliers to meet the demand. Another risk that this sector is facing is the risk of execution, which is correlated to the above risk. As a result, most projects ends up in time and cost overruns.

II. HISTROY 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).

2.1 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).

III. METHODOLOGY

This study involves identifying various lean construction tools and techniques that are prevalent in construction industry from 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 were 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 were ranked on the basis Relative Importance Index (RII)

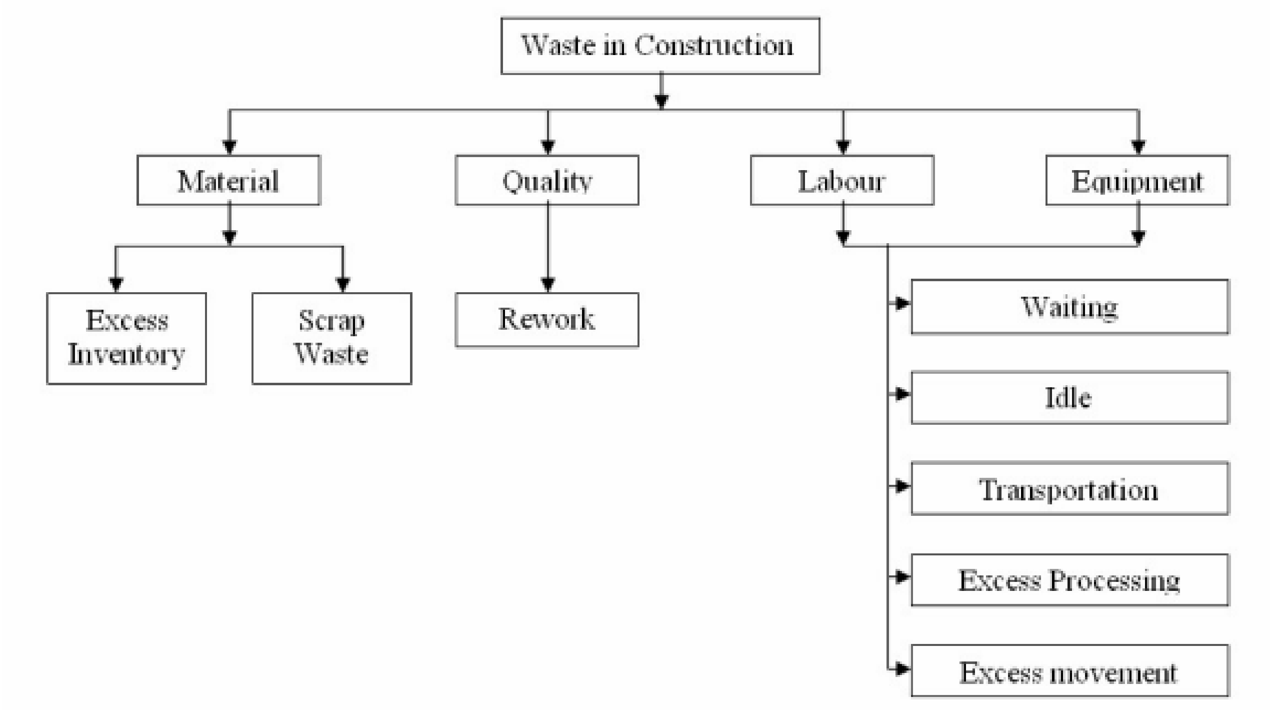
3.1 Questionnaire Design

Lean technique	Benefit	Questions
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?
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 latevariations?

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?
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 (e.g., Assigning of multi-skilled labor to different activities on site)?

3.2 QUANTIFICATION OF WASTE

Critical waste and waste cause variables identified from questionnaire survey represents only the perception of respondents regarding the waste in construction industry. Also, it has been identified from literature review that very few studies have been conducted to quantify all types of waste in construction.



3.3 DATA COLLECTON

From Sites Data regarding waste was collected from six ongoing building construction projects. The sites were located around Chennai and Palakkad, Kerala. The site names were kept confidential as per the request of the companies. The size of the projects varied from Rs. 200 million to Rs. 900 million. Critical waste and waste cause variables were identified through questionnaire survey and analyzed in detail in this chapter. Also, data regarding various waste types were collected from six building construction sites and waste types were quantified in terms of cost. A site wise comparison has also been made. Data regarding waste was collected from six building projects, for periods ranging from 10-14 days for each project.

