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Application of Lean construction In terms Of Delay In construction industry

Vinny Raj KP, Fazil P

Dept. Of civil engineering, Cochin College Of engineering and technology, Valanchery

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Abstract -*A growing number of construction firms are embracing the Lean methodology that emphasizes maximizing value for the customer while minimizing waste. The approach is simple and attractive in an industry where budgets, timeframes, and safety are all critical. But the Lean approach to project delivery is very different than traditional construction methods, making proper execution of the philosophy and techniques difficult to implement. The construction industry has demonstrated a decline in productivity when compared to other industries over the past twenty years. Lean concepts have caused a revolution in manufacturing design, supply, and assembly. Applied to construction, lean concepts can change the way work is done throughout the facility delivery process*

1.INTRODUCTION

Although there are still debates about whether the productivity of the construction industry is increasing or declining, the performance of the construction industry is widely perceived as unsatisfactory compared too many other industries. The lack of improvement in the industry be contributed to a number of factors, including industry fragmentation, lack of trust between key participants, the traditional contracting environment, craft-oriented culture, increased regulations, safety issues, and lack of process innovation. Contractors are under enormous pressure for continuous improvement to enhance their productivity and competitiveness locally and internationally. To achieve this goal, construction companies are looking to other industries such as manufacturing to examine the effectiveness of their measuring, monitoring, and improvement techniques.

Lean is a production management strategy for achieving significant, continuous improvement in the performance of the total business process of a contractor through elimination of all wastes of time and other resources that do not add value to the product or service delivered to the customer (Womack et al. 1996). Lean concepts have resulted in dramatic performance improvements in manufacturing, the principles behind lean concepts have been effectively applied to construction, as shown in many previous studies, such as those published in the annual conferences of Lean Construction Institute

1.1 Objective

Since delay mitigation has countless benefits towards achieving efficient it is high construction practices, we believe that time a developing country like India starts to imbibe principles that focus on reducing wastes through delay minimization to upcoming projects. The corresponding elimination of wastes and a product that reflects the needs of the customer would go a long way into the wholesome development of the construction industry as a whole.

To bring about a radical shift in how the construction industry must view time, materials and money, the introduction of lean principles to projects from their infant stages is imperative.

This project aims to:

(1) Identify the most prominent delay factors in construction projects

(2) Categorize the delay factors in construction projects into Transportation, Inventory, Motion, Waiting, Over Processing, Over Production and Correction related

(3) Quantify relative importance of delay factors and to demonstrate the ranking of factors and categories according to their importance level on delays

(4) Analyze the data obtained to find the most delay inducing factors through various tools and techniques

(5) Address the most contributing factors and categories causing delays and make recommendations in order to minimize or control delays in construction projects.

Creating awareness among builders and contractors about Lean techniques and their implementation in the construction industry

1.2 Lean Construction

The traditional approach to construction focuses on what the customer wants you to build – what's included in the plans and specifications. Lean construction, on the other hand, recognizes that what the customer values is deeper than that. It isn't just about what to build, but why. Truly understanding value from the customer's point of view requires a different level of trust, established very early in the planning phases of a project.

Lean construction borrows from the manufacturing approach developed by Toyota after World War II. Of course, it is much easier to produce repeatable, fore cast able results in the controlled environment of a factory

floor than in the more unpredictable world of construction. Greater variation and workflow disruptions are to be expected. It is also important to note that there is no one cookie-cutter approach to Lean construction. There are a number of tools including the Last Planner System, Integrated Project Delivery, Building Information Modeling, 5s, can be used in combination to achieve lean. This gives practitioners a wide range of options that can be applied to each project. There are, however guiding principles that help firms achieve lower costs, reduced construction times, more productivity and efficient project management. They represent a holistic approach to the construction process.

Lean construction brings together all stakeholders including the owner, architect, engineers, general contractor, subcontractors, and suppliers. The project team not only delivers what the client wants, but they provide advice and help shape expectations throughout the project. Once you have a clear understanding of value from the customer's point of view, you can lay out all of the processes necessary to deliver that value. This is called the value stream. For each activity, the necessary labor, information, equipment, and materials are defined. Any steps or resources that don't add value are removed.

A primary goal of Lean construction is eliminating or minimizing waste at every opportunity. Lean construction targets eight major types of waste:

DEFECTS: Defects are anything that is not done correctly the first time, resulting in rework that wastes time and materials.

OVERPRODUCTION: In construction, overproduction happens when a task is completed earlier than scheduled or before the next task in the process can be started.

WAITING: The most common scenario that leads to waiting in construction is when workers are ready, but the necessary materials needed for the work to be completed have not been delivered or the prerequisite prior task has not been completed.

NOT UTILIZING TALENT: Workers on a construction project have a range of skills and experience. When the right person is not matched to the right job, their talent, skills, and knowledge go to waste.

TRANSPORT: The waste of transport happens when materials, equipment, or workers are moved to a job site before they are needed. It can also refer to the unnecessary transmission of information.

INVENTORY: Materials that are not immediately needed are considered excess inventory. They tie up budget, require storage, and often degrade when not used.

MOTION: Movement that is not necessary, like distance between workers and tools or materials creates the waste of motion.

OVER PROCESSING Over processing happens when features or activities are added that have no value to the client. Ironically, this often occurs when taking steps to eliminate the other types of waste.

The ideal state of a Lean construction project is a continuous, uninterrupted workflow that is reliable and predictable. The sequence is key in construction; you can't start building the frame until the footings are set, for example. Clear communication between all parties is essential to achieving flow. When one part of the project gets behind or ahead of schedule, it is essential to let everyone know so that adjustments can be made to avoid the wastes of waiting, motion, and excess inventory.

Creating reliable workflows depends on work being released based on downstream demand. Lean construction recognizes that this is best done by those performing the work, often subcontractors. Participants communicate and collaborate closely with each other to determine the schedule of tasks.

The belief that it is possible and necessary to continuously improve processes and eliminate waste is the heart of the Lean philosophy. Opportunities for improvement are identified and acted upon during the project and applied to future projects.

The construction industry is not immune to the tendency to stick to old ways and resist change, but the many benefits of the Lean approach are compelling more and more firms to take on the challenge. When projects come in on time, on budget, and with exactly the value the customer expected, everyone involved is better for it.

1.2 Corona virus And Construction Sector

The impact of COVID-19 pandemic on the global markets and commercial activity is responsible for exposing the construction sector to a number of challenges– challenges that may worsen if the disease spread is not curbed. According to the Global Data

report, estimated growth for the construction industry in 2020 has been predicted to go down to 0.5%. Hence, for the time being, it's quite hard to anticipate a possible recovery programme that is fool-proof. Perhaps the biggest concern is regarding the 'stalled projects'. Lockdown enforcement is turning quite antagonistic to the timely fulfilment of various projects. For government-commissioned projects, a missed deadline may not be severely dealt with but for private sponsors- it's going to take a huge toll. This may end up creating a number of legal problems for renewal or penalty percentages, especially in the case of various 'time-bound' projects. A serious issue is arising in terms of fixed cost procured by construction firms beforehand in terms of money spent on land lease, site facilities, electricity charges, etc.

A number of stalled or cancelled projects will automatically result in losses for the company. Getting projects from paperwork onto the ground sites is another challenge in many spheres. This mainly depends on two factors– availability of labour and availability of material. The labour force currently can't be commissioned as their presence at a site clearly defies the social distancing protocol that needs to be followed. However, in projects that follow the distancing protocol, construction firms need to keep a thorough check on their employees- both permanent as well as commissioned. This is critically important for the unorganized workforce employed in the form of daily wagers. Construction firms need to keep their accommodation, sanitation, and more importantly, their travel history (state/regional) documented so as to prevent any spread while working on a project. This involves scenarios where construction firms need to spend extra bucks to provide masks, gloves, PPE gears, sanitizers, etc to the workers. Thermal scanners, medical facilities, disinfection tunnels need to be kept available 24*7.

