

Application of Lean Six Sigma in the Construction Industry

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ABSTRACT

It is of utmost importance in the construction industry to finish the project in the stipulated timeframe and in the given budget. It is important for the industry to deliver the most in the least amount of money. Lean Six Sigma is a method of systematically reducing waste and reduce variations which helps in saving cost and time. This paper attempts to study Lean Six Sigma current understanding and applications in the construction industry.

For this study a detailed analysis of multiple research papers has been made and data has been collected from the industry experts in the construction field to understand the current practices of LSS and their applications. Analysis is made by questionnaire to the industry experts to understand their view on application on Lean Six Sigma in the construction industry

Lean Six Sigma is a practise used by the industry to reduce process, minimise waste and reducing time and cost of the project by using the right methods. Within this article, at-tempts are made to explain Lean Six Sigma methods of opti-mizing cycle scheduling in the construction sector and how it works to reduce the overall project costs.

As far as Lean Six Sigma Applications in Construction indus-try are concerned, there is very little literature available. Al-though, there have been several studies highlighting chal-lenges in construction industry process and exceeding cost, waste & time.

Keywords

Lean Six Sigma, Construction, Process Improvement

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Introduction

The construction industry has always faced difficulties in providing the product at the right time. Since consumers are constantly seeking high quality product at a lesser cost. The market has become competitive and the construction sector is experiencing intensified competition due to glob-alization and deregulation, hence companies need to re-think their strategies. We have often heard about construc-tion projects overrunning budget and time. Hence it is of utmost importance for Construction industry to provide the most at the minimal cost & time. The cost and time required for the project can be reduced by application of some operational methodologies which have been used and have proven to be helpful in various industries since more than a decade, one of which is Lean Six Sigma. This methodology has been majorly used in the manufacturing industry to reduce process variations, reduce waste, to reduce process timing by making them leaner, reducing time & cost required for the making of the product. These methodologies can also be applicable to the construction industry as construction industry also has multiple activities which are repetitive and which causes wastage of cost and time.

In addition, word lean was initially used to define the methods of better production in manufacturing of automobiles throughout this time at MIT Sloan, JFK invented it to characterize a distribution approach which could be implemented manufacturing facilities to ensure maximum efficiency and quality level. He also tells in his article that the usage of new technology is not the only solution if they are implemented without efficient policies for controlling the output. These have been the foundation for the lean production concepts and policies since the last three to four decades.

It is not challenging to comprehend how similar a construction company and a building site are from other manufacturing plants and products for the individuals who have spent years in this sector. In the manufacturing plants there is always a set of people who are devoted to improving the efficiency and reducing the process time and reaching perfection. Somehow it is not the case with construction sector as every project is a prototype, they are not making the same product repetitive times like making the same building multiple times in a society. All the activities in a day week or a month might be different from each other and might not be similar. The lessons learnt from the last project might not be applicable in the next project but there is always room for improvement and improving the processes to reduce waste and time required.

Lean is a method which systematically helps reduce the tasks which do not add value to the program. It does so by removing undesirable steps in the process. This method ensures desirable quality of the product or offering for the customer or client.

Some of the Lean practices are:

- Doing things right at the first time – Consistently doing right at the first time to achieve nil faults which helps reducing the waste generation and helps improving the time required for the activity as rework can be avoided
- Minimisation of waste – Removal of any non-value adding tasks and make complete use of the available resources.
- Continuous Improvements- Quality enhancement and reduction in the costs can help improve the efficiency and profitability of an organisation.
- Flexibility- Improving the diversity of the products or processes can help improve productivity without affecting the performance of the organisation.

- Improving relationships with suppliers- Improving the relationships with the suppliers can improve the lead time and quality of service from the supplier and gives better flexibility to improve the productivity of the organisation.

Six Sigma a customer focused, well defined management framework that aims to provide near perfect goods or services. The aims of Six Sigma are to reduce the defects and inconsistencies so that the system can become more reliable and predictable. Six Sigma was originated by Motorola in 1980s. Six Sigma translates to 99.9997%. Six Sigma keeps the customer at the first place. This supports evidence for rational decision taking. What makes Six Sigma so famous is the amount of money it has saved for numerous companies. Some people claim that Six Sigma approach has help save billions of dollars for companies.

Six Sigma is a systematic solution for problem solving. In Six Sigma, problem solving is performed using DMAIC system. In this system there are five levels:

- Define,
- Measure,
- Analyse,
- Improve,
- Control.