3.4 Material Scrap

Waste Material scrap wastes for the following materials were investigated: steel reinforcement, cement, river sand, bricks/blocks, coarse aggregates of 20mm and 10mm size. These materials were chosen because of their importance in terms of both cost and potential for generating waste in construction sites. The total material cost for the 6 materials monitored varied from 22.90% to 34.35% of project cost and is represented in the Fig. The results indicated that scrap waste of materials in 6 sites were almost low when compared to studies undertaken in other countries. However, the wastage of 10mm aggregate and reinforcement (including all diameter sizes) was found to be higher than the value assumed at the sites.

Material	Project A	Project B	Project C	Project D	Project E	Project F	Average
Cement (t)	4.65	4.07	5.10	0.71	1.27	8.03	3.97
20mm Aggregate (m^3)	3.10	1.83	3.00	1.20	1.47	na	2.12
10mm Aggregate (m^3)	5.05	3.95	5.30	1.84	12.33	na	5.69
River Sand (m^3)	3.87	3.52	4.20	3.00	1.37	na	3.19
Blocks (Nos.)	3.28	2.56	4.00	0.93	2.40	na	2.63
Reinforcement (t)	3.90	3.21	4.90	2.95	3.76	7.81	4.42
Cost of scrap waste for abovelisted materials as % of material cost*	3.79	3.17	4.59	2.58	4.15	7.87	4.36

3.5 Labour Inefficiency

Inefficiency of labour was evaluated using work sampling. Work sampling was used because it is relatively simple and inexpensive, easily understood, possesses statistical reliability, and gives an overall picture of the distribution of the activities of labourers.Work sampling technique measures the time engaged by labourers in various activities.

