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Identifying Wastes in Construction Process and Implementing the Last Planner System in India

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Abstract: ***Most of the Indian contractors are not well equipped to handle the growing demand of infrastructure development; hence construction projects frequently run in to time and cost overruns, disputes and quality issues. This study aims to improve the construction industry in India by implementing lean principles to eliminate non-value adding activities (wastes). The purpose of this study is to 1) identify the wastes and their sources affecting the construction process, and 2) to identify problems and document lessons by applying a Last Planner System (LPS) to a sample project. First, the researchers identified that Delays, Rework, and Interruptions were the most critical wastes affecting the construction process and Poor management control, Poor Planning and Shortage of Resources were the major sources of the above mentioned wastes. Second, the researchers report the Percent of Planned Complete (PPC) analysis results and experienced problems after implementation of LPS at the sample project. It was observed that much more improvement could have been achieved if there was consensus between the owners and the contractor on the implementation of the LPS in its entirety. Some of the problems experienced in the implementation of the LPS like lack of scheduling, resource and material shortage were found to be similar to those in developed countries.***

Keywords: Lean, Construction Wastes, Sources of Wastes, Last Planner, India

I. INTRODUCTION

The construction industry in India is the second largest industry in India after agriculture [1]. It accounts for 11% of India's GDP and has generated employment for about 33 million people in the country [2]. The construction industry in India is highly fragmented in which only 0.4% of the total 250,000 can be classified as medium to large firms (based upon the number of people employed per firm) [1]. Most of the Indian contractors are not well equipped to handle the growing demand and hence the projects quite frequently run in to time and cost overruns, disputes and lower quality. Another major factor causing delays is the lack of proper "Trust" between the contractor and the owner due to which the disputes often end up as litigations and the work gets stalled [3].

The Indian firms are mostly involved in the "Design-Bid-Build" and "Design-Build" projects, though there is a shift to the "Fast Track" construction projects. To monitor the projects, the firms still employ the traditional method of project monitoring which includes the earned value estimate of finding the schedule and cost variances. There is reluctance in the Indian firms to change their mindset and their construction practices, in-spite of the increasing focus on the quality of projects; this is partly due to the lack of global participation in Indian construction industry. The foreign players consider India a non-profitable venture primarily due to corruption, lack of adherence to contracts, absence of proper dispute resolution mechanism [3] and hence the big Indian players being few in number tend to enjoy a monopoly over the works.

Though the above mentioned problems need significant thought and time, it is imperative that increased emphasis is given to new project management strategies so that the Indian growth story doesn't meet an abrupt end. The medium and big firms need to look to the developed nations and also China for new strategies and implement them here after some research.

Over the last decade, lean construction along with its various tools like the Pull Approach, Just in Time (JIT), Total Quality Management (TQM), Continuous Improvement, Last Planner System, etc. has gathered a lot of momentum in the developed nations. The challenge now lies in implementing the lean principles and tools in the developing countries. Recently, Khanh and Kim [4] analyzed the existing barriers on implementation of the Last Planner processes in the Vietnam construction industry; and they identified the relationship between Production Planning and waste occurrence [5]. In another study, Banawi and Bilec [6] identified that the Lean, Green, Six-sigma framework increases productivity, quality, and reduces wastes through implementing this framework to a residential complex in Saudi Arabia.

Though there have been few studies in implementing lean principles and tools in the developing countries [4,5,6], the knowledge on wastes in construction process and lessons learned on implementing the Last Planner

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System in the developing countries are lacking. To find a possible solution to this problem and to improve the construction industry in India, the researchers make an effort to implement lean principles by identifying non-value adding activities (wastes). Thus, this study aims to 1) identify the wastes, and their sources, affecting the construction process in north eastern India, and 2) to identify problems and document lessons learned by applying the Last Planner System (LPS) to a sample project. To accomplish this aim, first, a questionnaire based survey was conducted to identify wastes. Second, the Last Planner System (LPS) was applied to a construction project in India to identify problems and document lessons. This paper presents the following findings: key wastes and their sources in Indian construction practices, and a sample project implementing the Last Planner System. From the sample project, the Percent of Planned Complete (PPC) analysis results and experienced problems during the implementation are documented and reported.