Literature Review

As per Oglesby, Project planning fundamentally implies setting up the course of project execution. Project discussion includes sketching out a strategy, settling on what could possibly be done, planning how it will be done, when will it be done, and the amount it will cost (Oglesby et al 1989). It is comprehended that correct project planning and estimation of time and cost required may not really hold right. There are different variables that influence the plan yet there is opportunity to get better and to enhance it in such a way, that the wastages of time and cost are decreased. What is Lean Construction?

According to Lean Construction Institute "A collaboration-based system that is founded on commitments and accountability. It requires a significant shift in the trust that each stakeholder places on another. The adversarial relationship that has existed in the industry between contractors and design teams over many centuries is challenged, with all stakeholders having to align with goals and objectives. In projects where Lean construction management principles are applied, teams integrate through collaborative tools and search for ways to eliminate waste. Teams seek to continuously improve through reflection. Lean processes are designed to remove variation and create a continuous workflow to drive significant improvement in predictability and strongly encourages respect for all people involved"

(Sawant & Pataskar, 2014) According to a contextual analysis this study attempts to show the uses of six sigma in the construction by taking a pilot project on floor tiling in a 2bhk level. The research attempts to distinguish the spots where most deformities occur and attempts to decrease the quantity of imperfections by applying six sigma standards. The paper depicts what sort of procedure and instruments are utilized to survey the use of Six Sigma in Construction industry. Six Sigma specifically may give a more extensive

meaning of consistency, thorough execution evaluation, and recurring procedure, and execution upgrade.

(T.Subramani, Khan, Raj, Najeeb, & Rajan, 2018) , this paper tells about how lean technologies can be used in construction industry to reduce waste using SPSS. The paper classifies the activities and then identifies the areas and functions in which lean technology can be applied. The data was collected from people involved in construction sector and analysed which activities involve maximum wastes and how can lean technology be applied to reduce them and improve the productivity. The most affected activities are ranked using SPSS. The applications of Lean technology have always attracted the key coordinated players of the construction industry. The implementation and trainings of the application has increased the interest and the industry is looking into more applications and advancements in this domain.

(Alwi, Hampson, & Mohamed) discusses issues concerning variety, non-value-adding exercises and waste are normal for the construction business. It is activated generally by such a great amount of accentuation on the strategy for creation, through which materials are changed over into a solid structure without putting satisfactory time into setting up the cadence of the including tasks. Through defining the occurrence during phase of non-value adding operations, building managers or project managers can easily identify the best solutions and ways to apply any new waste reduction techniques, leading to increased productivity for the project. The research findings gave an idea of different waste concerns between developing and developed countries.

(Bos, Kemper, & Waal, 2014), this paper focuses on identifying the causes of delay per project Identify improvement methods that can reduce the delay per project and identifying what can be the method of measurement system and monitoring system for the continuous improvement of the processes.

(DESALE & DEODHAR, 2013) in their research feature existing literature and examine process improvement techniques utilized in the construction business and examination of highlights and standards of six sigma. Interviews of a project manager, a field and a cost engineers on were directed dependent on quality, execution and the board viewpoints. The investigation principally centers the benefits of actualizing Six Sigma in Construction and simultaneously illuminates a couple of misfortunes Particularly, Six Sigma can give a wide-running quality idea, far reaching execution estimation, and synchronization in dull procedure is and execution improvement.

(Rajprasad, Saminu, & Babu, 2014) published a paper in 2014. The research aims to have a superior interpretation of the Last Planner Process, which is a concept in the Lean Construction used to analyse the different timetable structure that are used. The paper focuses on implementation of the Last Planner Program in private residential housing. The knowledge is collected via questionnaires from respondents. The outcomes were broken down utilizing the product (SPSS). The overview is led from each organization that contrasts from the strategy they execute with respect to the outcomes were gotten utilizing SPSS programming, in the first instance the research analysis

carried out in various organisation were asked specifically to regarding the building methodology that they adopted.

(Okonkwo & Mbachu, 2015) contrasted Six Sigma and other customary Project Management Techniques and explored the worthiness of its us-age inside little and medium scale construction organizations. The study put forth attempts to set up total investigation of 59 recovered well devel-oped instruments with information from significant professionals in the construction business. The study concluded that there is no uncertainty about the beneficial outcomes of the execution of Six Sigma in the construction sector. The professionals were Project Managers/Engineers, Senior Geotechnical Engineer, Group IT Managers, Quality Assurance Managers, and Planning Engineer and so on.

