International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878, Impact Factor (2014): 3.05

Defects Reduction in High Rise Residential Building using Six Sigma: A Case Study

Susmy Michael[1], Sahimol Eldhose[2]

[1]PG Student, Department of Civil Engineering, Toc H Institute of Science and Technology,Arakkunam, Ernakulam, Kerala, India

[2]Assistant Professor, Department of Civil Engineering, Toc H Institute of Science and Technology, Arakkunnam, Ernakulam, Kerala, India

Abstract: ***For multi-storeyed buildings, amount of defects during the construction works are most common. Thus it is important to determine the defects which lead to low quality in the construction projects, in case of architectural, structural and constructional standards. Therefore, a sequential approach is required to achieve good standards both in design and construction. Construction quality assessment system and six sigma quality management system are systems that could provide this approach. Six Sigma is a quality improvement technique based on statistics which can provide a broader quality concept, detailed performance measurement, coordinated and can avoid repeatable process thereby reduces variations. The objective of the present study is to evaluate the quality in a multi-storeyed buildings through six sigma. Also suggests various improvising methods for the quality of the building by minimising the defects. In this paper, DMAIC phase of six sigma is used for improving the quality of the buildings. Factors affecting the cause for defects is determined and then six sigma is used for data analysis. Thereaftersigma level quality of the building is calculated which helps to reduce the costs for variations, improve quality of the product, greater utilization of labor and facilities.***

Keywords: Six sigma, Quality management system, Construction quality, Assessment system, DMAIC

1. Introduction

Quality control in construction means ensuring the overall quality in construction with less defective material and good workmanship in order to ensure the performance of the facility of building according withthe design. For the purpose of ensuring compliance, selective samples and statistical methods are commonly used as the basis for accepting or rejecting work completed and batches of materials. Six sigma is a statistical problem solving methodology which is a powerful lever to reduce defects, by ensuring the quality. Nowadays, 98 percent or 99 percent accuracy is considered excellent; six sigma is becoming the universally recognized standard of quality. The term six sigma (6σ) originated as a performance measure or a measure of quality. Six sigma, process goals are set in parts per million (PPM) in all areas of the building production process. Six Sigma has now evolved as a technology for improving business efficiency and also focusing on productivity, cost reduction, and ensures quality.This paper involves determine the factors that cause defects in buildings and to evaluate quality level of an apartment via Six Sigma and to express the quality in construction in sigma levels thus to reduce defects by eliminating the root causes.Many studies have conducted about the importance of six sigma methodology in quality planning for various activities of construction industry so that how it made effectively to improvise the project by reducing cycle time and the defects. Studies clearly reveals the use of DMAIC and DFSS of six sigma methodologies. It also explains the use of quality control tools as well as the various analysing techniques.

Six sigma is a quality initiative that can be applied in the building industry and can be applied to reduce defects in internal finishes (Low Sui Pheng 2004).Improvisation of information sharing within supply chain operations for a marine transportation services organization. They had done a case study and used Design for Six Sigma (DFSS) methodology to design an information technology solution that effectively communicates information between the layers with in the supply chain regarding the movement of materials via inland tank barges (Erin M. Mitchell2015). The implementation six sigma approach for quality evaluation of RMC plant at Mumbai. They made a detailed study on steep rise in the production of Ready Mix Concrete (RMC) in India due to ever increasing demand of concrete from the infrastructure as well as the real estate sector. They found that the existing sigma level of the process has been found to be 1.23, which is very less than the manufacturing industry and RMC production process has been found neither stable nor capable (A. D. Lade 2014). A research of the evaluation indicators and methods of asphalt pavement surface segregation based on six sigma. The paper deals with the improvement of the quality by inspection standards based on surface segregation and then puts forward the six sigma standards (Yuan Jianbo 2014). The studies about the Concrete operations at these sites entail a sizable scope of work—particularly at the early construction stages—and require a significant volume of water(Ben Hannah2013). The research on lean construction with the adoption of six sigma methodology to improve sustainability in the buildings. They had found that byusing six sigma with lean construction has enabled the sustainability in the Malaysian construction industry (Mohd Arif Marhani 2013).A Six Sigma team can determine and improve the key input variables affecting the cracks in lightweight partition walls. They have done a case study methodology in this research to illustrate the tools of Six Sigma by using the project charter to define problems (Kuo-Liang Lee2013).

2. Methodology

The first phase of the study consists of determination of the root causes which affects the quality of the building using a questionnaire survey ratings. Then the sigma level for buildings is calculated using the DPMO computation methodology after identifying the defects and the root causes

for the defects are analysed and suggests the improvisation method or eliminates the root causes for defects.

