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INTEGRATION OF LEAN, GREEN AND SIX-SIGMA INCONSTRUCTION PROCESSES

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Abstract - *The overall goal of this research was to develop and implement methods to improve the performance and the efficiency of construction process prior to and during the construction phase in design-bid-build (DBB) projects. In order to accomplish these goals, the three methods Lean, Green, and Six--sigma were implemented in two different scenarios and validated by case studies. First, a framework was developed that integrated the three method- Lean, Green, and Six--sigma with an overall layout of the Define, Measure, Analyse, Improve and Control (DMAIC) improvement model. The framework was then validated through the construction process of installation of pile caps for an educational institute during the constructional phase in Pittsburgh.*

1. INTRODUCTION

The construction industry contributed over $639 billion to the United States gross domestic product (GDP) in 2009. Moreover, the U.S. has over nine million workers employed in the construction industry. While nervous construction related studies have focused on the reduction of waste, increase of productivity, or minimization of environmental impacts, to date, limited research has been done to combine all three efforts. This research integrates three methods; lean to reduce waste, Green to lower the environmental impact, and Six-sigma to improve quality and productivity, in the belief that all three methods together could help minimize all of the above- mentioned impacts generated by constructed activities.

1.1 LEAN GREEN SIX SIGMA(LG6) MODEL

The LG6 model has two parts: level one contains the basic information about the construction process under consideration, including the name, scope of work, date, client information, and project requirements. Some main points about the three methods lean, green and six-sigma are listed at level one of the LG6 model, where it is essential to give the user a reminder of what the purpose of each method is level two: divided into five functions, basedon the DMAIC stages.

1.1.1 Define

The define phase identifies the starting date of each step its incremental duration and the total duration of the construction process. It is important for contractors to lay out all the steps they usually follow in finishing a certainjob so that each step can be evaluated individually to determine to what extent it absorbs resources and generates waste.

1.1.2 Measure

This phase consists of quantifying all consumed resources (materials, equipment, and manpower) for each step in the process as wellas the associated cost. Fuel consumption by equipment and task was aggregated under the equipment section in order to more easily quantify thefuel related environmental impacts.

1.1.3 Analyze

In this phase, all steps are evaluated using both lean and green criteria. First, applying the Lean "value-added" concept, the contractor needs to identify any steps in the process that consume resources without generating value. These should be eliminated or modified to achieve a morelean process.

Second, as every step in the process consumes resources and is responsible for producing some share of the total emissions, the LG6 modelof applies Green\LCA to quantify the specific incremental environmental impacts generated by each step in the process. To help the user calculated the environmental impact, the LG6 model provides a summary of the most common materials used in construction, such as concrete, steels, blocks, Etc... Along with the characterization factor for associated environmental impacts. Using values generated in database from the time SimaPro7 software (Goedkoop and oele 2008), these characterization factors represents the magnitude of impact per single unit in each specific impact category.

1.1.4 Improve

In this phase, the process owner has the opportunity to consider alternatives that offer better performance in terms of efficiency, economy and/or specific environmental impacts. Considering the output from the Define, Measure, Analysed stages, the contractor can now easily identify which steps in the process are most

wasteful of time and money under which have the greatest associated environmental impacts.

1.1.5 Control

The purpose of the stage is to keep performance at targeted level. The LG6 uses the defect per million opportunities criteria to measure the overall performance of the process. Applying the DPMO tells how efficiently the process is performing according to the Six-Sigma scale. The output from the DPMO is converted to a Sigma level, where the more closely the value approaches the number 6, and the fewer defects the process will generate.

Table 1.1 DMAIC Steps

DMAIC Steps	Examples of tools or methods
Define: Identify the problem and the issues causing decreased customer satisfaction.	• Five whys and how System thinking. • Flowchart.
Measure: Collect data from the process.	• Measurement system analysis (MSA). • Benchmark.
Analyze: Evaluate the current process; identify the root causes of the problem.	• Cause & Effect diagram. • Continual improvement. • Experiment.
Improve: Act on the data to change the process for improvement.	• Pareto Chart. • Design of Experiments (DOE). • Failure Mode and Effects Analysis(FMEA). • Process improvement. • Variation reduction.
Control: Monitor the process to sustain thegains	• Management commitment Control Plan. • Process behavior chart.