(Ansah, Sorooshian, & Mustafa, 2016) paper, the theoretical models of construction management and the instruments have been reprimanded. The requirement for practical and strong models that will help project groups to manage the issues of squanders in projects are required. In this paper, LC approach and the significance has been talked about. A significant level of non-value-added exercises exist in the construction sector which are inclusive of construction cost. Lean construction targets decreasing the losses in process. And furthermore, the use of lean tools & methods will limit wastage, improve execution and lead to an extraordinary cost-cutting. It is anticipated that this paper will add to the information and practice from delay control or waste reduction and furthermore fill in as a benchmark for improvements.

(Sriram & Revathi, 2016) depicts the utilization of Six Sigma thoughts in Construction undertak-ing to show up at purchaser fulfilment. The pur-pose of development organizations nowadays is to complete an undertaking inside specified time period and cost by the important rules and subtleties, decline of waste and usage of material/assets. The principles of Six Sigma with a feasible methodology in development industry underlines on diminishing assortment and killing the foundations for squanders. A relevant investigation was coordinated in a private structure development in which Six Sigma gauges were applied for turn away the intricacies in inner completions. A deformity valuation sheet has been prepared and the level of the method has been found. DMAIC was applied to update the idea of the current method by separating the blemishes, their degree of quality, the causes and effect of distortions and proposals to clear out those. The disclosures of the assessment suggest that suitable setting up, the administration backing and minor changes are required to im-prove the idea of work and moreover for improv-ing purchaser fulfilment.

(Taner, 2013) expects to recognize the Factors for the successful utilization of Six Sigma in con-struction organizations in Turkey. In this, so as to recognize and comprehend the current quality practices, a survey-based methodology was util-ized. Participation and responsibility of top ad-ministration, joint effort and duty of middle-level managers were seen as the Critical Factors for the construction organizations to present Six Sigma, though constrained information about the frame-work to start and insecurity impedes its applica-tion. Indian firm can draw motivation from this exemplary instance of Turkey.

Methodology And Data

The main goal of this research was to identify which activities can Lean Six Sigma be applied in the construction sector. The study of Lean Six Sigma in construction sector becomes an interesting topic because of its practical applications that construction sector can have. Literature survey for practical papers available to study the applications and scope of applications of Lean Six Sigma in the construction industry have been done. The literature available and the research papers available for the applications in construction sector gives us the idea of how Lean Six Sigma can improve the overall quality efficiency by reducing waste. This is done through primary and secondary research. The primary research involves the study of the literature already available and the secondary research is done by a questionnaire survey from the construction sector helping us in identifying the right functions in which Lean Six Sigma can be applied. These questions in the survey help us identify the right functions for the application of Lean Six Sigma. LSS has already proven its benefits in the manufacturing sector by best results and find potential in the construction sector as well

These questions help us identify the right functions for application of Lean Six Sigma. The interview with experts in the sector had 7 questions that were answered by 35 people. The data have been collected and analysed for further reference.

The views of knowledgeable people from the survey and the questionnaires have been considered to identify the application of LSS in the construction sector. The questionnaire was designed based on the information that is required to understand the current scenario and how LSS can be applied to the construction sector. The Questionnaire tries to understand the views of the people in the construction industry.

Questionnaire was as given below:

1. Does Lean Six Sigma techniques increase productivity compared to conventional techniques?
 - Strongly Disagree
 - Disagree
 - Neutral
 - Agree
 - Strongly Agree
2. Which Major problem is faced by construction industry?
 - Delayed Projects
 - Cost more than estimated
 - Lower margins
 - Waste generation
 - All of the above
3. Can Lean Six Sigma be applied in Construction Sector?
 - Yes
 - No
4. Can DMAIC be applied in Construction Sector?
 - Yes
 - No
5. Can Lean principles be applied to Construction Sector?

- Yes
 - No
6. Which Lean Practices do you think can be applied in the construction sector?

- Preventive Maintenance
- Just-In-Time
- Cycle time reduction
- Zero Defects
- Scrap Reduction
- Setup time reduction
- Inventory Management
- Supply Chain Management
- Human Resource Management
- Increase in Labour Productivity

Techniques	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Preventive Maintenance					
Just-In-Time					
Cycle Time Reduction					
Zero Defects					
Scrap Reduction					
Setup Time reduction					
Inventory Management					
Supply Chain Management					
Human Resource Management					
Increase in Labour Productivity					

Q7. How difficult is it to implement the LSS practices in the construction sector?

- Very Difficult
- Difficult
- Neutral
- Easy
- Very Easy

Q8. Which Activities of construction can LSS be applied?

- Flooring
- Brickwork
- Cement work
- Installing windows
- Shuttering

Findings & Analysis

The findings are based on primary research done by the review of literature to understand the applications of LSS in construction sector and secondary research by the questionnaire with the professionals from the construction industry.