II. BACKGROUND

A. *Lean Construction*

The traditional method of project management has a long history. It is being used to manage all kinds of construction projects ranging from small residential to huge infrastructural projects like bridges and dams. However, in the recent years due to the growing domestic and international competition, development of highly complex and uncertain projects this technique of project management has often come under severe criticisms. The construction industry has been suffering from problems of low productivity, poor safety, inferior working conditions and most importantly inferior quality. In developing countries like Saudi Arabia poor project planning, ineffective site management and poor communication are major issues affecting the construction industry [7]. Many have attributed automation and increased computer integration as a solution to the above mentioned problem [8]. Hence, there has been little progress in the field of Lean construction over the years. However, recently many parts of construction industry have started to shift towards enablers of lean production theory like prefabrication, off-site fabrication, or modularization.

Another significant feature or rather a flaw of Critical Chain Project Management (CCPM) of project management is the fact that all the cost and time overruns are attributed to the fact that the contractor's workers fail to follow the schedule and budget during construction. No question is ever raised on project planning which precedes the construction. It has been observed that the majority of the failures are a result of bad or incomplete planning on part of the planners [9]. Many uncertainties are not incorporated into the schedules by the top management as the only motive is to win the project contract. The schedules are derived from experiences based on the history of other so called similar projects. Contractors still do not give importance to the fact that all construction projects are different and hence it is not correct to establish detailed schedules at the onset and trying to follow the same. The consequence of such an action is disastrous for the contractor as the quality of the construction is compromised and a lot of time and money has to be spent on rework.

The application of lean production principles in the construction industry is lean construction. However, the lean production principles which are originated from the manufacturing industry cannot be applied directly to the construction industry. There is a marked difference in the construction industry from its manufacturing counterpart. The main problem that lies in the road towards lean construction is that, most companies do not see construction as a flow and transformation based process [8]. They believe that all activities are conversion based and hence they do not try to reduce the Wastes in construction. Past researchers [10] have identified the following wastes in construction: waiting for resources, travelling time movement (of operator or machine), idle time (of operator or machine), resting, and rework. Recent study conducted by Khanh and Kim [5] also reported that time for waiting, transportation, communication, inspection and instruction related to time wastes. A classification of the main causes behind the wastes has also been provided by Serpell et al. [10] and those are: lack of resources, lack of information, inappropriate method, poor quality, poor planning, bad allocation, poor distribution, ineffective control, failures in external flows, and environmental causes.

Most of the wastes listed above are a clear demonstration of lack of adequate planning and management control. Information of the above mentioned wastes beforehand can help the project managers to take extra precaution during the execution of the project. One major solution to the above mentioned wastes can be increased emphasis on short term planning as most of the wastes mentioned above are a result of ineffective short term planning [10].

Many tools are available to achieve this goal, but in this study, the researchers focused on Last Planner System developed by Glenn Ballard [11], which has been successful in other parts of the world [12-14], to remove the wastes and to shield the downstream work from the uncertainties in the upstream construction processes in India.

B. *Last Planner System*

Developed by Glenn Ballard [11], it aims to reduce / remove the uncertainties plaguing the construction project processes. In CCPM, there is strict adherence to the master schedule even when great obstacles lie in its path. Supervisors keep on pressurizing the subordinates to produce despite obstacles. Many times these obstacles result in poor quality output which remain in the project supply chain throughout.

Last Planner System (LPS) aims to shift the focus of control from the workers to the flow of work that links them together. The two main objectives of Last Planner System are to make better assignments to direct workers through continuous learning and corrective action and to

cause the work to flow across production units in the best achievable sequence and rate. Planning for the project cannot be performed in detail much before the events being planned. Consequently, deciding what and how much work is to be done by a design squad or a construction crew is rarely a matter of simply following a master schedule established at the beginning of the project. Hence it is imperative that Last Planner System focuses on making a 6 -8 weeks look ahead schedule with detailed weekly plans in discussion with the last planners (people who actually execute the work) based on the current situations. The activities from the master schedule are broken down to greater detail. Assignments are prepared for the workers to work upon. Ballard [12] suggested that assignments should satisfy the following criteria before being allocated to the workers:

1. Work should be clearly defined.
2. Work should be sequenced properly.
3. All pre requisites for the work should be obtained and the constraints should be removed.
4. Work should be sized based on the availability of the crew.