The availability of material and the associated supply chain bottlenecks cannot be overlooked in these turbulent times. Depending on the region of availability, material procurement is yet another herculean task. The present stocks of specialized construction materials, processed equipment (that are imported from foreign countries) are our only respite till the lockdown is lifted. Even materials obtained locally are not accessible due to government curbs on the interstate and inter district movement.

A number of stalled projects in big shot construction companies like KEC International, L&T, and Ambuja cement speak volumes about the issue. The unavailability of materials (mostly China-based) is also creating a need to venture into other possible markets and this may involve a lot of paperwork/ contracts/ agreements in a relatively short period of available time.

Another challenge faced by the construction sector is the overburdened contractor who is responsible for maintaining the proper functioning of not only his key staff but also at the subcontractor level. The subcontractors who are critical for the delivery of any project are currently under immense stress. Many are on the verge of bankruptcy that may occur either immediately in case of a site shut down or after a period of time. In case a site shuts down, the construction sector workforce is left vulnerable to the vulgarities of the market as most of the work must take place on-site and cannot be done remotely. Investment and funding in the construction sector is yet another problem being encountered. With the world slipping into a phase of recession and clients delaying investment decisions, a number of *MNCs*' are lying low and adopting safer practices, the same is the case with bank investments.

So an investment deficit may be encountered in the coming times and it won't be wrong to predict potential acquisition of a distressed/ insolvent firm due to major work shortage or abrupt cessation of projects due to monetary issues. With the changes encountered in the methodology of day to day work, traditional routes for businesses to create or upgrade their profiles are no longer employed; instead, alternative methods are being sought. This is evident in way of client-firm interaction or online business meetings which may not be a long term option since the construction sector is site-specific .The construction sector is also facing the challenge of bringing about necessary changes that need to be carried out for both the capital and corporate cost budgets. The companies presently need to review their expenses so as to create a balance in this turmoil. This also involves the need to lay off the workforce which yet again exposes the employees to an unprecedented future and may increase with worsening of the disease severity.

In present circumstances of drastic climate change, the shutting down of industries worldwide has somewhat lead to a substantial decrease in the carbon dioxide emissions along with other greenhouse gases. This is another sphere where countries can work forward to develop technologies involving cleaner fuels. Government stimulus actions along with steps taken by the Reserve Bank of India may momentarily throw a pulse of revival in the economy especially the construction sector. Steps like tax benefits or direct cash disbursals are necessary especially at the subcontractor levels.

2. METHODOLOGY

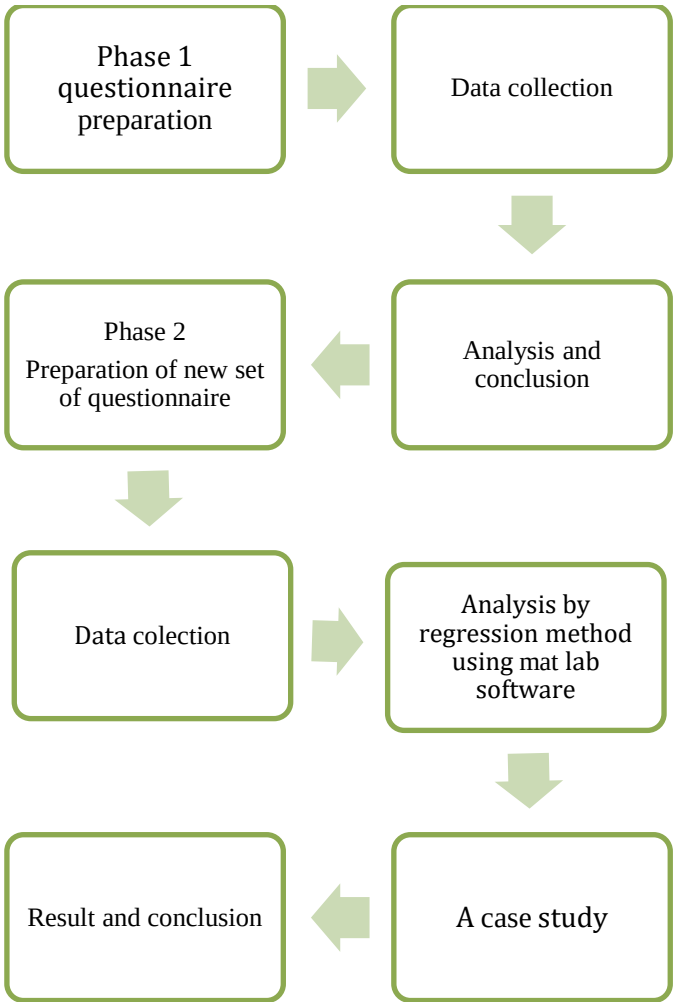

Fig -1: Methodology

2. QUESTIONNIRE

	1	2	3	4	5
Are you familiar with lean construction ideas?					
Do you think that lean construction techniques could improve the productivity in construction					
Do you think lean construction when used at site level could generate cost saving					
How frequently does your company use the lean construction tools for planning purpose					
Do you think lean material supplies are suitable solution in construction					
In your general view how frequently do the following causes of waste occur on construction project *a) Material* *b) Time* *c) Coast*					
Do you think the last planner scheduling could replace the critical path method					
Value stream mapping is under taken to understand how activities create value for the customer					
Employee is concerned with waste elimination in their daily work					
Material flow is adhered to consistently throughout the daily work activities					
Material, equipment, and other resources are provided in a “just in time manner “ when needed					
Material are ordered as close as possible to exact needs					
The source of delays related to *a) Cost* *b) Time* *c) Quality* *d) Human resource*					

e) Risk *f) Communication*						

Table -1: Phase 1 questionnaire

WASTE IN CONSTRUCTION INDUSTRY

Following are the different wastes generated in the construction industry. Kindly rank these waste based on your experience and related to your current project . *(Please rank the answer that mostly suite your views as 1, 2, 3…….7)*

Sl.No.	WASTE	RANKING
1	Transportation	
2	Lavatory	
3	Motion	
4	Waiting	
5	Over processing	
6	Over production	
7	Correction	

Identification Of The Various Root Causes In Waste Generation

The various factors or causes which lead to the generation of the respective wastes are categorized below. Kindly rate these factors based on their significance as per your opinion and experience through various project.