$$\text{Cost of labour inefficiency} = \frac{T1N1DdW}{100}$$

were,

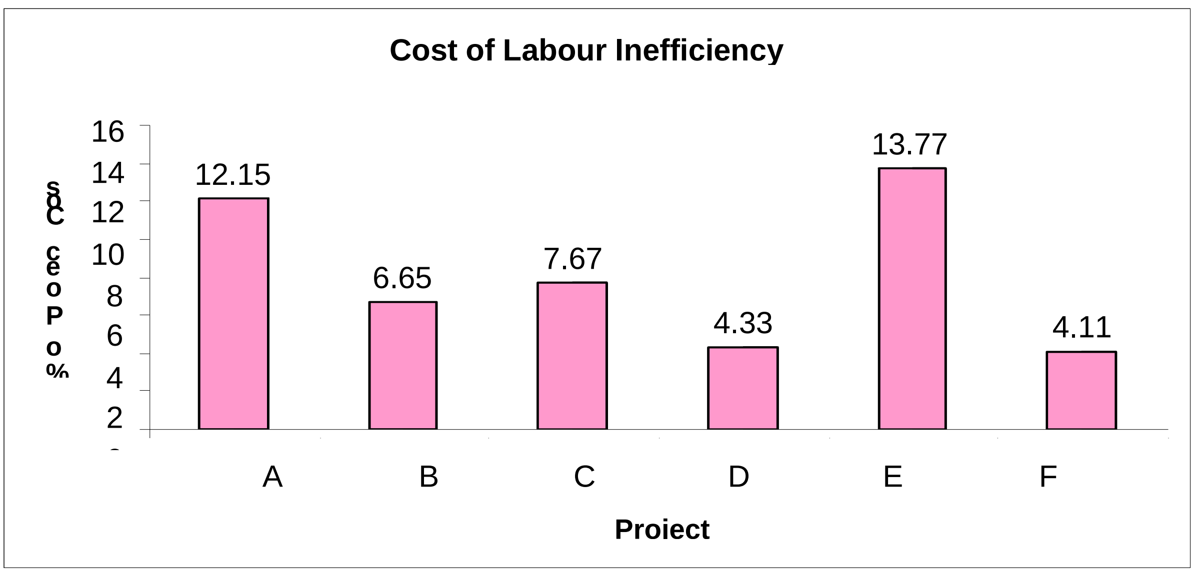
Dd = Project duration in days

Nl = Average number of labourers per day

Tl = Average non value adding time of labourer in %

W = Average daily wage of labourer

Parameter	Project A	Project B	Project C	Project D	Project E	Project F
Average%VA time	32.50	33.63	26.19	27.06	29.85	26.42
Average% NVAR time	11.92	14.25	11.13	17.19	13.62	14.08
Average % NVA time	55.58	52.13	62.69	55.75	56.53	59.50
Average,number of labourers per day	150	100	120	900	2000	680
Project duration (months)	24	24	24	17	24	20
Total cost of inefficiency (Rs Million)	8.50	5.32	7.67	38.38	122.10	36.41
Waste in % of project cost	12.15	6.65	7.67	4.33	13.77	4.11



3.6 WASTE MINIMISATION

Minimizing waste in construction sites will lead to increase in overall project performance. Various improvement measures can be adopted to minimize each type of waste. For the purpose, interviews were conducted with construction industry experts to get their opinions for minimizing waste in construction sites. The industry experts include 3 project managers and 3 planning managers. Also, improvement measures from literatures are consolidated and explained in the following sections.

SUMMARY

The Indian construction industry is characterized by challenges such as low productivity, lack of skilled labour, time and cost overruns etc. These are associated with considerable waste present in the construction sites. While a few large construction companies have started to look into waste reduction and process improvement issues through concepts like lean construction, most organizations are yet to address this issue. As a prerequisite to implementing lean, which focuses on elimination of wastes, it is important to understand and quantify the amount of waste actually present in Indian construction sites. However, there has been hardly any research findings published in the Indian context on the incidence of waste in the construction industry. In general, project managers tend to conceptualize "waste" as physical construction waste rather than a more generic conception of the term that will include both the incidence of material losses as well as the execution of unnecessary work by resources that generate additional costs but does not add value to the product. Thus, this project aims to investigate the incidence of waste in Indian construction industry, focusing mainly on building projects. Variables that related to waste activities were identified from literature review. The data collected was analyzed using the concept of relative importance index to determine the rank order and hence, the criticality of the variables.

CONCLUSIONS

Identification of Waste

The following conclusions were drawn regarding waste based on the questionnaire survey conducted among construction industry participants.

- Workers resting during construction, waste of raw materials on site, idle workers, waiting for materials, and travelling empty handed were identified as the top five critical waste variables.
- Poor planning and scheduling, lack of skilled labour, design changes, inappropriate construction methods, and unclear specifications were identified as the top five critical waste cause variables.
- Among the waste categories, human resource was found to be the most critical followed by operations, material, waiting, and repair.

Quantification of Waste

The following conclusions were drawn after quantifying waste based on the data collected from six building projects.

- The material scrap waste as percentage of material cost varied from 2.58% to 7.87% among the projects studied.
- Excess inventory cost as percentage of material cost varied from 0.79% to 5.15% among the projects studied.
- An attempt has been made to track the rework costs. However, none of the construction sites studied maintained proper rework data. Hence, cost of rework could not be quantified properly because of lack of documentation of this date.
- The average percentage time spent by labourers and equipment's in nonvalue adding activities was found to be 57% and 61% respectively.

Waste Minimization

The following conclusions were drawn regarding various improvement measures for minimizing each type of waste in sites based on the data collected from questionnaire, site visits and the interview with construction industry experts.

- Material waste can be reduced by using prefabrication construction methods, repetitive designs, optimized cutting of reinforcement, ensuring modular coordination in design, practicing just-in-time delivery of materials etc.
- Construction companies should implement proper quality tracking systems to track the costs of quality accurately.
- Labour inefficiency can be reduced by strict supervision of work, continuous monitoring of productivity and comparing with standard norms available, balancing the crew etc.
- Equipment inefficiency can be minimized by regular maintenance and inspection of equipment's selecting right equipment for the work, adequate supervision etc.

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