The assignments satisfying the above criteria enter the workable backlog. All the other assignments are postponed till the time they satisfy the above mentioned criteria. In this way the workers are never overloaded, they only do what they promised and this helps to keep a track of the productivity. Failure to keep commitments is investigated so that they do not occur again. This is done by a factor known as PPC (percent planned complete). Ideally this should be 100% as everyone is expected to keep his commitments but generally a value of 80% is considered to be good. All the above lean construction tools are used in the Last Planner System. As the Last Planner System involves the pull approach to form workable backlog, it utilizes the just in time tool, since all the people involved in the project come together to form the look ahead schedule.

III. RESEARCH METHODOLOGY

A. Identifying Key Wastes and their Sources in Indian Construction Practices through a Survey

Phase 1 of the project involved identification of key wastes in Indian construction practices. As explained earlier, waste is any process which consumes resources without adding any value to the project. To identify the wastes in the Indian construction practices, a questionnaire-based survey was conducted. The questionnaire was similar to that was employed in Chile for its construction sector by L.F. Alarcon [16]. Although some waste categories were not relevant to the Indian construction industry, the questionnaire proposed by L.F. Alarcon [16] for the Chilean industry was retained in its original form for this study. The activities classified as wastes in the questionnaire [16] are: 1. Work not done, 2. Unnecessary movement of materials, 3. Re-Work, 4. Excessive vigilance, 5. Unnecessary Work, 6. Extra supervision, 7. Defects, 8. Additional space, 9. Stoppages, 10. Delays in activities, 11. Wastage of Materials, 12. Extra processing, 13. Deterioration of Materials, 14. Clarifications, 15. Unnecessary movement of labor, and 16. Abnormal wear and tear of equipment.

The sources of wastes were grouped into three categories namely as below: Management related, Resources related and Information related [16].

Management Related:

1. Unnecessary Requirement
2. Excessive Control
3. Lack of Control
4. Poor Planning
5. Excessive Red Tape

Resources Related:

1. Excessive Quantity
2. Shortage
3. Misuse
4. Poor Distribution
5. Poor Quality
6. Availability
7. Theft*

Information Related:

1. Unnecessary
2. Defective
3. Unclear
4. Late

*"Theft" was added to L.F. Alarcon's [16] questionnaire based on the authors' personal interviews and feedback from construction professionals at some other construction sites in India.

The main aim of the questionnaire was the development of a cause effect matrix, which helped in identifying the major wastes and their corresponding sources of wastes. The respondents were asked to identify at least six construction waste processes prevalent in their organization from the list given. After identification of the wastes they were asked to identify wastes using numbers - 1 to the desired number. For the identification of the sources of wastes, the respondents were asked to mark the sources given with the corresponding number of the waste. For e.g. if Rework was identified as a waste with a number 1 then all the sources corresponding to the waste Rework were to be marked as 1 in the 1st column. Similarly if Delays was identified as a waste with number 2, then all sources corresponding to Delays had to be marked as 2 in the 2nd column. The same had to be repeated as per the number of wastes identified by the respondent.

Prior to the administration of the survey, a presentation was held which was attended by members from academia and engineers working at a group of construction sites in India. The aim of the presentation was to introduce the topic of lean construction to the fraternity so that the waste processes in construction processes become conspicuous. A total of 23 participants attended the presentation. The questionnaires were given to all those present for the presentation and were sent to other companies in practice. Out of the 30 questionnaires administered as hard copies 28 have been obtained (from 1 owner and two contractors including project manager, owner's representative, owner's in house engineers, field

manager, field engineers, etc.). The details of the backgrounds of the participants can be found in Bhatla's Bachelor Thesis Project report [17]. To ensure the participants choose the most appropriate waste category, the authors guided the participants when they raise questions while administering the survey. The results and findings of the questionnaire survey are presented in the next section.