(*Ranking based on significance like: - 5-extremely significant effects, 4-very significant effect, 3-significant effect, 2-slight effect, 1-no effect)*

1) TRANSPORTATION

SL NO	ROOT CAUSES	RANKING
1	Ineffective planning and scheduling of the project.	
2	Improper project coordination.	
3	Equipment necessary to do the job not available on time.	
4	Strikes called by political parties , organizations etc	
5	Labor strikes	

2) UNNECESSORY INVENTORY

Sl.No	ROOT CAUSES	RANKING
1	Ineffective planning and scheduling of the project.	
2	Lack of adequate space for storage of materials	
3	Lack of weekly project evaluation meetings.	
4	Lack of experience of supervisor	
5	Inadequate instructions provided by supervisor	
6	Lack of experience of craft man	
7	Lack of team spirit among craft man	
8	Un availability of materials in time at the work place	
9	Delay in material delivery	
10	Frequent revisions of drawing/design resulting in additional work/re work	

3) EXCESS MOTION

Sl.No	ROOT CAUSES	RANKING
1	Ineffective planning and scheduling of the project.	
2	In proper project coordination	
3	Site conjunction	
4	Lack of interaction among the site community	
5	Communication problem among craft man and supervisor	
6	Un availability of tools on time at the work site	
7	Equipment necessary to do the job not available on time	
8	Accident causing hindrance to work at site	
9	Strikes called by political parties etc	
10	Frequent revisions of drawing/design resulting in additional work/re work	

4) WAITING

SL.NO.	ROOT CAUSES	RANKING
1	Ineffective planning and scheduling of the project.	
2	Improper project coordination	
3	Interference from other traders or other crew members.	
4	Disputes with consultants / owner causing stoppage of work.	
5	Lack of interaction among the site community	
6	Communication problem among craft man and supervisors	
7	Slowness in decision making.	
8	Lack of periodic meeting among management, site persons and contractor.	
9	Lack of experience of supervisors	
10	Inadequate instructions provided by supervisors.	
11	Supervisor absenteeism	
12	Lack of experience of craftsmen.	
13	Rework due to field errors committed by craftsmen.	
14	Craftsmen absenteeism.	
15	Unavailability of materials in time at the workplace.	
16	Slow response on doubts arising from the drawings.	
17	Frequent revisions of drawing / design resulting in additional work / rework	
18	Design difficult to construct	
19	Unavailability of tools on time at work site	
20	Equipment necessary to do the job not available on time.	
21	Lack of maintenance of tools and plans.	
22	Slow equipment repair in case of breakdown.	
23	Accidents causing hindrance to work at site.	

24	Climate changes.	
25	Strikes called by political parties, organizations etc.	
26	Labor strikes	
27	Poor pay.	
28	Lack of monetary incentives .	
29	Lack of workmanship.	
30	Disregard of craft worker suggestion /ideas.	

5) OVER PROCESSING

Sl.No	ROOT CAUSES	RANKING
1	Ineffective planning and scheduling of the project	
2	Lack of weekly project evaluation meeting	
3	Lack of periodic meeting among the management, site personal and contractors	
4	Lack of experience of supervisor	
5	Inadequate instructions provided by supervisor	
6	Lack of experience of craftsmen	
7	Lack of team spirit among craftsmen	

6) OVER PRODUCTION

Sl.No	ROOT CAUSES	RANKING
1	Ineffective planning and scheduling of the project.	
2	Improper project coordination	
3	Lack of adequate space for storage of materials	
4	Site conjunction	
5	Lack of weekly project evaluation meeting	
6	Lack of periodic meeting among the management, site personal and contractors	
7	Lack of experience of supervisor	
8	Inadequate instructions provided by supervisor	
9	Lack of experience of craftsmen	
10	Lack of team spirit among craftsmen	

7) CORRECTIONS

Sl.No	ROOT CASUES	RANKING
1	Ineffective planning and scheduling of the project	
2	Interference from other trades or other crew member	
3	Disputes with consultant/owner causing stoppage of work	
4	Lack of interactions among the site community	
5	Communication problem among craftsman and supervisors	

6	Lack of weekly project evaluation meeting	
7	Lack of periodic meeting among the management ,site person and the contractor	
8	Lack of experience of supervisor	
9	Inadequate instructions provided by supervisor	
10	Supervisor absenteeism	
11	Lack of experience of craftsmen	
12	Rework due to field errors committed by craftsmen	
13	Lack of team spirit among craftsmen	
14	Craftsmen absenteeism	
15	Poor quality of materials	
16	Unavailability of drawings in time at work site	
17	Errors in the drawings	
18	Slow response on doubt arising from the drawings	
19	Frequent revisions of drawings/design resulting in additional work/rework	
20	Poor quality of tools provided /used	
21	Lack of maintenance of tools and plants	
22	Disregard of craft worker suggestion/ideas	

Table -2: Phase 2 questionnaire

4. ANALYSIS AND RESULTS

4.1 Analysis of Questionnaire Made In Phase1

Some salient features of the survey conducted have been delineated as follows. We have chosen to use a rating system to compare the different levels of responses. Survey researchers have generally measured values using standardized techniques of ordering a set of competing alternatives provided by the investigator (Alwin. F.et al., 1995). While rankings are preferred to a certain degree, ratings serve as an effective alternative. From the research done by Alwin. F., although ranking methods tend to be preferred for measuring social values, the empirical evidence available from past research suggests that rating techniques may be used just as effectively. Since the rating approach encourages positive correlations, we have used it to a large extent in the preparation of this survey.

Question (4): How frequently does your company use the lean construction tools for planning purpose?

A simple weighting system using the Likert scale (a bipolar scaling method) has been assigned: Mostly: 3 points, Sometimes: 2 points, Rarely: 1 point, Never: 0 points

a) Overall usage of each tool:

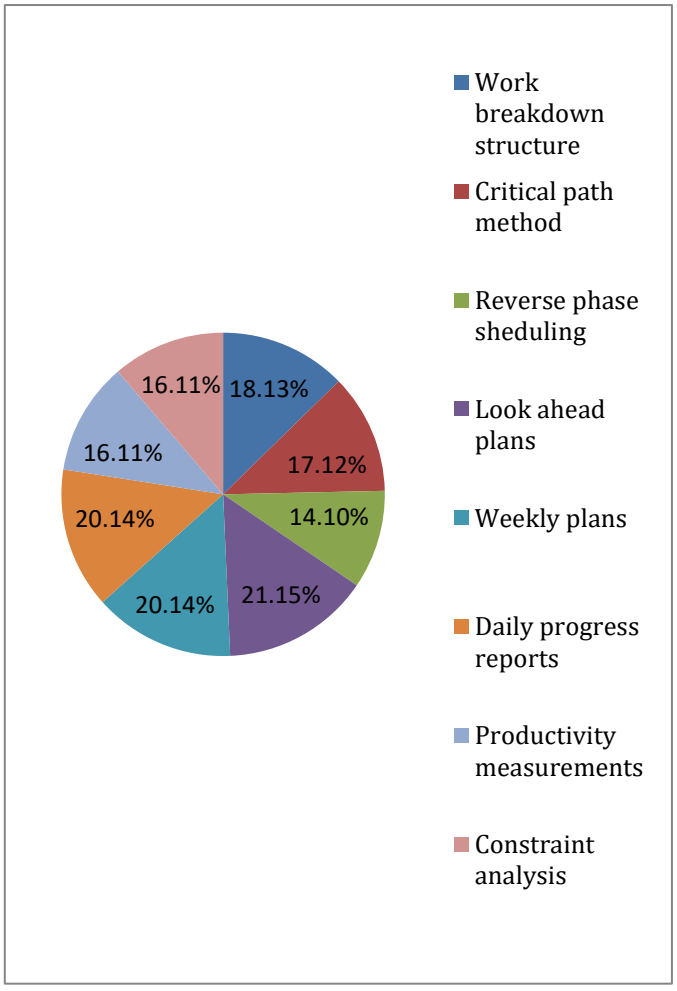

Fig -2: extent of usage of various tools used in planning

It was observed that while typical Lean principles, especially look-ahead planning and weekly planning were done by the company, it was not practiced as a partofLean.Theseconceptswerefoundtoaidtheindividual's company,intermsof overall efficiency. Tools like reverse-phase scheduling were not as common as the others, possibly because it is conceptually more advanced. An awareness drive on lean principles could thus be deemed as a starting point while promoting lean principles to the construction industry.