3. Factors Determination

A sample questionnaire is prepared and is distributed among various construction sites such that a rating system is adopted for the identification of factors affecting the quality of building projects. The questionnaire includes construction parameters like labours, measures, materials, methods, equipment unassignable events, scheduling, contract procedures and site management safety measures adopted at the construction site such that from the questionnaire survey the factors affecting quality in the construction sites is determined.

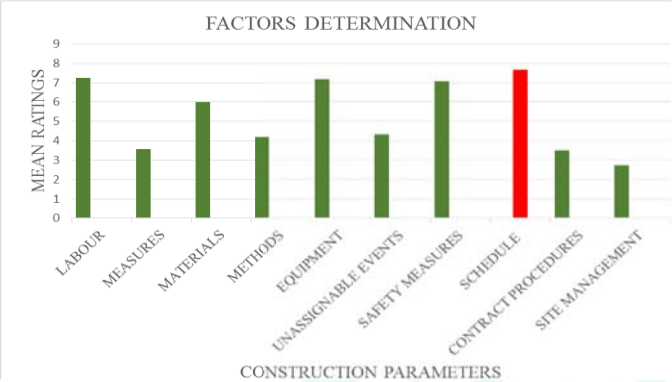

Figure 1: Rating factors affects building quality

4. Rating System

From the factors the key legends is identified by scoring the most important factors that affects the quality. The highest factors mostly affecting the quality in the construction building are lack of knowledge about construction, errors in testing the quality of materials, use of low quality tools, unsafety measures at sites and delay in completing the works. Thus these are the 5 parameters that has to be eliminated at the earliest. Hence for these parameters the sigma level of the building can be calculated with the use of data collected from the site.

5. Sigma level of building- a case study

Project selected for the study is an apartment and the occupancy group is A1 group building having two basement + ground + seventeen floors. Sigma level of the building can be obtained from the sigma conversion table by computing the DPMO i.e. Defects Per Million Opportunities. According with the six sigma defects are defined as anything that does not meet engineering requirements or customer requirements also laid down product or process standards and opportunity refers to a chance or an event that a product or service may not meet the laid down performance standard. Sigma level of the building can be obtained by computing DPMO i.e. the expected number of defects found per million opportunities. The 3 distinct pieces of information are required for computing DPMO:

- Number of units
- Number of opportunities per unit
- Number of defects

DPMO =(Number of defects × 1000000) / ((Number of defect opportunities/Unit) × Number of units))

The 5 factors affecting the quality were identified and the sigma level of the building for these each sample can be evaluated in sigma levels. Here each item of work as per the weekly progress reports from the companies are evaluating. The table 1. Shows that mindlessly increasing the defects would reduce the DPMO whileincreasing the Sigma levels. Thus six sigma can be defined as a set of techniques for quality improvement, higher Sigma levels sound like good thing. Table 1 shows the sample data sheet for the building.

Table 1: Six sigma sample data sheet to identify defects

Date	*Activities*	*Parameters*					*Defects*
		Delay in schedule	Dimensional quality	Lack of knowledge in labours	Idle equipment (low quality)	Safety measures	
27-06-15 to 4-07-15	PCC			✓			1
	Raft slab & beam			✓			1
	Basement 2nd columns						0
	Basement 1st columns		✓				1
	Basement1roof slab RCC			✓			1
	Ground floor columns						0
	1st floor columns		✓				1
	1st floor roof slab casting						0
	2nd Floor Column						0
	2nd roof slab RCC			✓			1
	3rd roof slab						0

Data from Table 1. Shows the DPMO for the corresponding building is 168421 and the sigma level from the sigma conversion table is 2.45 i.e. for the works in the week 27-06-15 to 4-07- 15 is having the success rate is of 83.5% according with the sigma conversion table.

Similarly, sigma level from 27th June 2015 till 24th October 2015 has been calculated and the mean sigma level of the building is computed. Table 2 shows the various sigma level of the building from June to October as per the work progresses the data is computed using DPMO methodology such that the sigma conversion table helps to calculate each sigma level and success rate for the building at each week thus helps to find out the most defect affecting activity in the construction site. By knowing the defect affecting activity value stream mapping can be introduced to improve process.

Table 2: Sigma level of the building for 4 months

Date 2015	*DPMO*	*Sigma Level*	*Success Rate (%)*
4-07	150000	2.55	85.2
11-07	160975	2.54	84.2
18-07	170731	2.42	82.35
25-07	223809	2.25	77
1-08	146666	2.645	86.25
8-08	186956	2.43	83
15-08	133333	2.62	86.5
22-08	75000	2.98	93.2
29-08	156214	2.51	84.15
5-09	95612	2.81	91.5
12-09	105231	2.77	89.7
26-09	142561	2.635	86.45
3-10	189223	2.45	84.1
10-10	77452	2.91	92.4
17-10	62612	3.15	94
24-10	54800	3.1	95

From Table 2 the mean sigma level of the building can be computed by taking the average i.e. Sigma level is 2.7.Hence the overall success rate of the building is 89%.