B. Implementing the Last Planner System (LPS): A Case Project

The most critical wastes identified in the survey were related to planning and hence it was decided to go for the implementation of the Last Planner System which is an integrated planning tool for the implementation of lean construction, to reduce the wastes thus identified. It was believed that since the Last Planner System is in essence a tool which promotes proper planning of the construction process and involves all the parties concerned with a construction project, it helps in mitigating the planning and management related wastes.

For the implementation of the Last Planner System, the authors tried to find a construction site which also involved electrical and plumbing works apart from the regular civil / structural works. This was done in order to examine the potential of the Last Planner System to increase the cooperation among the different parties concerned with the project to expedite the construction process. The project chosen was a 3 story academic / office building covering an area of 865 sq. m per floor in a major city in India (approximately Rs. 4.5 crores or USD $1 million (in 2010)).

The work is monitored by using Percent of Planned Complete (PPC) and the inability to achieve a high PPC is investigated for process improvement and to prevent the problems from re occurring. PPC is the method used for monitoring of the project. Unlike the techniques of earned value estimate which is traditionally used for monitoring of projects, the PPC measurement has the following advantages:

1. Work is selected by the workers themselves and hence there is less chance of time over run.
2. The causes for the non-completion of work are mentioned explicitly while analyzing PPC.
3. PPC helps in continuous improvement of the construction project as efforts are made to prevent the reoccurrence of problems.

IV. Results and Analysis

A. Key Wastes and their Sources in Indian Construction Practices

As explained earlier, waste is any process which consumes resources without adding any value to the project. To identify the wastes in the Indian construction practices, a questionnaire-based survey was conducted. Out of the 30 questionnaires given to the participants of the survey, 28 responses were obtained. Although the sample size of 30 could not be reached, this in line with suggested guidelines for recommended sample sizes in similar qualitative studies [18,19]. Table 1 shows the frequencies of the wastes as obtained from the questionnaire. The most critical wastes are listed as under on the basis of their frequency of occurrence:

1. Delays (20 out of 28)
2. Rework (23 out of 28)
3. Interruptions (19 out of 28)
4. Defects and Unnecessary Labor Movement (15 out of 28)

Other wastes like uncompleted work, ineffective work, materials wasted, and unnecessary material handling also accounted for a significant proportion of the total wastes mentioned by the respondents. These results are similar to those observed by Ramaswamy and Kalidindi [2] in an independent project done in another part of India almost at the same time as this study. They observed that wastes due to non-value added activities by labor and equipment were much higher compared to the material wastes generated on sites.

The cause effect matrix as shown in Table 2, points out the most important sources of the critical wastes (columns), which were easily identified, based on their frequency of occurrence in the matrix (number in the cell), as follows:

1. Wastes – delay, unnecessary labor movement, and interruption were caused primarily due to the absence of proper management control at the site along with poor project planning. Shortage of resources was also equally responsible for the occurrence of delay and interruption. This highlighted the fact that there was no scheduling / planning being done at the various sites and the work was carried out by the word of mouth. Another important fact to note was that the subcontractors sometimes worked without any supervision of the site engineers and this highlighted the need for more management control. Also, in the absence of proper planning, the supply chain management at sites was erratic resulting in frequent material / resource shortage.

TABLE I
WASTES AND THEIR FREQUENCIES OF OCCURRENCE IN THE RESPONSES

#	Waste Categories	Frequency (Out of 28)	#	Waste Categories	Frequency (Out of 28)
1	Uncompleted Work	14	9	Unnecessary Material Handling	11
2	Rework	20	10	Excessive Surveillance	2
3	Ineffective Work	11	11	Excessive Supervision	2
4	Defects	15	12	Excessive Space	-
5	Interruptions	19	13	Delays	23
6	Materials Wasted	11	14	Extra Processing	10
7	Damaged Material	8	15	Clarifications needed	14
8	Unnecessary Labor Movement	15	16	Abnormal equipment wearing	3