Fig -3 Breakup of Individual tools applied in the construction industry

It is noticed that individuals rarely have not heard of/implemented the aforementioned tools. While look-ahead planning, weekly planning and daily progress reports were practiced in most companies, advanced techniques like productivity measurement and constraint analyses were lesser in practice. These could be attributed to the requirement of specialized training and knowledge for the efficient application of these two tools in particular.

Question (6): In your general view how frequently do the following causes of waste occur on construction projects

a) Overall view of reasons for wastage (materials, time, cost) in the work site:

While most companies were faced with wastage of resources from frequent design changes and wait for resources, many other factors contributed as well. Accidents in the work site did not seem to be as contributing a factor, along with pilferage and lack of trust. Individuals also seemed to attest to the fact that the contribution of wastes varied largely based on the type of construction involved (High rise structures v/s residencies). In the cases of large structures, the system seemed to be more organized, with fewer occurrences of wastes.

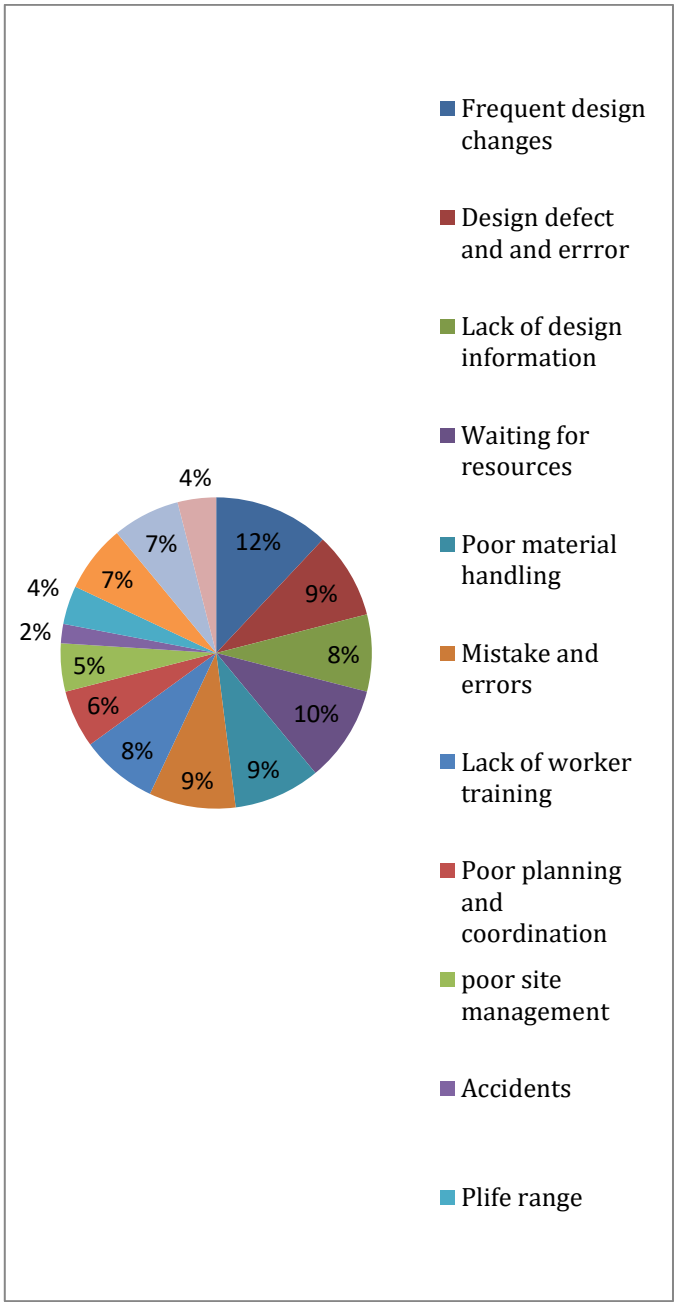

Fig -4 causes of waste during construction

In the case of smaller constructions, due to the lesser scale of risk and cost involved, individuals who have a stake in the progress of construction (clients, architects, consultants, people who source materials, supervisors, foremen and workers) are laxer which directly translates to more occurrences of wastage.

b) Breakup of occurrences of individual wastes in the work site:

1. Frequent design changes were less influential towards waste generation in projects like that of Sobha Constructions since all its sectors (architects and engineers) had direct lines of contact within a single framework. The same could not be said for individual consultants as the client-engineer-architect network was more susceptible to breakdown at various levels of intensity.
2. Lack of design information was not a very contributing factor possibly since engineer experience is possibly at an all-time high, especially in a developed system like Calicut.
3. Poor material handling directly correlated to incorrect unloading of goods at site, where workers poorly handled various resources like steel andcement.
4. Site management issues were less influential towards waste generation in projects like that of Sobha Constructions since all its sectors (architects and engineers) had direct lines of contact within a single framework.
5. The same could not be said for individual consultants as the client- engineer-architect network was more susceptible to breakdown at various levels of intensity.
6. Accidents are at minimum in site, possibly due to stringent government regulations in terms of litigations in the event of a misharp.
7. Pilferage in site as mostly seen in the finishing stage of construction, though its contribution was negligible.
8. Situations of rework were not as contributing to overall wastage since construction starts nowadays only after complete approval of most stages of work
9. A lack of trust was more prominent among individual contractors as opposed to large scale construction companies