Firstly, to understand what are the key success factors in the construction sector after an extensive literature survey this paper identifies approximately 9 critical success factors for the construction sector.

- Top Management Involvement
- Vision & Planning
- Education & Training
- Communication
- Organisational Infrastructure
- Project Tracking and Review
- Resource Allocation
- Continuous Improvement
- Process Management

These critical success factors are then verified by using the questionnaire survey that has been filled by experienced professionals in different levels in the construction sector.

Here we understand what are the critical success factors that affect the construction sector and how they affect the Client, Contractors and Users. As there is enough room for improvement and making the process more efficient.

From (Sathe & Allampallewar), we look at the cost comparison of traditional buildings by taking feedback from experts. We notice that almost every time the cost of construction lands up more than

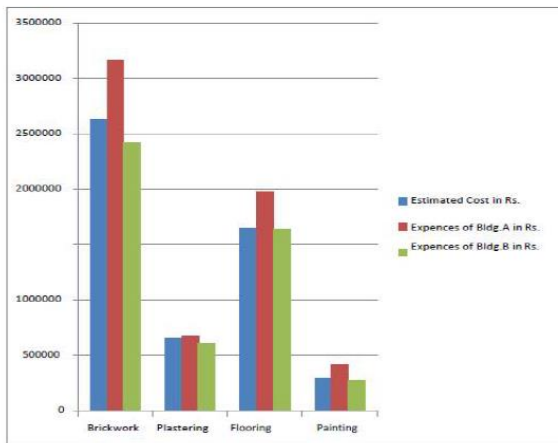
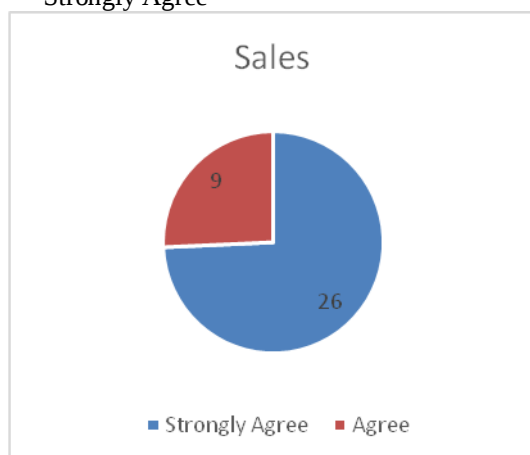


Figure 3 : Cost comparison of traditional building and six sigma methodology

Interview results

Q1. Does Lean Six Sigma techniques increase productivity compared to conventional techniques?

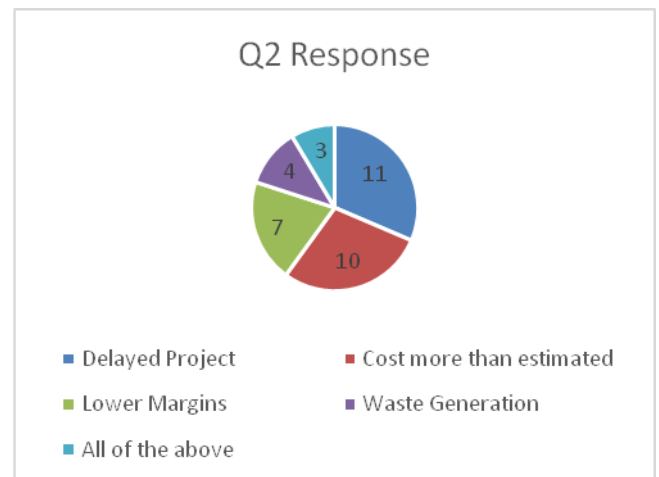
- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree



For the first question all the participants agreed to the sentiment that LSS can increase the productivity. This question has seen a positive response from every domain and function in the construction sector. Hence, we understand that LSS has potential in the application where the requirement of quality and cost is high, LSS can be applicable in public sectors as well.

Q2. Which Major problem is faced by construction industry?

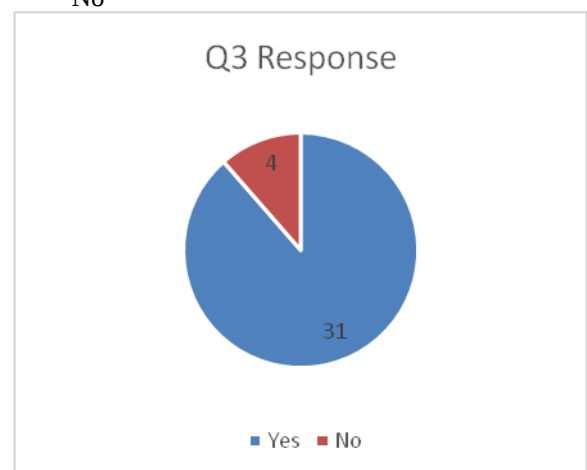
- Delayed Projects
- Cost more than estimated
- Lower margins
- Waste generation
- All of the above



11 out of 35 respondents said that the overshooting of the cost is the major problem faced by the construction industry. 10 out of 35 people said that problems are the delayed projects. There are various factors which affect the time required to complete the project. Construction sector usually works on the system of doing more in less amount of money.