TABLE II
CAUSE EFFECT MATRIX

Wastes	***Sources of Waste***	**MANAGEMENT RELATED**	Unnecessary requirement	Excessive Management Control	Poor Management Control	Poor Planning	Excessive Bureaucracy, paperwork	**RESOURCES RELATED**	Excessive amount	Shortages	Misuse	Poor Distribution	Poor Quality	Availability	Theft	**INFORMATION RELATED**	Unnecessary	Defective	Unclear	Late
Uncompleted Work			2	2	4	6	2			8	2	1	1	2	2		1		6	4
Rework			6	5	6	6	3		1	2	4	3	5	1	2		2	4	6	1
Ineffective Work			1		6	6	3		1	5	3	5	5	1			1	4	4	3
Defects			3		5	4	1		2	1	5	3	9	2	1		1	6	4	2
Interruptions			2	3	9	11	4		1	10	3	4	5	3	2		5	4	4	6
Materials Wasted			3	1	4	4	1		1	1	5	4	5		3		1	4		2
Damaged Material			1		5	4	1		1	2	2	3	5		2		1	3	1	
Unnecessary Labor Movement				2	10	9	2		1	4	3	7	5	2			1	2	4	3
Unnecessary Material Handling			2	1	4	5	1		2	1	3	6	2		1		2	2	3	3
Excessive Surveillance																				
Excessive Supervision			1	1	1		1		1											
Excessive Space																				
Delays			2	4	11	9	6			9	5	5	6	3	3		2	3	3	8
Extra Processing			3	3	1	7	5		1		1	3	2					1	3	3
Clarifications needed			2	3	5	7	3			1	3	2	2	1			1		4	2
Abnormal equipment wearing			1		1	3			1	1		3	1	1			2	1	2	2

2. Rework was another significant waste. As obtained from the survey majorly the management related wastes along with poor quality of resources and unclear information contributed towards this waste. It was observed that there were frequent design changes at the sites which highlighted the need for proper planning before progressing on with the work; another important factor leading to this waste was excessive management control and unclear information. In the absence of clear directives, the subcontractors were sometimes forced to do work which was not as per the design specified. It was also observed that at times work was carried out using substandard materials leading to frequent confrontations between the various parties involved in the project and ultimately resulted in rework and delays in the project.

3. The major sources of the waste - defect were usage of poor quality materials and incorrect / defective information. On further investigation it was found that incorrect information was sometimes passed onto the subcontractors from the management and this resulted in defects in the construction which later had to be reworked upon.

4. Another important waste highlighted in the survey – frequent clarifications needed – was attributed mainly to the absence of proper planning. It was observed that at times the management failed to obtain clear directives before starting the work and this resulted in the subcontractors seeking frequent clarifications (request for Information or RFI), which sometimes also led to stoppage of work, during the course of the work. There was lack of proper planning before starting any activity.

5. The other wastes like Uncompleted Work and Clarifications needed were found to be considerably less significant when compared with the above mentioned wastes. Their sources were observed to be the absence of proper planning at the site, shortages of resources, unclear information, and poor management control.

The findings of this research were similar to those from other developing countries in Asia like Saudi Arabia [7], Vietnam [4] and China [14] where ineffective planning and control, poor site management, poor communication between the parties involved and unreliable availability of materials were the major issues affecting the construction industry.

B. Implementation of the Last Planner System in India: A Case Project

As observed from the survey, the construction in India is affected by delays, interruptions and rework, which have been attributed to mostly the management related sources like poor management control and poor planning along with shortage and poor quality of resources. It was decided to go for the implementation of the Last Planner System which is an integrated tool for the implementation of lean construction, to reduce the identified wastes. The Last Planner System has been successfully tested and applied in diverse environments and various countries all over the world [20]. It was believed that since the Last Planner System is in essence a tool which promotes proper planning of the construction process and involves all the parties concerned with a construction project, it helps in mitigating the planning and management related wastes.

