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Achieving Total Quality Management in Construction Project Using Six Sigma Concept

Dr.Divakar.K[1] and Nishaant.Ha[2]

[1]*Associate Professor in Civil Engineering, Coimbatore Institute of Technology, Coimbatore-641014*
[2]*Assistant Professor in Civil Engineering, Kumaraguru College of Technology, Coimbatore-641049*

Abstract - *A Six Sigma approach is one of the most efficient quality improvement processes. In this study, six sigma concepts were applied in construction scheduling process to avoid delay as well as to maintain the quality of the construction activities. Detailed schedule of the building was analysed & also the updated schedule was verified. At this stage, DMAIC (Define, Measure, Analyse, Improve and Control) principle was implemented. The variation in the scheduling due to delay of the activities was noted down. Delay reasons and their impacts in the whole project were calculated. All delayed activities were considered as "Defects". DPMO (Defects Per Million Opportunities) was calculated. By using this value, Sigma Level was identified. Pareto Chart Analysis was made. With the help of Six Sigma, ways to overcome schedule variation due to delay was recommended.*

Keywords: DMAIC, DPMO, Sigma Level, Pareto Chart.

1. INTRODUCTION

In the current field of construction, time optimization as well as the quality control is one of the prime requirements. To achieve this, several quality control approaches and also delay reduction techniques are adopted and also followed in the construction field. This study aims to execute the construction activities as per the estimated schedule without any variation as well as with the required quality and satisfaction by the customer or the owner of the project. To obtain this, Six Sigma concepts and its principles were applied in the analysing or verifying process of construction scheduling, during the execution stage of the construction activities. DMAIC (Define, Measure, Analyse, Improve & Control) methodology was adopted. Hence, with the help of Six Sigma the ways to achieve Total Quality Management in construction are analysed in this study.

2. LITERATURE REVIEW

Pande P et.al. (2000) explained the power of the six sigma movement in the world's most successful companies. Adan Valles et.al (2009) applied Six sigma project at a semiconductor company dedicated to the manufacture of circuit cartridges for inkjet printers. They were tested electrically in the final stage of the process measuring electrical characteristics to accept or reject them .

Low Sui Pheng and Mok Sze Hui (2004) examined the strategies and concepts of Six Sigma and implemented those concepts in construction industry. A. D. Lade et.al. (2015) analysed the quality performance of Ready Mix Concrete (RMC) plant at Mumbai, India, using the six sigma philosophy had been evaluated using various quality tools and sigma value was calculated. According to the sigma level, recommendations were given for the improvement. Seung Heon Han et.al. in their study they developed a general methodology to apply the six sigma principles on construction operations rather than construction materials in terms of the barometers to measure, evaluate, and improve construction performance. Lean and Six sigma in construction field was analysed with the help of several literature reviews by Sunil V. Desale et.al. (2013). Abdulaziz Ali Banavi (2013) was developed and implemented methods to improve the performance and the efficiency of construction processes 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. The root causes behind waste generation were determined via developing and administrating a questionnaire to a local construction company.

Mehmet Tolga Taner (2013) conducted a survey-based approach which is used to identify the Continuous Improvement (CI) initiatives commonly practised in large-scale Turkish construction companies as well as understanding the approach of these companies to Six Sigma. According to the questionnaire survey, the three most important Critical Success Factors lowering the performance of companies were found to be high costs, high amount of waste and lack of a well-implemented customer management system. Kuo-Liang Lee, and Yang Su (2013) were demonstrated a Six Sigma project of determining and improving the key input variables affecting the cracks in lightweight partition walls. The case study of residential building was taken in which six sigma was applied for internal finishing work, six sigma principle was adopted to improve quality and was checked against the sigma level by Sneha.P Sawant & Smitha V. Pataskar (2014).

Theo C. Haupt et.al explained about Total Quality Management (TQM) and its implementation techniques in construction site to achieve quality in several accepts. H.

James Harrington et.al examined the quality and productivity problems and improvement opportunities that face the construction industry today were defined. The latest studies which focused on increase the business quality through implementing TQM in construction industry was pointed out and its suitable applications in the different phases of project construction was identified by Ahmed S. Agha. The level of effectiveness of the implementation of TQM principles by the construction contractors was identified by Abu Hassan et.al. Khaled F. Sherif examined the existing barriers of TQM and in-depth survey was conducted in two Libyan construction companies. Low Sui Pheng et.al (2014) created a framework for implementing TQM in construction.