Q3. Can Lean Six Sigma be applied in Construction Sector?

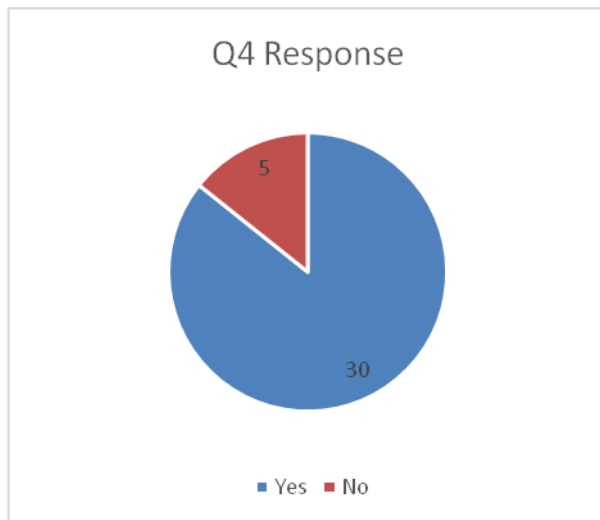
- Yes
- No



Almost all the respondents said that Lean Six Sigma can find its application in the construction sector. They were also open to consider some of the practices to increase the productivity. They were also ready to consider the idea of trying and testing these theories to see if there can be any substantial benefit out of the Lean Six Sigma practices which can help them save money and resources.

Q4. Can DMAIC be applied in Construction Sector?

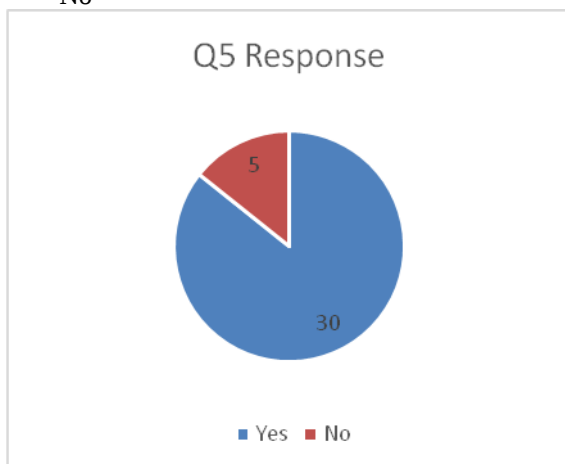
- Yes
- No



30 out of 35 people agreed that DMAIC (Define, Measure, Analyse, Improve & Control) practices can be implemented in the construction sector. They also voiced their concern about the extra efforts required to practice this method but agreed that this can improve the quality of the product and reduce the waste that is generated.

Q5. Can Lean principles be applied to Construction Sector?

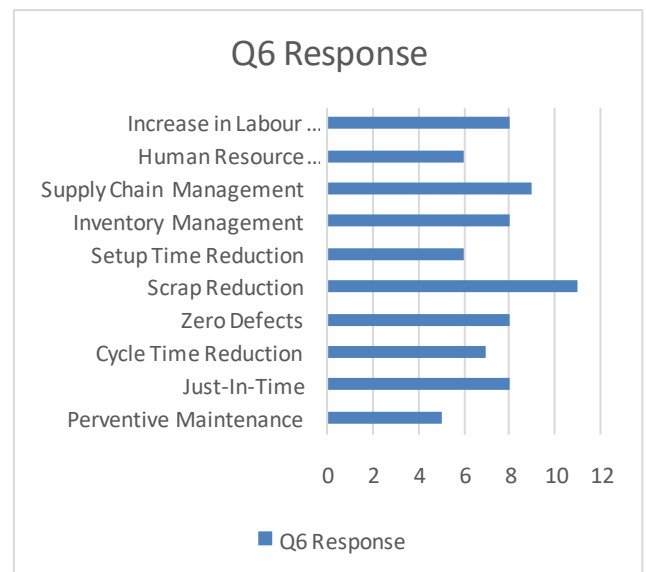
- Yes
- No



30 out of 35 people mentioned that lean principles can be applied to the construction sector as they improve the process efficiency and identifies the bottleneck processes and how can the organisation improve.