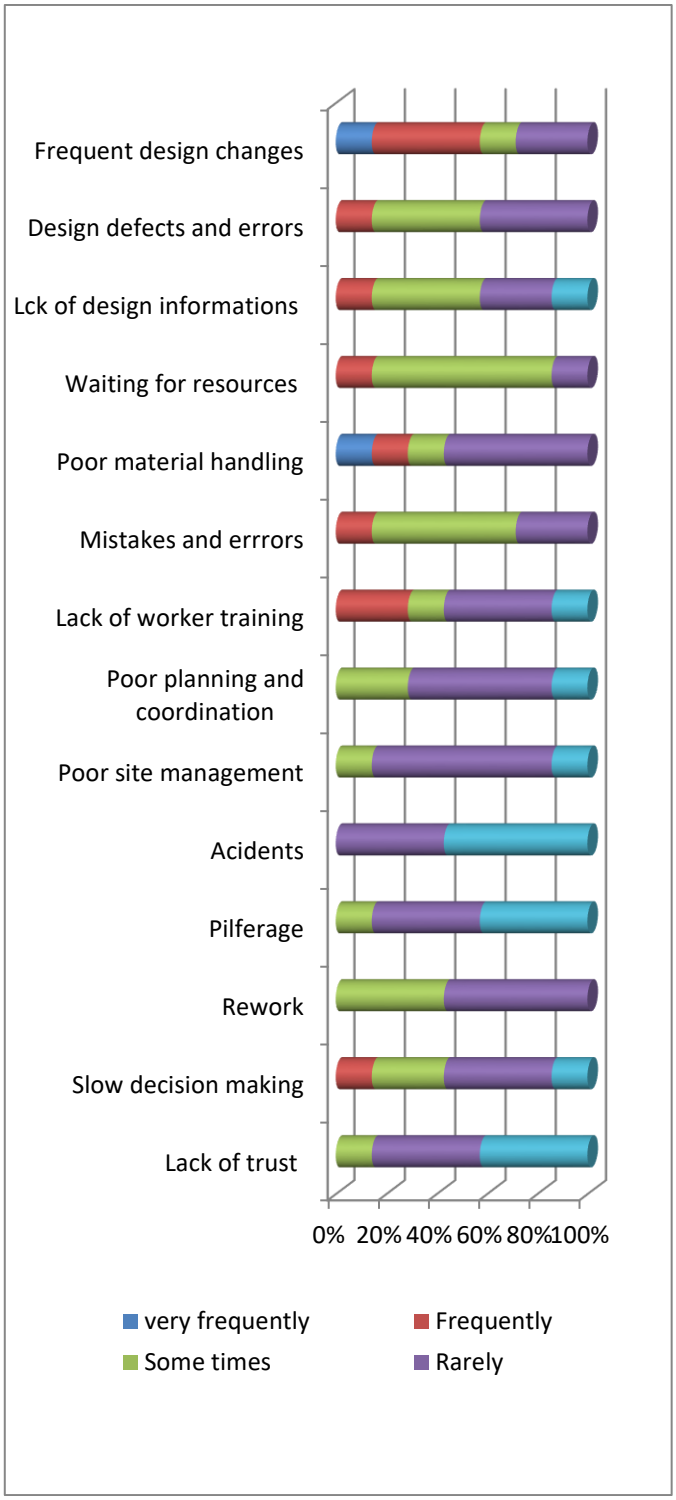

Fig -5 Occurrences of waste in the construction industry

Question (11): Detailed study on the sources of delays in the industry (Time related delays)

A simple weighting system using the Likert scale has been assigned

a) Overall time related delays

It was observed that while most delays had significant share of occurrence, delays in site mobilization and inefficiencies in scheduling had a smaller contributing factor based on the scale used. This could be attributed to the fact that the work site has evolved overtime to come to what it is today (a more efficient workflow system is under implementation).

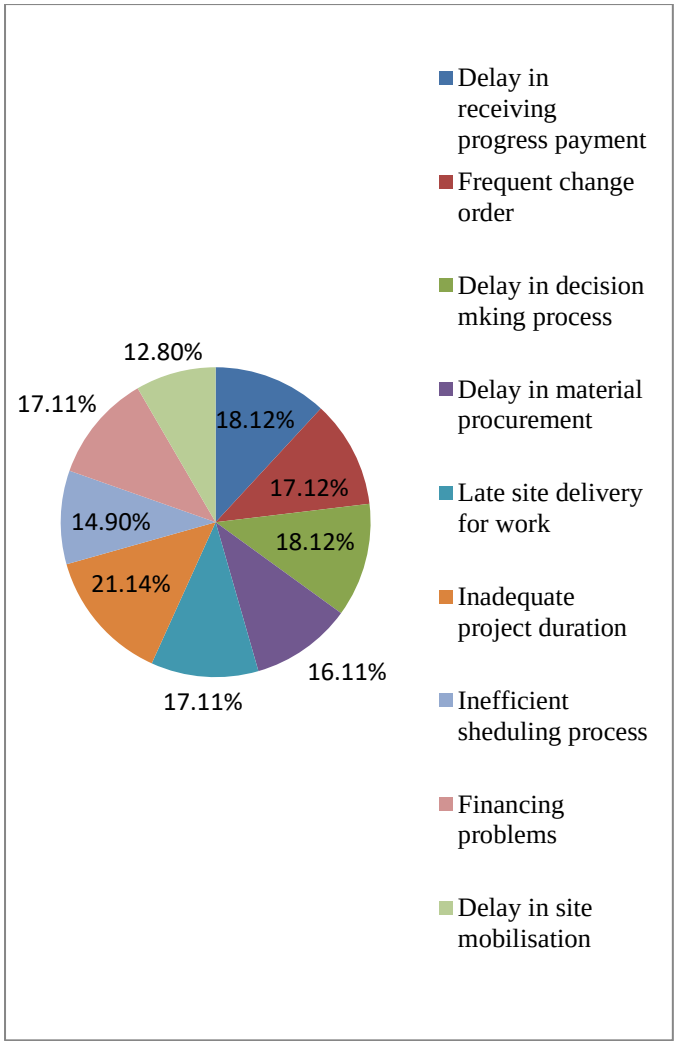

Fig -6 Time related delays in the construction industry

b) Breakup of time related delays by intensity:

1. Delays in scheduling and site mobilization were the least causes of delay according to individuals surveyed.
2. Delay in receiving progress payment, a reasonably prominent cause of delay could be attributed to the system of practice wherein the contract is seen to be more as a guideline than a stringent set of rules. This inadvertently leads to unforeseen delays during the construction process, and is seldom overcome.
3. Financing problems were more of an issue with individual contractors who had to negotiate various systems to achieve time bound results

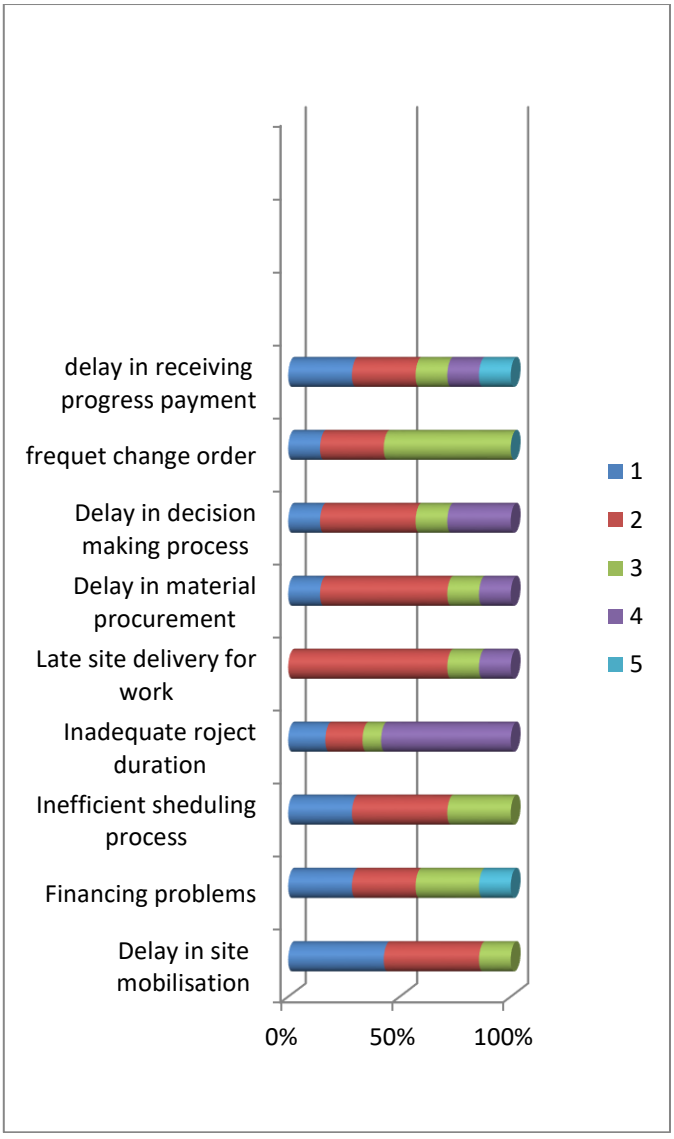

Fig -7 different time related delays in the construction industry

4. Late site delivery of materials like steel and cement were seen to be a predominant, albeit less delay inducing instance. While the amount of delays comparatively less, since type of delay is seen in many cases, there is a need to come up with quantitative solutions to integrate various systems to achieve time

bound results.