3. SIX SIGMA CONCEPT IN CONSTRUCTION SCHEDULING

The major aim of six sigma approach is to reduce the defects in the process. The level of six sigma value is 3.4 Defects Per Million Opportunities (DPMO). In scheduling process, all delayed activities and the activities without satisfying the predefined quality requirements are considered as "defects". Then, number of completed activities is considered as total number of opportunities. With the help of these data, Sigma level can be calculated and the percentage of accuracy can be determined. Accuracy will gets increased by increasing the level of sigma value. To overcome these defects and also to improve the sigma value / accuracy of the project, predefining the possibilities of defects opportunities should be worked out during the pre-execution stage itself and possible counteractions are to be analysed. During the construction execution stage, updating the schedule should be done several times and sigma value is calculated at every stage respectively.Then, possible counteractions for the remaining works should be focused accurately and also necessary steps should be taken to avoid same types of defects in the remaining project and have to work according to that.

4. METHODOLOGY

DMAIC (Define, Measure, Analyse, Improve & Control) Methodology is one of the prime factors of six sigma approach. Hence this methodology wascarried out in this study.Delay Reduction and client satisfaction were considered as CTQ (Critical To Quality) factor.

4.1 Define

During Define Phase, Detailed updated schedule was analysed. Basic details of the project are given in (Table 1)

Table 1 Observations

Type of Project	IT Building
Total Area	2.2 acres
Built up Area	1.7 acres
No. of Floors	B2 + (G+13)
Project started on	01/04/2015
Estimated Duration	365 days
Updated schedule as on	19/02/2016
Total no. of completed activities	202
No. of delayed activities	53
Re-estimated completion as on	15/07/2016

4.2 Measure & Analyse Phase

In this phase, Defects Per Million Opportunities (DPMO), Sigma Level and percentage of accuracy were calculated.

DPMO was calculated using the following formula,

DPMO = ((1,000,000)X) / YZ

Where,

X - Number of Defects

Y - Number of Units

Z - Number of Defect Opportunities/Unit

In this study, Number of Defect Opportunities is the chances or test by means of which we identify whether the activities delayed or not. Hence, itwas taken as 1. After applying all the values in the above formula,

DPMO - 262376.2

Sigma level was identified by interpolating the values from the following standard table 2

Table 2 Sigma Levels and their DPMOs

Sigma Value	DPMO
1	690,000
2	308,000
3	66,800
4	6,210
5	320
6	3.4

Sigma Level - 2.1

Percentage of accuracy & defective percentage was identified with the help of sigma level value. The following table 3 was used for calculating the percentage of accuracy.

Table 3 Sigma Levels v/s Percentage Accuracy& Defective Percentage

Sigma Value	Percentage Accuracy (%)	Defective Percentage (%)
1	30.9	69.1
2	69.1	30.9
3	93.3	6.7
4	99.38	0.62
5	99.77	0.023
6	99.99966	0.00034

Percentage Accuracy - 71.52%

Defective Percentage - 28.48%

By referring that updated schedule, delayed activities were categorized separately. Delayed duration for each activity was mentioned. According to the higher delayed duration, the rank was given. Major delayed activities were identified. Then, delay reasons for the delays were analyzed and noted down. With respect to maximum priority, delay reasons were tabulated (Table 4).

Table 4 Delay Reasons and its Priority

S.No	Delayed Reasons	No. of activities delayed	No. of days delayed
1	Shortage of Labour	11	138
2	Delay in drawing submission & approval	6	73
3	Delay due to verification & submission of Tender documents	7	70
4	Delay due to providing payment by the client	4	48
5	Slow Preparation of documents	13	45
6	Insufficient information about the work	1	35
7	Plastering Delayed	1	30
8	Delay in procurement of materials	4	26
9	Rain Interruption	2	25
10	PO delayed	2	23
11	Delay in concreting	1	10
12	Delay from the client side	1	10

Pareto chart analysis was made. Pareto chart consists of both line graph and the bar chart. In descending order individual values are mentioned and denoted as bars. Cumulative total of all individual values are denoted as line graph.

In this study, delay reasons were mentioned in x-axis & percentage of delay was mentioned in y-axis.

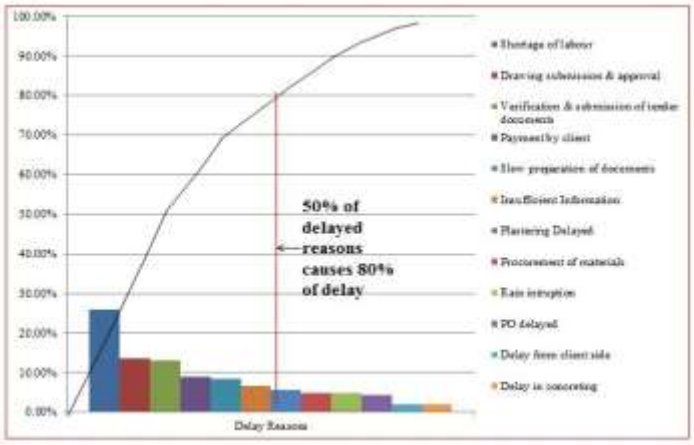

Fig. 1 Pareto Chart Analysis

This analysis showed that 50% of delay reasons caused 80% of delay. Hence, we have to eliminate those delays having higher priority at the early stage of the project itself.