Implementation of the Last Planner System

There was considerable excitement and enthusiasm in the project team for implementation of the Last Planner System along with some skepticism given the highly unorganized nature of the Indian construction industry. However, due to lack of trained and skilled planners / schedulers at the site the learning curve for implementation of the Last Planner System was steep. The strategy for the implementation was similar to that used at a construction site in England [13]. The Last Planner System was formally started at the site on December 20th 2009. It was implemented as follows:

1. Creation of a milestone based Master Schedule for the remaining works - Since there was no schedule being followed at the site all the

remaining activities till completion of the project were incorporated in the Master Schedule; the hand over date was taken to be 4/30/2010.

2. Selection of works to be completed in the coming 4 weeks were noted in the 4 Week Look Ahead Plan - On the basis of the master schedule thus developed, activities were selected which were to be completed in the coming 4 weeks. They were noted down in the prescribed format along with their completion dates based on the prevalent conditions.
3. Identification of all prerequisites of the activities in the look ahead plan and their procurement - All the prerequisites (pending activities, labor requirements, material requirements, equipment, specifications etc.) of the activities listed in the look ahead were identified so that they can be procured / completed before starting the work.
4. Creation of a Weekly Work Plan (WWP) by selecting activities from the look ahead plan whose prerequisites had been procured - The activities for which all the resources had been procured were enlisted in the WWP and were required to be completed in the coming week.
5. Weekly performance monitoring by calculating the PPC (Percent of Planned Complete) and taking necessary action to prevent reoccurrence of problems. The activities in the WWP which had not been completed were noted along with the reasons for non-completion so that they were not repeated again. As suggested by Ballard [11] the elements of the Activity Definition Model were used at the primary categories to provide a guide for reasons analysis that facilitated in identification of actionable causes. The primary categories were directives, prerequisites and resources. Once placed within one of these categories, a plan failure was analyzed.
6. The Steps 2 – 5 had to be repeated every week (Monday).

Percent of Planned Complete (PPC) Analysis Results

The Last Planner System implementation performance was assessed by PPC analysis as shown in Table 3 and Fig. 1. Fig. 1 shows an uneven trend, beginning with an initial slump during the 1st week, PPC rises to 100 % in the 4th week only to fall back to 28 % in the following week. For the period of week 6 – 10, a PPC level of approximately 75 % was sustained, but beginning of week 11 till the end of the project there was another slump.

In the initial few weeks, a low PPC was understandable as that was a transition phase / learning curve wherein the management was exposed to the idea of the Last Planner System and the need for proper planning to eliminate / reduce the wastes observed from the questionnaire survey. Numerous efforts were made to make the management and the owners aware of the Last Planner System and the imminent benefits from its application, a number of site visits were held along with informal discussions with the site engineers and the subcontractors in order to make them comfortable with the idea of planning and scheduling of the project. It was observed that the site engineers got acclimatized to the Last Planner System beginning the 4th week when a PPC level of 100% was reached. However, due to the sudden shortage of labor at the site and due to non-payment of dues, the PPC level for the following week dropped to 28 %. During the next month there was a considerable improvement in PPC due to the review meeting which was held on 5th week in which all the major parties concerned with the project participated and took note of the prevalent situation. During the meeting all the wastes at the site were discussed, major among those were the problems of labor shortage due to non-payment of dues and cement shortage. It was decided that a stock of 50 bags would be maintained at the site and the accounting system for the wages of the labor would be improved to prevent a reoccurrence of such a situation.

TABLE III
PPC ANALYSIS RESULT

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PPC (%)	16.67	50	16.67	100	28.57	92.30	64.28	72.72	75	80	55.55	60	20	50
Tasks completed	1	4	1	7	2	12	9	8	6	4	5	6	1	3
Tasks allotted	6	8	6	7	7	13	14	11	8	5	9	10	5	6
Reasons														
Rain														
Prerequisite	4	2	3				3				1	4	4	1
Design / Directives changed					1				1					
Equipment			1				1							
Labor			1					2	1	1	2			1
Work started late	1							1			1			
Other		2												1