5. Financing problems were more of an issue with individual contractors who had to negotiate with clients, possibly even on a weekly larger construction systems had a more streamlined source of financing, that delay occurrences were comparatively limited in number and intensity

Question (11): Detailed study on the sources of delays in the industry (Cost related delays)

1. The fact that delays have a large comparative share of occurrence due to extra work not including contract, design problems and wastage of materials attests to the fact that the work place is still not fully professionalized. All these delays can easily be overcome by the simple existence of a networked system of rules and regulations that guide affected parties to follow the norms of construction in all respects.
2. Cost penalties due to un foreseen accidents, penalties due to delays and theft at site were not contributing towards cost related delays in comparison.

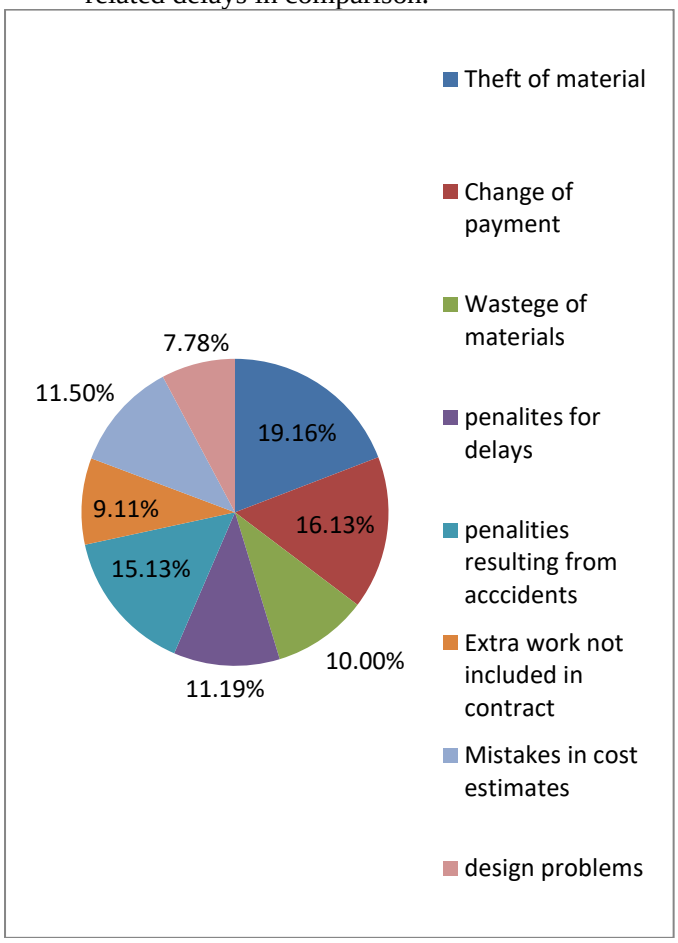

Fig -8 cost related delays in the construction industry

c) Breakup of cost related delays by intensity.

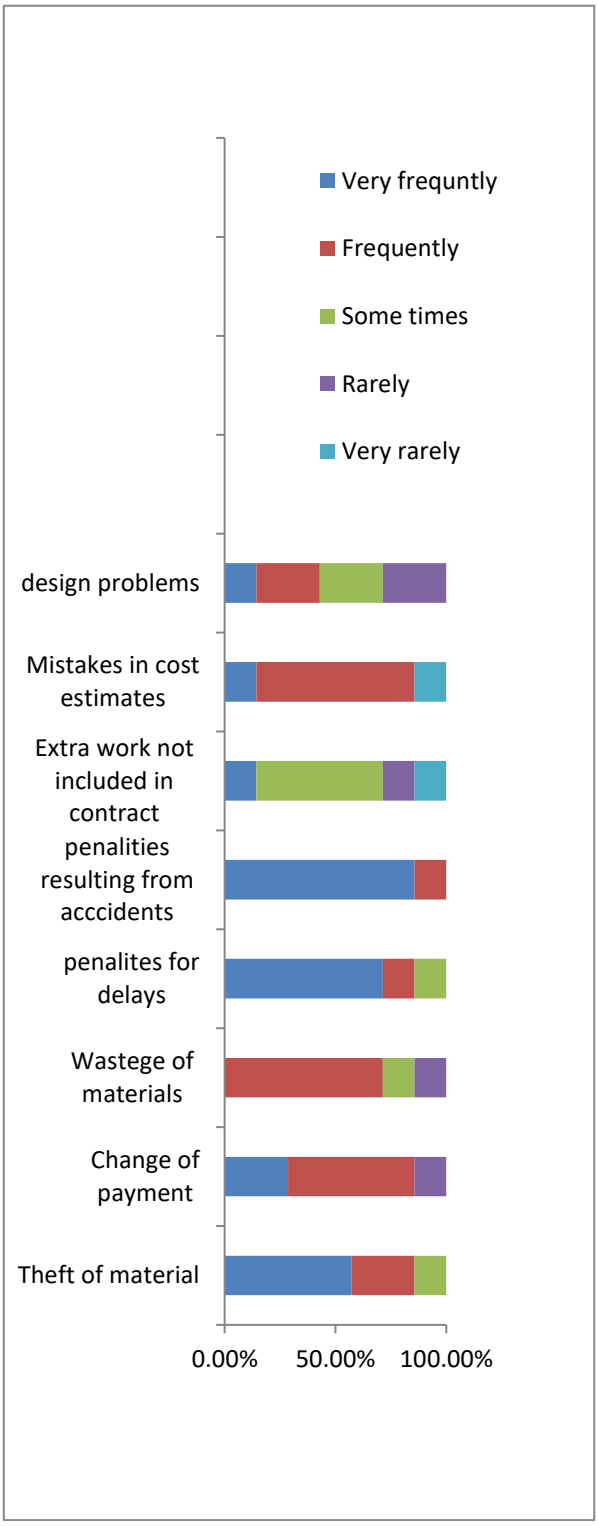

Fig -9 Different cost related delays in the construction industry

1. Delays from wastages in the work site are evidently a leading factor in the rise of cost. The instance of such material waste is so large in number that only stringent enforcement of laws governing the procurement and usage of such materials could curb this form of delay in the field.
2. Extra work not included in contract leads to notable cost based delay as the current system does not penalize contract violations beyond a certain extent.

Question (11): Detailed study on the sources of delays in the industry (Quality related delays)

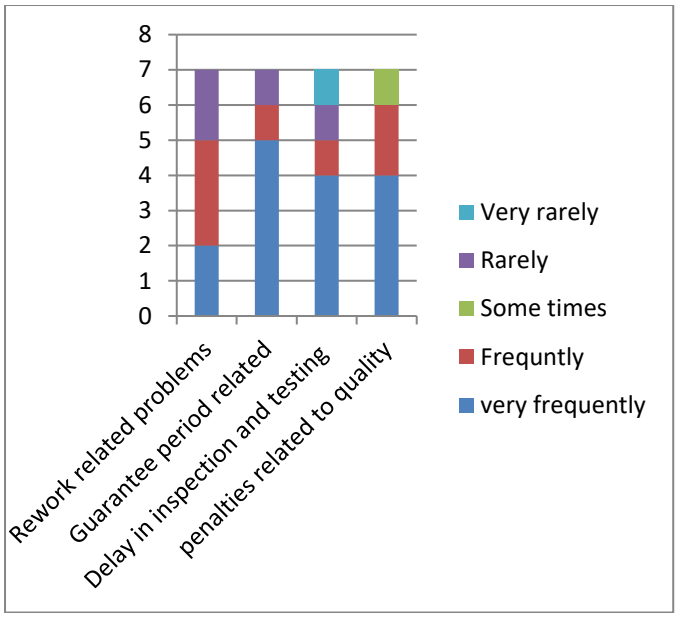

Fig -10 Different quality related delays in the construction industry.