6. Result and Discussion

With the help of data from table 2. The defect analysis is done for the building using the standard six sigma conversion table such that it helps in identifying number of defects in the building with respect to the weekly progress of activities in the building. Thus the result shows that the success rate for the building is not enough according with the six sigma principles. As the activities progresses the defects will increase. Therefore it hinders the project management framework also it increases the variations during the construction works as the sigma level for the building is only 2.7. Table 3 shows the defect analysis and the number of defects for 100 activities in a week as per the six sigma conversion table, such that it helps in reduction of defects by a good project network that helps in reduction of variations during or after the construction phase. Defect analysis pave way to form control charts to establish some control limits using statistical process control techniques with the help of mean and standard deviations obtained from the site. Thus within the limits the process which can be controlled.

Table 3: Defect analysis as per sigma conversion table

Building 1			
Defects Per 100	*Defects Per10000*	*Defects Per Million*	*Success Rate*
17	1684	168421	83.5
15	1500	150000	85.2
16	1610	160975	84.2
17	1707	170731	82.35
22	2238	223809	77
15	1467	146666	86.25
19	1870	186956	83
13	1333	133333	86.5
8	750	75000	93.2
16	1562	156214	84.15
10	956	95612	91.5
11	1052	105231	89.7
14	1426	142561	86.45
19	1892	189223	84.1
8	774	77452	92.4
6	626	62612	94
5	5480	54800	95
AVERAGE			
15	1475	147500	85.95

Table 3. Concludes that for every 100 item of works or activities in a week may possess 15 defects in the case of building. Thus there is a need for the improvisation of sigma level.

7. Statistical Process Control Technique

Statistical quality control is an improvisation method to reduce defects using statistical techniques. It uses the method of acceptance sampling in which determines whether a population of items should be accepted or rejected based on inspection of a sample of items. Control is maintained through the use of control charts with upper and lower limits. The process is in control if sample measurements are between the limits and thus the defects can be reduced by rejecting the samples those are not within the limits. It mainly depends on the limits established and the control charts helps to avoid delay in schedule, untrained workers allocation to each works and to control safety measures etc. by giving particular upper and lower control limits.

8. Conclusion

This study explored the feasible strategies for the quality improvement of the construction processes and operations by combining the six sigma principle. The research helps to find out factors affecting quality of building which includes delay in schedule, low quality materials, low quality tools, lack of knowledge in labours and safety measures. The computation of sigma level of multi storeyed residential buildings is done and the sigma level of building clearly shows that the quality level in accordance with six sigma are not enough. The success rate for the building lies in between 85-90%, while considering each activities this shows that to attain sigma level there should be reduction in defects while doing each item of work .Hence it is necessary to find out root causes which affects the quality of the building and has to be eliminated.Statistical quality control with static analysis technologies is an improvisation method which can reduce the amount of defects

References

[1] A.D. Lade, A. S. Nair , P. G. Chaudhary, N. R. Gupta (2014); ―Implementing Six Sigma Approach for Quality Evaluation of a RMC Plant at Mumbai, India‖.*Journal of Management in Engineering (ASCE),* Vol 12(issue 2), pp. 1-4.

[2] Ben Hannah, Lucy Martin, Marisol Uriarte, Tami Haase Ph.D. (2013); *"*Water Usage Optimization during Concrete Operations*". Journal of Management in Engineering (ASCE), pp*. 3114-3121.

[3] Celep Oguz, Yong-Woo Kim, John Hutchison, and Seungheon Han. (2008); ―Implementing Lean Six Sigma: A Case Study in Concrete Panel Production‖.*Journal of Management in Engineering (ASCE),* pp. 336-346.

[4] Erin M. Mitchell, Jamison V. Kovach. (2015); ―Improving supply chain information sharing using Design for SixSigma". *ELSEVIER Journals, pp* 1-8.

[5] Hany Abd Elshakour M. Ali, Ibrahim A. Al-Sulaihi, KhalidS. Al- Gahtani. (2013); ―Indicators for measuring performance of building construction companies in

Kingdom of Saudi Arabia"ELSEVIER *Journal for Engineering Sciences,*pp 125-134.

[6] Jayesh Pathak, Tushar N. Desai. (2011); ―Six Sigma Quality Management Technique –An Overview"*Journal of Engineering Research and Studies,*Vol 2(issue 3),pp 64-72.