Q6. Which Lean Practices do you think can be applied in the construction sector?

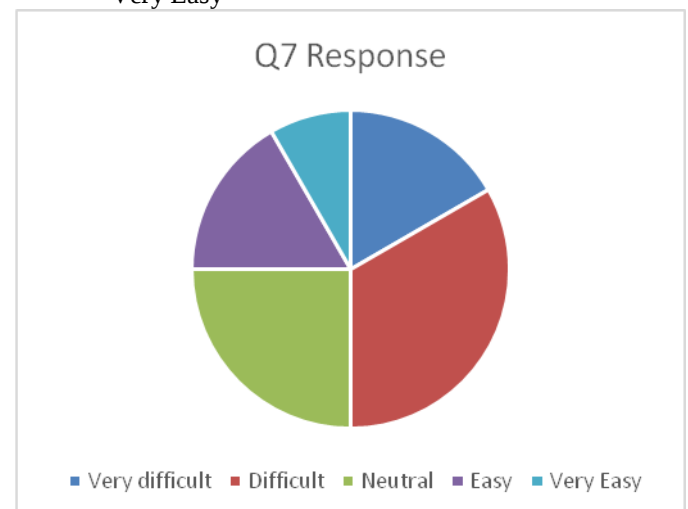
- Preventive Maintenance
- Just-In-Time
- Cycle time reduction
- Zero Defects
- Scrap Reduction
- Setup time reduction
- Inventory Management
- Supply Chain Management
- Human Resource Management
- Increase in Labour Productivity



The respondents chose multiple lean practices that can be applied in the construction sector. The overall response from the respondents was that the LSS practices can improve the overall productivity of the industry.

Q7. How difficult is it to implement the LSS practices in the construction sector?

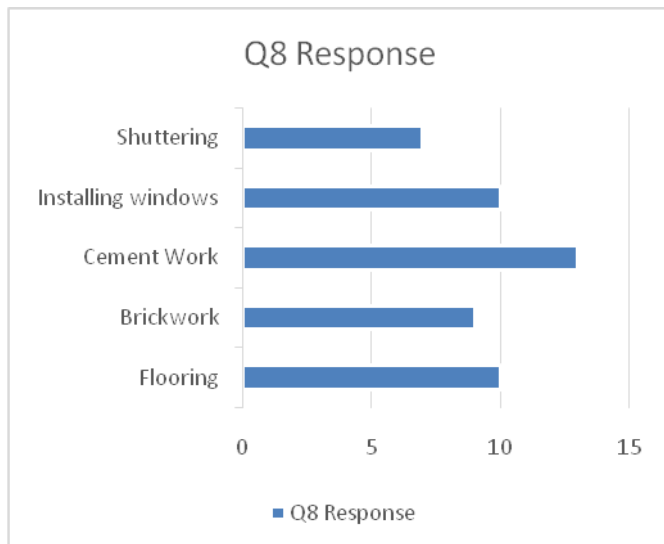
- Very Difficult
- Difficult
- Neutral
- Easy
- Very Easy



The respondents show trust on the LSS practices but are sceptical about the additional resources that will be required to closely monitor and supervise each process. The LSS practice may involve continuous measurement of performance to understand the bottleneck and redefine the processes.

Q8. Which Activities of construction can LSS be applied?

- Flooring
- Brickwork
- Cement work
- Installing windows
- Shuttering



Respondents believed that most of these parameters are repetitive and generate some amount of wastes during process. Hence there is a room for LSS practices here in these activities to improve their productivity to save time and money.

The seven unwanted activities that can be reduced by applying LSS found by the research are

- Excessive Transportation
- Unnecessary Inventory
- Lack of material due to waste
- Waiting
- Over Production
- Over Processing
- Defects

It is important for a construction company who wants to increase the quality of the project and reduce the cost and bring the cost in the estimated value that they should reduce the amount of defects that are involved during construction it is also important to optimise their processes to avoid delays and monitor the processes to reduce the defects.