1. Delays in inspection and testing were seen to be a delay primarily among smaller scale consultants, as the effect played by the sections of the government was prominent. The lags occurring out of the inefficient government bodies in the construction sector cannot be overlooked in this regard.
2. Rework of structures due to client miscommunication is a factor of concern, especially among systems where regular correspondence between parties is not in practice

Question (11): Detailed study on the sources of delays in the industry (Human resource related delays)

In comparison, lack of permanent staff was not a noticeable factor of delay, especially among large scale companies. A lack of skilled workers though, seemed to be a common cause of delays. This accentuates the need for implementation of Lean principles, from the ground up.

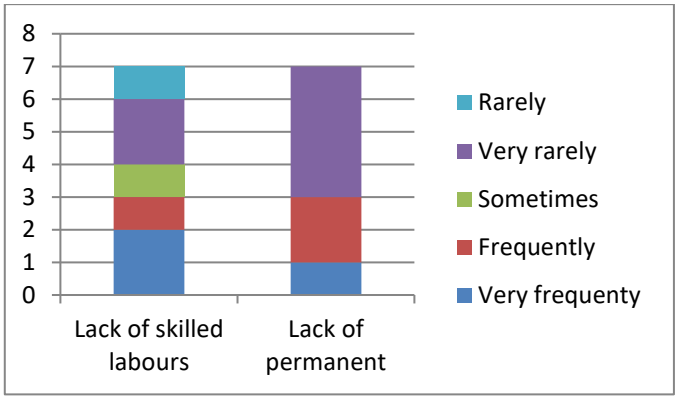

Fig -11 Different human resource delays in the construction industry

Question (11): Detailed study on the sources of delays in the industry (Risk related delays)

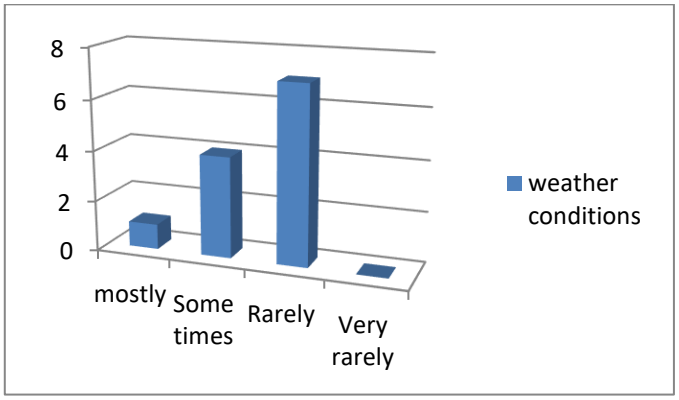

Fig -12 Risk related delays in the construction industry

The presence of rain, especially in the monsoon season from June to September did not seem to affect construction as expected. In contrast ,the lack of water thereof, during tight periods from March to May was considerably delay inducing. This delay was more accentuated for individual contractors.

Question (11): Detailed study on the sources of delays in the industry (Communication related delays)

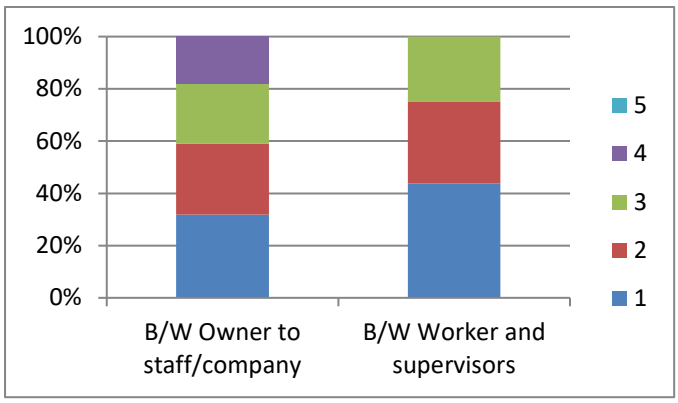

Fig -13 Different communication delays in the construction industry

Out of all delays, a lack of communication was not thought to have a considerable effect in the construction process. Nevertheless, communication gaps between client requirements and actual engineer implementation is a reality.

A general cause of delays as told by various individuals who were interviewed was the inefficient government bodies that play a part in the construction sector. A long gap between the application of a license, document registration, land surveys, bills etc. And the actual passing of the same is a real cause of concern. Streamlining of the process by the implementation of a unified system where all official formalities can be a solution to the same. In other words, Green Channel implementation becomes a real need.

4.2 Analysis Of Questionnaire Made In Phase2

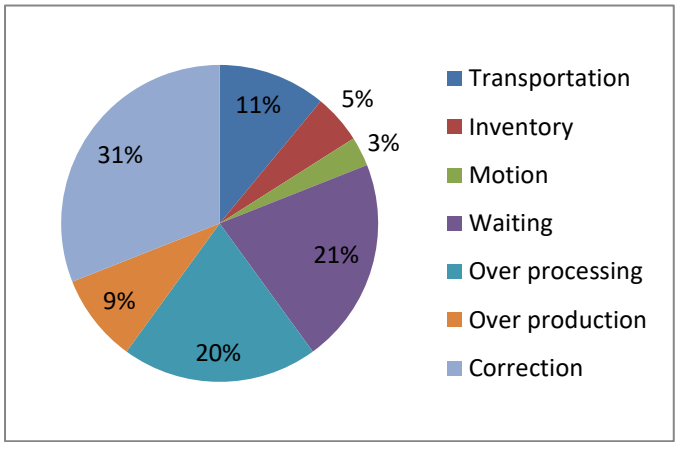

Fig -14 Most significant wastes in the industry

The pie-chart clearly shows that the most significant type among the wastes considered is corrections, followed by waiting which in turn is followed by over- processing.

CORRECTIONS

Construction projects involve many challenges that jeopardize the cost, scheduleandcontractualobligationsassociatedwitht heproject.Onemainsourceof these challenges is corrections. It was found that the primary reasons for corrections occurred in the design stage rather than the construction stage.

Some of the recurring causes of corrections in the design stage were frequent revisions of drawings, slow response on doubts arising from the design, unavailability of drawings at the work site and errors in drawings/design. As a result of these design changes unexpected problems arise which affect the entire construction process thereby leading to an increase in cost and time delays. It was found that a lack of understanding between the client and the consultant, miscommunication between the civil engineer and the drafters and poor supervision and inspection were the driving forces that lead to rework in the design stage.

Other prime causes of corrections were interference from other trade so or other crew members, disputes with consultants/ owner causing stoppage of work, lack of experience of crafts men and rework due to field errors committed by craftsmen. This was attributed to a lack of focus on quality among laborers and supervisors.

WAITING

Wasteofwaitingisanyidletimeproducedwhentw ointerdependentprocesses are not completely synchronized. A systematic addition of time wastes in various stages of a project finally ends up causing significant delay to the project.

The leading cause of delay due to waiting was found to be Labor strikes and hartals called by political parties in Kerala.

Another major contributor is climatic interferences. Construction work had to be stalled due to the untimely rains during the month of March. Also, the shortage of water in the summer months of May and June lead to a lot of delay in concrete works in Kerala.

Other factors were due to interference from other traders or other crew members and also due

to rework due to field errors committed by craftsmen.

OVER-PROCESSING

This term generally refers to unnecessary steps in operations, such as reprocessing, double handling, added communication, and double checking which adds no value to the product. Over-processing is often inserted into a process as a result of dealing with defects, over production or excess inventory. It was found that lack of experience of craftsmen was one of the major factors of over processing in Kerala. It was often found that more workers than what was required were assigned to do a work which lead to further coordination problems.