2 DATA ANALYSIS

In this chapter discuss the analysis outcome from the data collected. It covered questionnaires analysis, semi-structured interview and discuss of the findings. The questionnaires were distributed to construction professionals, building contractors, site engineers and labours in and around coimbatore district. The questionnaire were set to find out the labour shortage in construction, from engineers/contractors perception, site engineers perception and labour point of view towards decreasing labours in construction industry.

The data was analysed by calculating the frequencies and mean of the findings. On the other hand, the structured interview were conducted with the building engineers/contractors, site engineers and labours in and around coimbatore through discussions are made to render a bigger insight and understanding of the labours and construction industry.

The data was analysed based on the data collected from the respondents. Respondent's are building engineers/contractors, site engineers and labours. Totally of thirty two (32) questionnaires were distributed, 25 were responded to questionnaire properly.

To find the factors, the companies were chosen for conducting direct interviews are low, medium, and high level companies. The companies chosen for finding the factor by questionnaire survey are low and medium level companies in and around coimbatore, since the affect maximum by labour shortage

Questionnaires are given to get the perspectives of Engineer/Contractor, Site engineer, Labour.**3**

3 CONCLUSION

Waste management has become a necessary task in the construction industry due to the abundant amount of waste generated by construction activities every year. For objective to one, I explained a Frameworkdeveloped to identify and reduce waste during construction processes by integrating three methods: Lean, Green and Six Sigma. The consumption of materials was the highest contributor to the most impact categories including contributing to global warming, being carcinogenic having respiratory effects, depleting Ozone and contributing to eco toxicity. In the Six Sigma stage, potential causes of waste were identified, then validated and ranked using a questionnaire that was administrated to a construction Consulting Company. The root cause, responsible for 46% of waste occurrences during the construction phase, was identified as "design changes during Construction" by questionnaire respondents.

The Framework presented here has been designed to improve process performance during the construction phase of project by reducing waste best through a retrospective diagnosis. Error and mistake happen most of the time during construction due to the inherent complexity of the process. Typically project works go through five phases: programming, design, construction, operation, and

demolition. Next section I clearly explained about all these five phases and other thing included in it.

In conclusion, the LG6 model is comprehensive, step-wise tool that can helpany process owner to pre-plan the process, highlighting any potential with generators early so they can be avoided.TheLG6 model is easy to implement, provides tangible result, addresses multiple applicable alternative, provides for performance control and continuous improvement, and above all is proactive

In this project, the study denotes the risks occurred in the construction industry thus the risks causes the different impacts on completion of the project. The study is based among the tool named "Risky Project Pro". The schedule has been done in the MS-Project, then the tool has been used for the further process. According to the methodology, The risks factors are identification based on the literature collected and by consulting the experts, based on this the questionnaires were prepared. Totally for ten companies the questionnaires were given, out of which three had an effective reply. Thus the response rate is 60% which is considered a good response in this type of survey. According to them the major part of risks in high-rise buildings are caused due to technical, financial, physical and constructional problems. This paper has presented a general review of structural systems for tall buildings. Unlike the height-based classifications in the past, a system-based broad classification (i.e., exterior versus interior structures) has been proposed. Various structural systems within each category of the new classification have been described with emphasis on innovations. As far as the engineers concerned Lack of knowledge of arbitration has the maximum risk rating and other risks are material shortage, shortage in supply of electricity, poor quality of procured materials, loss due to fluctuation of interest rate, accident in site sub-contractor related problems, error in drawings, improper verification of contract documents, and competition from other companies. The least risk rating given by project engineer is environmental risk, relation with government departments, local protectionism and industrial disputes.

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