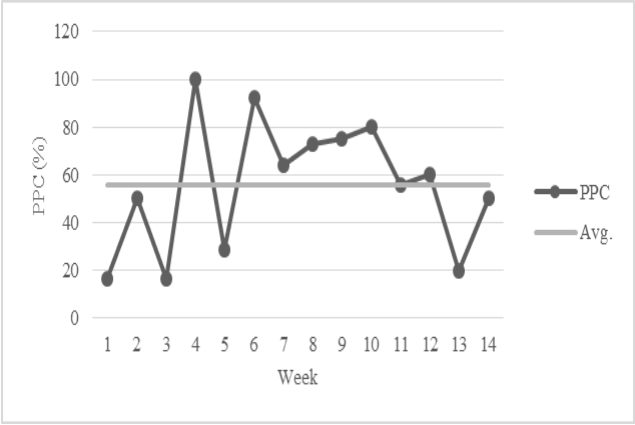

FIGURE I
PPC VARIATION ANALYSIS RESULT

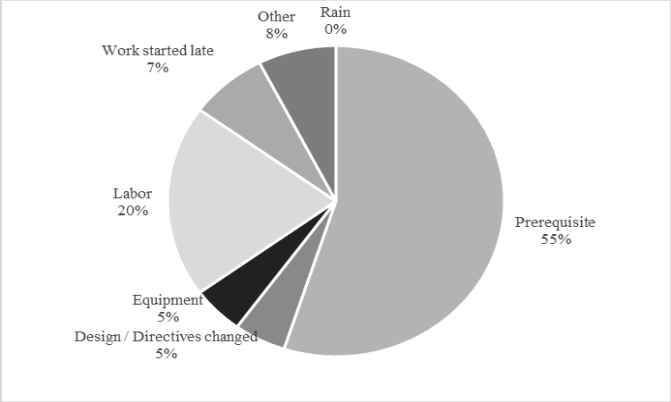

FIGURE II
REASON CATEGORIZATION

In weeks 6-9, the number of weekly allotted activities increased due to the commencement of the electrical works. The sub-contractor handling the electrical work was extremely efficient and adapted to the LPS very quickly. Among the different subcontractors working at the site, their performance was better as they completed 16 tasks out of the 18 tasks which they committed to do during the period of the study. During weeks 10- 13 of the case study, labor problems became prominent at the site, it was observed that there was a continuous inflow and outflow of labor at the site. Major problems were noticed in the supply chain management of the contractor during this time. As the contractor was directly dealing with suppliers (no weekly meetings were held on site with the suppliers) there were repeated failures to procure the prerequisites on time and hence many activities remained in the look ahead schedule for nearly a month (MS box fixing and Window grills installation). Furthermore, many succeeding activities like internal plaster were also held up due to the non-completion of the electrical works. In the last 2 weeks of the study, a sudden and severe cement shortage developed on site which lasted for 5 days leading to an extremely low PPC of 20% in the penultimate week. This problem was resolved in the following week after another major review meeting with the contractor; the contractor gave commitments to procure the prerequisites of the activities pending in the look ahead schedule during the last week, but again due to his "lack of seriousness", the contractor was not able to keep majority of his commitments.

An average PPC of approximately 60% was achieved for the duration of the project which was less than 80% PPC achieved in two projects in Saudi Arabia [20]. One reason for this difference is due to the longer duration of the projects in Saudi Arabia, which lasted for 17 months each. This allowed for a stable PPC to be reached as the users became more accustomed to the Last Planner System

As shown in Fig. 2, failure to obtain prerequisites (materials) or complete the prerequisite activities by the allotted date and labor shortage were the main reasons for plan failure. Together they accounted for 75 % of the total reasons leading to plan failures.

Ballard's Activity Definition Model [11] was applied to find out the cause of the failures related to the above mentioned plan failures. In the first 2 weeks of the case study it was observed that some prerequisite related failures were due to the inability of the Last Planners to identify the all needed prerequisites. This was understandable as they were new to the concept of the Last Planner System and needed some time to get used to it, so some prerequisites were not identified in the weekly plans. The majority of the prerequisite related failures were caused because the provider of the prerequisite failed to keep his promise. Hence, the prerequisites were not delivered on time and this led to failures in the plan. On further analysis it was found that the Last Planners were also partly responsible for some failures as they sometimes over committed work beyond what was possible based on the available resources and hence were not able finish the allotted work.