Also it was noticed that there was a lack of clear quality standards .Often times it is seen that the foreman makes his own suggestions which in some instances may contradict to what is actually required. Other leading factors include lack of periodic meetings with the site personnel, supervisors and civil engineers and also in effective planning and scheduling of the project .The following table lists the percentage breakup of the various specific causes of delay. It may be noted that certain factors occur in more than one category (since some specific causes of delay can realistically occur for more than one type of waste).

4.2.1 Percentage Breakup of Various Root Causes of Delays

Based on the percentage breakup of the various factors, the most delay inducing factors turn out to be:

1. Delay arising from the frequent revisions of drawings/design resulting in additional work/rework
2. Delay arising as a results of interference from other trades or other crew members
3. Delay arising due to the slow response on doubts arising from the drawings

All 3 causes of delays fall under Correction delays, which affirm to Correction delays having the highest prominence (31%) in delays (see Fig. 5.13).

The same data has further been normalized so as to account for discrepancies occurring out of personal preferences and experiences. Since a rating of 3 (say) for a particular cause of delay can mean a low value for Person A, an average value for Person B and a high value for Person C, normalization helps to find trends in the rating patterns of the particular individual, helping the interviewer gauge more accurate interpretations out of the data obtained. In a way, normalization helps to alleviate one of the prime drawbacks of a Likert scale system in a rating based survey, which is the differences in rating opinion so various individuals are not accounted for. Correspondingly, the following table lists the percentage breakups of various delays

4.2.2 Normalized Percentage Breakup Of Various Root Causes Of Delays

Based on the percentage breakup of the various factors, the most delay inducing factors turn out to be:

1. Delay arising from the frequent revisions of drawings/design resulting in additional work/rework
2. Delay arising due to the slow response on doubts arising from the drawings
3. Delay arising as a results of interference from other traders or other crew members
4. A doubt arising from drawings has emerged as the secondary cause in the normalized breakup, as opposed to interference from other crew members in the un-normalized breakup. This tells us that delays due to drawing errors and slow responses collectively share a huge chunk of the to all delays experienced.

All 3 causes of delays fall under Correction delays, which affirm to Correction delays having the highest prominence (31%) in delays

A salient feature of the normalized breakup of root causes of delays is that the top 3 causes of delay does not change in Table 5.1, but rather, the share of these causes' increases. This proves that the data obtained is more or less stable to changes, and we can possibly conclude that these 3 causes of delays are in fact, the leading cause of delays in even a larger sample size. In other words, the 3 causes are vouched for by most, if not all respondents.

Regression Analysis

Regression analysis was carried out using MATLAB R2015a. It aimed to obtain factors that are most significant. Any delay related to these factors could potentially cause a big delay in the whole project. It was found out that the factors with the highest positive regression coefficients are the most significant. Many trials were carried out by eliminating the insignificant factors i.e. the ones which got a low total score from all respondents.

It can be seen that the highest coefficient of 15.1152 was obtained for slow response on doubts arising from the drawings. This analysis identified a fourth cause of delay that was not arrived at in the previous methods of analysis, showing that in such a study more than one method should be used to get a comprehensive and holistic view of all the causes.

5. CONCLUSIONS

This project studied the lean construction concepts and its application In conjunction with a contractor, actual concrete construction projects were observed and problem areas contributing to delay and other wastes were identified. At the project level, lack of coordination among contractors was cited as one of the major factors contributing to project delays. An integration of the Last Planner concept and linear scheduling method to improve communication and short-term scheduling effort was achieved. At the operation level, a systematic approach of waste identification, operation re-design, and employee training was applied to eliminate wastes in the field operation. A case study on bulkhead installation was used to demonstrate this approach. This project shows how lean principles can be applied to both project and operation level through an empirical study.

Meanwhile, the efforts of applying lean concepts must be justified by its benefits to project performance. Future project should quantify the benefits of lean applications by collecting and analyzing performance data from actual construction projects. This data analysis will measure objectively the effectiveness of lean applications and assist future decision making on investing in lean concepts. The construction industry has demonstrated a decline in productivity when compared to other industries over the past twenty years. Lean concepts have caused a revolution in manufacturing design, supply, and assembly. Applied to construction, lean concepts can change the way work is done throughout the facility delivery process So far we have looked almost of the facts of what describes Lean construction principles in the practical sense, so far as to look at one of the prime examples of it in Kerala, namely Crescent Builders.

While the primary intention of this ambitious project was to look at and ultimately implement Lean in the industry, we had to content ourselves with looking at delays at an extensive scope. Primary issues we faced in this regard were the lack of practical approach towards good construction practices in the State, and limited avenues to explore a multitude of firms which potentially does practice Lean principles in their day-to-day activities

The use of a Questionnaire system (particularly the online version) helped us to efficiently analyze a good sample size of respondents, and we were able to modify the same to accommodate a more root cause based survey.

The use of a Likert scale to identify trends in the survey is effective, but is a source for error due to respondent individuality. Use of Normalization and Regression analysis helped to all aviate some of these flaws, and the resulting analyses have been delineated with our take on how and why each delay could occur in a realistic setting. The concept of wastes and delays in the industry is a serious matter of discussion in the present day and age, a time when optimization is key towards achieving efficient and cheap construction practices in both large and small scales.

The environment becomes a prime factor in this regard, and we understand that the proper management of the prime causes of delays in the industry would surely help us mitigate the imminent crisis we would face with regards to shortage of resources and threats towards mother Earth. Ultimately, our study focused on looking at the key wastes in the industry and we were able to satisfactorily come to the conclusion that frequent revisions due to drawing errors/reworks was one of the primary causes of delay, with a good sample size to back the result.

Wastes due to Correction, Waiting and Over Processing are something that most of the companies we considered faced, and it is high time we look into practical ways of mitigating most, if not all of these wastes. We believe we have drawn out a few solutions to tackle the same, taking inspiration from some companies that presently follows Lean principles in practice. While the findings are by no means exhaustive nor conclusive owing to the inherent flaws in a survey system of limited sample sizes, this project may be considered as an effort to see the issues the current industry faces in all levels of the hierarchical tree. All things considered, we believe we were even able to impart a portion of the knowledge we gained from our studies to various individuals involved in the industry, the end objective always focused on seeing how we can improve the construction scenario in the State. Further research and expansion of the existing survey will go a long way towards pinpointing the core issues the industry faces on a long term basis.

6. SUGGESSIONS

Delays to the projects can be reduced by applying measures which can be reflected as mitigation of delays. This mitigation of delays is possible only by re- sequencing of the works where ever possible and without increasing the resources and manpower.

The works that can be achieved without any additional cost to the project is the mitigation. The mitigation of delays can be possible by also applying the knowledge gained through previous projects experience and these can be implemented where ever their application can be suited for any specific requirement in the process of project learning. Such knowledge management will help in mitigating delays and the awareness of such knowledge through lessons learnt feedback can in fact be helpful in preventing the delays itself. In general, the following methods can be adopted for avoiding or minimizing delays in the construction industry:

1. Frequent progress meetings
2. Use up-to-date technology utilization
3. Use proper and modern construction equipment
4. Use appropriate construction methods
5. Effective strategic planning
6. Commitment to projects
7. Proper material procurement
8. Accurate initial cost estimates
9. Clear information and communication channels
10. Acceleration of site activities
11. Frequent coordination between the parties involved
12. Proper emphasis on past experience
13. Proper project planning and scheduling
14. Complete and proper design at the right time
15. Proper site management and supervision
16. Compressing construction durations
17. Ensure timely delivery of materials
18. systematic control mechanism

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