The prior studies and the suggested introduction tell us that there has been a comprehensive research and knowledge gathered on Six Sigma definition with give this a specific understanding of current methods of applying DMAIC methodology Which seeks to establish and provide efficient process management and quality assurance strategy in construction

Places which are applied for six sigma systems are generally recognised among manufacturing sectors and may be applied in the custom instruction sectors as well previous case studies show that truly implement the idea and was collective action between top management and staff. we also understand that the staff should be aware about Lean Six Sigma practices to truly implement them

Discussion

We understand that Lean Six Sigma can improve methodology and give a good Framework for continuous improvements in the productivity in the construction sector. Moreover the responses also gives us a fair idea about importance of additional research and way forward. It is not just about the practices of Lean Six Sigma but also it was

the organisation vision and values. As per the interaction with the respondents we understand that there is a positive sentiment about Lean Six Sigma practices in the construction sector there has been individual success on implementation but large amounts of implementation and Measurement is required to achieve more productivity. It also gives us a gradual but incremental improvement in the practices. In a Holistic view Lean Six Sigma can globally be applied in the construction and public sectors which undoubtedly will give a lot of cost savings and allow opportunities for further improvement. You also understand that the Awareness of instructional practices should also reach to the higher management on the organisational leadership

Lean Six Sigma practices remove the risk when applied effectively and improve productivity significantly. However, we understand that there is large cost and effort required to implement these practices on a regular basis When the work force operates collectively and not in a conventional way in the construction industry each person's productivity plays role so that he can put his entire effort and complete the task with efficiency. Hence cooperation with the aims and priorities of the output and clear emphasis on teamwork and communication during pre-construction implies to a reduced risk of rework

As in the manufacturing industry Just- in-time and waste administration can also be used as an essential practice during the prefabrication phase. These principles advise that we use prefabricated material as much as possible. Prefabricated materials are ready to install material can be inspected for or higher quality and delivered to the site for direct installation. As an example, there are construction of 20 story hospital that had been done within a month which had approx. 90% of material that was premade. The activities mostly were getting to the site and direct installation. Although there is a risk of increased cost and also parts and designs that cannot be changed at a later stage, it makes sure that the decisions are made correct and effective in the design phase itself. If done correctly it makes sure that there is minimum risk of project delay, cost overshoot due to delay and reduces the requirement time of labour.

As referenced, the administration of Lean development relies vigorously upon the joint effort of the entire group. Dealing with a Lean advancement venture requires the support and consolation of all partners by comparable, aggregate critical thinking to prompt the quality improvement cycle.

Probably the most effortless ways to deal with guarantee productive, open participation between all the venture accomplices is using computerized assets and applications to advance contact and critical thinking which improves communication between the organisation. Project Management and construction management software are some tools that can help the cross functional teams to gain access to critical information and important knowledge to work together in real time to answer challenges and queries. The usage of best technologies are critical ingredient for taking advantage of Lean Six Sigma concepts efficiently to improve productivity.

Accomplishing the greatest focal points of running Lean Six Sigma depends generally on all knowing and adjusting

behind the needs and desires for the engineer. Understanding the aspects of an undertaking are seen to be the most imperative to the maker and end clients encourages groups to make the right, quickest decisions, without losing the outcome. At the point when proprietors understand that their wellbeing stays at the base of any choice taken on the activity, the pace with which issues are resolved increments impressively. Decision formation and participation are delegated, enabling the project to push toward completion more rapidly.

Ventures additionally recorded an improvement in effectiveness by adjusting the ideas of Lean development the board to an undertaking, which converts into improved rate of profitability. Yield levels are the focal figuring units and are subject to their estimates by a subcontractor or other "working" bunch on a task. In the end, the key to profitability is to meet the production rate used for an estimate. Any efficiency gain decreases the likelihood of income reduction which positively leads to an organization's sustained economic growth.

Prior study also shows that the construction labour is working at 60% efficiency and that most amount of efficiency is lost in waiting for material or necessary information. Some amount of efficiency is also lost due to poor processes and inefficient processes.

Since Lean practice use prefabrication at whatever point plausible, material waste administration regularly gives a huge potential to efficiency gains. Increasingly managed fabricating situations require for controlled investigation of the items and the procedures and expansion of the utilization of every raw material. Limiting the requirement for creation and surplus supplies adds to reserve funds which would then be able to be put back into the business.

The mixture of Lean concepts and IPD (Integrated Project Delivery) brings the unified design teams back in view. In developing a structured project management process that provides for all team participants and relies on collaboration, all partners are motivated to collaborate towards the same objective of effective execution of the project. In the integrated approach where an environment of confidence and reverence occurs as mentioned, it contributes to more transparent collaboration and information sharing as a result this helps the whole team to align itself together with the expected outcome and the priorities of the owner. The teams should handle preparation, expense and efficiency in a manner that does not affect core results and add value to the results.

In a more inclusive process, IPD enables free dialogue with all stakeholders at a period that gives the idea early impact. LSS helps enable each person to voice their opinions and contribute to the project in the decentralised decision making.