Majority of the Resources related plan failures occurred during the 2nd half of the study period. Labor shortage was experienced at the site and there was continuous inflow and outflow of labor from the site. It was observed that the subcontractors selected tasks for the work plan hoping that they would be able to get the labor before the start of the activity. This worked sometimes but in majority of the cases the labor was not available and this led to significant plan failures. Superficial labor shortage at the site was also reported due to nonpayment of the labor dues.

Other factors like change in design or directives in the middle of the week and late starting of work together accounted for 12% of the total plan failures. These failures occurred due to the lack of coordination between the owner and the contractor and also because of the relative inexperience and lack of interest of the site engineers. There were also some directive changes in the middle of the week which highlighted the need for better coordination between the owners and the contractor. Most potent design / directive changes originated because of the inability of the contractor to understand the needs of the project and failure to correctly interpret the directives from the owners. The above mentioned factors had huge consequences which led to a lot of and frequent rework at the site which could have been avoided through better coordination among all the members of the project.

Problems Experienced during the Implementation of the Last Planner System

- No planning / scheduling techniques were being followed at the site. Main contractor was doing planning for the smaller sub-contractors with little or no input from them.
- The construction wastes were mostly viewed as wastage of materials.
- Lack of interest on the part of the contractor to implement the Last Planner System (Lack of adherence to the weekly schedules and the look ahead schedules.).
- Lack of interest among all parties towards a joint weekly review meeting to monitor the progress

of the work and to sort out the problems. This led to lack of coordination between the owners and contractor.

- There was excessive rework at the site due to the failure on the part of the contractor / site engineers to understand the requirement of the owners.
- There were acute problems in the supply chain management of the contractor, no effort was made to stick to the look ahead plan and order materials according to the date mentioned in it. This led to a huge buildup of activities in the look ahead plan.
- There were problems of labor shortage at the site during the 2nd half of the study period. It was felt that the contractor failed to pay the labor properly and this led to frequent inflow and outflow of labor from the site. Superficial labor shortage was also reported when the contractor failed to pay the labor on time which led to stoppage of work.

IV. Conclusions and Recommendations

At the end of the project work the major objectives have been achieved. Phase I of the project work involved the identification of the key wastes along with their sources using a questionnaire based survey. As obtained from the analysis of questionnaires collected, Delays and Rework were the most critical wastes plaguing the construction practices. Their sources, as found by the cause effect matrix, were Poor Management Control, Poor Planning and Shortage of the Resources Used.

Phase 2 of the project involved the implantation of the Last Planner System at a case project in India to identify problems and document lessons by applying a Last Planner System (LPS) to a sample project. Although the wastes could not be removed completely, they were made conspicuous and were documented. The PPC level ranged from 16.67 % to 100 % with an average PPC of 55.84% for the duration of the study. It was observed that much more improvement could have been achieved if the contractor would have taken keen interest in the implementation of the Last Planner System. There was also lack of interest among all the members of the project to sit for a weekly review meeting to solve the problems causing plan failures.

The following recommendations are made on the basis of this research to improve the construction scenario in India if the work is going to be done by local contractors:

1. Weekly review meetings at all sites (1 site per day) in which all members sit down and review the work done in the previous week, solve the problems to prevent reoccurrence, make look ahead plans and weekly plans using the Last Planner System.
2. As the Engineering department was understaffed at that moment, it was recommended that a dedicated project management team be formed which will maintain the weekly plans to keep track of the project and organize the review meetings.

Some of the problems experienced in the implementation of the Last Planner System like lack of scheduling, resource and material shortage were found to be similar to those in England [13], thereby showing that there are similarities in problems in the construction industry in developing and developed countries.

The study has thus contributed to the both academia and the industry by highlighting the challenges faced by the construction industry in India and also provided a basis for the development of further research in the area of lean construction. The study has recommendations that can assist in the achievement of the full potential of lean and Last Planner System not just in India but also other parts of the world with similar issues affecting construction projects. These include the need for full support, interaction and commitment from top management and proper planning by involving the last planners in a construction project. The results of this study can also be used by others in the industry to improve their management practices.

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