Before executing the construction work, possibilities of delay have to be analysed and worked out. All these analysis should be done for those predicted delays. With respect to the out comings, possible counteraction should be taken and maintained properly.

4.3 Improve & Control Phase

In this phase, general recommendations to overcome the delays were given. Trail sigma calculations were made. Then steps to be applied to achieve higher efficiency in construction projects were discussed. General recommendations to overcome the delays are shown in the following table 5

Table 5 General Recommendations

S.No	**Delayed Reasons**	**Recommendations**
1	Shortage of Labour	Resource Leveling, Resource allocations should be done properly.
2	Delay in drawing submission & approval	Detailed information about the particular work is to be analyzed and given to the design department. So that they can prepare the drawings in time.
3	Delay due to verification & submission of Tender documents	Proper contractor team should be employed
4	Delay due to providing payment by the client	Proper agreement should be framed & payment should be given according to that agreement
5	Slow Preparation of documents	Accurate information should be given. Should have a proper communication
6	Insufficient information about the work	Before executing the particular work, all required information should be gathered and documented properly
7	Delay in procurement of materials	Material Optimization should done properly according to the type of the work
8	PO delayed	Execution department should inform the purchase department about their material requirements in advance.
9	Delay in concreting	Resource Leveling should be done
10	Delay from the client side	Client & the contractor should have a proper communication. They should work according to the agreement

5. TRIAL SIGMA CALCULATION

1. By seeing the delayed activities, it was found that the many delay parameters were common & many delays were occurred due to the delay of the preceding activity.
2. 50% of delayed reasons caused 80% of delay in duration of the project.
3. If **DMAIC** principle is applied and the parameters are identified at the starting stage itself, we can improve the efficiency by achieving the several milestones of the project in time.
4. Assuming, that the recommendations given here are applied at the early stage itselfand also assume that the major six topmost delayed reasons are rectified
5. According to the schedule, 42 activities willget free. Now, Defects will be 11 out of 202 opportunities.
6. DPMO & Sigma Level is calculated as done earlier. The obtained values are,

   DPMO = 54455.45

   Sigma Level = 3.1
7. This value showed that the level of sigma value gets increased from 2.1 to 3.1, which means the level of accuracy got increased.
8. The percentage of accuracy for the sigma value 3.1 is **93.91%**. (i.e.) 22.39% of accuracy is increased from the previous accuracy. (Previous accuracy was 71.52%)
9. Hence, its proved that applying Six Sigma principles in construction scheduling, the efficiency of the project can be increased in several aspects.

6. STEPS TO BE CARRIED OUT - RECOMMENDATIONS

1. Several milestones are to be fixed. Each mile stone will act as a short-term goal according to Six Sigma concept.
2. For each milestone, we have to calculate the major parameters of delay according to the type of activity.
3. By analyzing this, we can avoid several shortcomings at the early stage itself.
4. Hence, it will show the way to complete those particular activities in time.

5. We can check the efficiency of the schedule by calculating the sigma value and also percentage of accuracy at the end of each milestone by analyzing the updated schedule.

6. At this stage, we can re-estimate the schedule for the remaining works as per the time limitations, resources limitations, client specifications, etc…

7. We can also take preventive measures to avoid same kind of delays in the remaining construction works.

8. During the execution of work, control limits should be fixed and have to work according to the control limits.

9. Control limits should be fixed within the client specification limit to achieve maximum efficiency and client satisfaction. (i.e.) For example, if the clients requirement for completing the particular activity with 100% accuracy within a specified duration. We have to fix the control limit as less than the specified duration and have to work according to that duration. Hence, we can obtain higher level of sigma & also we can have a proper control in the on-going project.

7. CONCLUSION

In construction industry, six sigma concepts are not popularized. But, the efficiency of this process is tremendous. We can achieve near perfect products or activities with the help of six sigma approach in construction. Construction scheduling is one of the prime factors in construction projects. By applying six sigma approaches and maintaining the activities in the proper way as per DMAIC principles, we can increase the overall efficiency of the project. Customer satisfaction can also be achieved.

This study showed that, Application of Six Sigma concepts in construction will results Total Quality Management (TQM), proper time management, quality control, etc… Hence, this process in construction will also give more efficiency in almost all construction project management approaches.

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