In exceptionally organized activities, significant accentuation is placed into coordinated effort at early structure stages, where building specialists will offer direction on financial plans and worth plans, counsel on buildability issues, and in general structure system arrangement. At the point when coordination and arrangement turns into a major need toward the start of a venture, there is a more grounded likelihood that the conclusive outcome will be reached.

Having been keen on early contribution on arranging, gear and general tasks, the contractors and subcontractors will

arrive at the improvement procedure with a significantly more exhaustive perspective on the venture's needs and targets. Also, there is more noteworthy certainty that effective creation can deliver the ideal advantage benefits for those concerned.

Activities might not turn easier and less complex how tasks are dealt with. Organizations need to begin thinking and executing Lean Six Sigma to keep balance in the structure business to deal with the developing intricacy of the endeavours. Although Lean development the board can appear to be hopeful on a basic level, when effectively applied it really lets groups streamline venture efficiency and diminish absolute hazard. The upsides of Lean structure can never again be ignored from a reduction in waste, improved ROI, better standard of work and that's just the beginning.

Six sigma practices of DMAIC can be effectively applied in this sector.

Define: Identify the questions and problems underlying which are causing decreased customer loyalty

Examples of tools or methods:

- Five Whys and how
- Brainstorming
- Flowcharts

Measure: Collect relevant data from the process about what amount of time and efforts are being required currently. This step includes collecting the right data to visualize what is the reason behind the problem that has been identified. The focus here can be to understand why the projects are getting delayed.

Examples of tools:

- Measurement Analysis
- Benchmark

Analyse: Analyse the data, find the cause of the problem and evaluate the problem. During analysis root causes for the problem can be understood. Different tools and methods can be used to analyse the data.

Example of tools:

- Cause effect diagram
- Experiment
- Continuous improvement

Improve: Find improvement parameters and implement them to modify the process

Example of tools:

- Pareto chart
- Failure Mode and Effect Analysis (FMEA)
- Process improvement
- Variation reduction

Control: Control the processes for sustainability and improved productivity

Examples of tools:

- Management Commitment
- Control Plan
- Process behaviour chart

Conclusion & Limitations

In construction management process control and monitoring is not a part of daily activity and is not a standard practice but if the company can apply Lean Six Sigma practices this can determine the overall efficiency of the project.

Waste generated in construction is relevant not just from the viewpoint of efficiency but also from the natural conditions in most locations the amount of waste generated is far higher than initially estimated causing unnecessary resource wastage.

This means that there is plenty of room for process improvement and improving the productivity by quick elimination of waste from construction methods. Construction waste are difficult to recycle once they are generated and recover owing to the heavy pollution rates. Researchers see a waste as a non-value adding operation which often affects the project success in form of cost overruns and delay.

Minimizing waste can have financial benefits too especially in some instances it may save time and money both. The financial benefits can be recognized by comparing previous projects where LSS were not applied and projects with LSS practices by doing a life cycle cost analysis.

The basic principle of Lean Six Sigma is that if efficiency is improved, it would also boost output, power, cycle time, inventory costs and other main factors such as waste management, energy supplies and the environment.

Identifying the non value adding activities and defining the right steps to improve the process and apply innovative methods. The recommended actions can be documented and implemented in the next projects as well which can be continuous improvement.

Firms that desire to apply the Lean Six Sigma approach inside their association should cautiously build up an organized usage plan. The usage of Lean Six Sigma is a key factor impacting the accomplishment of the philosophy. A top-down methodology is suggested for the usage procedure, along these lines the firm can reallocate required (HR) inside the firm and disseminate the strategy fundamentally all through the organization. Firms must know about the effect of Lean Six Sigma on the hierarchical culture.

Limitations

The research has Literature survey of practices of Lean Six Sigma in the construction sector and interview results from experts from the construction industry. The empirical study of statistical result to support the claim of process improvement and by what margin is not present. Further there is limited amount of research available on application of Lean Six Sigma in the construction sector.

Considering the application of Lean Six Sigma in the construction sector, these practices will require full time attention and a dedicated team to continuously monitor progress. Setting the right practices shall also require to understand the current practices and identify the bottlenecks and then find ways to improve on them. This is also a time consuming process.

Additional resources are also required for continuous process measurement, analysis, improvement and control. Designing such monitoring systems costs time as well as money. In most of the research the control systems were designed at the end of the project after analysis and provided as improvement actions. Such additional steps required to carry out LSS projects could contribute additional costs to the project.

There is not much awareness about the LSS principles amongst the people in the industry and how well these

principles can help them improve their productivity. Trainings and consultancy is needed in the construction industry to promote LSS practices and to teach the professional the right approach towards the improved productivity.

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