[7] John K. Michael, Brad D. Carey, and Kenneth T. Sullivan. (2009); ―A New Approach to Contracting Design Professionals by Six Sigma". *Journal of Management in Engineering (ASCE), pp*. 269-279.

[8] Kenneth T. Sullivan. (2011); ―Quality Management Programs in the Construction Industry: Best Value Compared with Other Methodologies". *Journal of Management in Engineering (ASCE), pp*. 210-219.

[9] Kuo-Liang Lee, Yang Su. (2013); ―Applying Six Sigma to Quality Improvement inConstruction"*Journal of Management in Engineering (ASCE), pp*. 464-470.

[10] Liang Guitao, Shi Hongran, Xu Yan. (2013); ―Applying Six Sigma to Supply Chain in Rural Logistics". *Journal of Management in Engineering (ASCE), pp*. 1163-1170.

[11] Low Sui Pheng, Mok Sze Hui. (2004); ―Implementing and Applying Six Sigma in Construction"*Journal of Construction Engineering and Management (ASCE),*pp. 482-489

[12] Maha Yusra, Abdul Rahim Othmanb, Sany Sanuri Mohd Mokhtarc. (2012); ―Assessing the relationship among Six Sigma, Absorptive Capacity and Innovation Performance"*ELSEVIER Journals Procedia - Social and Behavioral Sciences,*pp .570 – 578

[13] Mehmet Tolga Taner. (2013); ―Critical Success Factors for Six Sigma Implementation in Large-scale Turkish Construction Companies",*International Journal of Management and Marketing,* Vol 3(issue 4), pp. 212-225.

[14] Mohd Arif Marhani a, Aini Jaapara, nor Azmi Ahmad Baria, Mardhiah Zawawib. (2013); ―Sustainability through Lean Construction Approach: A literature review", *ELSEVIER Journals Procedia - Social and Behavioral Sciences,*pp .90-99.

[15] Myung Jin Chae, Sungmin Yun, Seung Heon Han, Soon Wook Kwon. (2010); ―A Case Study for Integrating Lean Six-Sigma and RFID Applications in Construction Processes through Simulation Approach", *Journal of Construction Engineering and Management (ASCE),*pp. 245-255

[16] Okonkwo, V. O., Mbachu, V. M.(2009), ―A Comparative Analysis of Application of Six Sigma Project Management Technique in Small and Medium Scale Construction Companies in Nigeria", *European Journal of Engineering and Technology,*pp 74-87.

[17] Rodica Pamfiliea, Andreea Jenica Petcu, Mihai Draghicic. (2012); ―The importance of leadership in driving a strategic Lean Six Sigma management",*ELSEVIER Journals Procedia - Social and Behavioral Sciences,* pp .187-196.

[18] Sebastian Koziołek, Damian Derlukiewicz. (2012); ―Method of assessing the quality of the design process of construction equipment with the use of DFSS (design for Six Sigma)", *ELSEVIER Journals Automation in Construction,*pp. 223-232.

[19] Seung Heon Han, Myung Jin Chae, Keon Soon Im, Ho Dong Ryu (2008); ―Six Sigma-Based Approach to Improve Performance in Construction Operations",*Journal of Management in Engineering (ASCE),* pp. 21-31.

[20] Sharad V. Deodhar,Sunil V. Desale.(2013); ―Identification and Eliminating Waste in Construction by Using Lean and Six Sigma Principles", *International Journal of Innovative Research in Science, Engineering and Technology,* pp.285-296.

[21] Sneha P. Sawant,Smita V. Pataskar.(2011); ―Applying Six Sigma Principles in Construction Industry for Quality Improvement ", *Journal of Construction Engineering and Management (ASCE),*pp. 407-411.

[22] Sunil Desale, S.V.Devdhar, Hemant Patil.(2013); ―Implementation Barriers for Six Sigma in Construction",*International Journal of Engineering Trends and Technology,* pp.175-178

[23] Thanveer M. Beary, Tariq S. Abdelhamid. (2005); ―Production Planning Process in Residential Construction using Lean Construction and Six Sigma Principles",*Journal of Construction Engineering and Management (ASCE),* pp. 105-115.

[24] Vinay V. Mudholkar. (2008); ―Six-Sigma: Delivering Quality to Mega Transportation Projects",*Journal of Transportation and Development (ASCE)*, pp. 284-288.

[25] Yuan Jianbo, Fei Haiyan, Ju Zhimin. (2014); ―Research of the Evaluation Indicators and Methods of Asphalt Pavement Surface Segregation Based on Six Sigma", *Journal ofRecent Developments in Evaluation of Pavements and Paving Materials (ASCE),* pp. 59-68.