Implementing Six Sigma Principles to Improve the Quality of Internal Finishing work in Residential Buildings

Sulakshya Gaur[1], M.C.Paliwal[2]

[1] *M.Tech Scholar (Construction Technology and Management), Department of Civil and Environment Engineering, National Institute of Technical Teachers Training and Research, Bhopal (M.P), INDIA.*
[2] *Associate Professor, Department of Civil and Environment Engineering, National Institute of Technical Teachers Training and Research, Bhopal (M.P), INDIA.*

ABSTRACT: *The level of quality is one of the most important parameter that any individual is interested when considering any product, and Six Sigma is one of the most important tool to check and improve the level of quality of any product by the use of its methodologies. Six Sigma with the use of its principles aims to provide a better sustainable product in terms of the quality. This dissertation that is presented here uses the principles and tools of Six Sigma to determine the level of quality in terms of Internal finishing works (with the help of various case studies in form of field survey) in the residential buildings and aims to provide various measures that can be used to further enhance the quality of the work. The problems and solutions for this were identified with the help of field survey and further analyzed with the help of various statistical tools and techniques such as Pareto Analysis, Spearman Correlation. The data that was assembled was analyzed with the help of Normal distribution and used 'W/S' test to check its normalcy. Further, the analysis showed that by application of Six Sigma principles in a proper way the quality of the work increased, in this case which was calculated on the basis of sigma level which increased to 3.08 from 2.50.*

KEYWORDS: Quality Management, Six Sigma, Internal Finishing Work, Pareto Analysis, Spearman Rank Correlation.

1. INTRODUCTION

A quality management is a continuous process of determining and managing the activities needed to achieve the set parameters of quality by any organization. A better quality parameter promotes more determination towards improvement of services and end product with a final motive to be more competitive and to develop a better customer base. Six sigma is an important tool used by various businesses to achieve more overall customer satisfaction. The concept if used properly, reduces the number of defects significantly and enhances overall quality and performance. Its main focus is to eliminate defects and reduce variations to obtain a more and better finished product. It combines various tested statistical and analytical methods and tools into one combined system. Six sigma provides number of benefits that include reduced cost, enhanced productivity, growth in existing market share, increased customer base, reduce in percentage of defects, development of better product and services etc. Many times the financial benefits that are obtained from six sigma can be overshadowed by various intangible benefits. For six sigma measures to be effectively applicable to across any work environment, a definite set of guidelines need to be followed otherwise the system to measure and identify the critical to quality parameters will be a total nothing which would lead to total chaos in long run.

2. SIX SIGMA METHODOLOGY

Six Sigma works for the most part on two strategies:

- DMAIC process
- DFSS strategy

Here we will just talk about the DMAIC system of six sigma.

DMAIC technique is utilized for effectively existing procedures that requires change due to falling underneath expected quality parameters. DFSS then again is for creating new items as well as process that fulfill Six Sigma quality levels.

DMAIC technique's fundamental Principles are:

- **Define**, the main phase of DMAIC is to frame a group, to decide the undertakings and appoint the obligations to singular colleagues, assurance of objectives and to audit the means of any procedure.
- **Measure**, the second phase of DMAIC process, is to have an arrangement for successful information gathering, to set up a legitimate information test and starter investigation of the made example.

- **Analyze**, the third phase of DMAIC process is to decide the main cause of the obtained problems, right way to deal with information and its change openings.
- **Improve**, the fourth phase of DMAIC process is to design, execute and approve the changes and corrective measures.
- **Control**, the last phase of DMAIC process, is for at last taking up of process or item upgrades and following their execution in the more drawn out run. It goes about as a change period of process from Six Sigma group to unique executers under point by point control design.

3. IMPLEMENTING SIX SIGMA IN INTERNAL FINISHING WORKS

The first questionnaire that was prepared to determine the quality of the work done and therefore its sigma level was done according to the parameters specified in CONQUAS. The Construction Quality Assessment System (CONQUAS), developed in Singapore since 1989, fills in as a standard appraisal framework on the nature of building ventures.

Accordingly the Internal finish work is further divided for Floor, Internal walls, Ceiling, Door, Windows and Components.

QUESTIONNAIRE 1									
Flat No.				Location..........................					
		Bedroom1	Bedroom2	Toilet1	Toilet2	Kitchen	Hall	No. of defects	No. of opportunities
Floor	Finishing								
	Crack and damages								
	Alignment								
	Hollowness								
	Jointing								
Ceiling	Finishing								
	Crack and damages								
	Jointing								
Wall	Finishing								
	Crack and damages								
	Alignment								
	Hollowness								
	Jointing								

Fig 1: Sample Questionnaire 1

The above mentioned components were checked for any defects under various parameters as shown in the sample of questionnaire 1 in Figure 1. The parameters that were found defective were marked as (×) and then total number of defects and opportunities were calculated. The Defects per Million Opportunities was calculated with the help of the formula:

$$DPMO = \frac{(Total\ number\ Of\ Defects)}{(Total\ number\ of\ opportunities)} * 1000000$$

The DPMO calculated is then compared against the sigma conversion table and the value of sigma or sigma level is then determined.

3.1 Correlation

There are number of factors that are responsible for the poor quality of work and for that several factors (7 factors) were chosen and same number of solutions were determined and they were correlated on the basis of ranking system to determine the most important problem and its counterpart solution for improving the quality of the work. For obtaining the said ranking a questionnaire was prepared and was sent to the trade professionals (Civil Engineers) that are working in the field and have a proper in depth knowledge about these problems and solutions in the form of google docs form and were asked to be ranked in their order of preference (i.e. which parameters they consider as most important and which they considered least important. Once the ranking was given by them and the data was collected back, the overall mean was calculated and the parameters were ranked on the basis of their mean. Finally spearman rank correlation formula was used to determine the correlation value.

Formula Used:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$$

Where,

ρ = Spearman rank correlation value

di = Difference in the rank of the observations

n = Number of observations.

This formula is used when the ranks are different i.e. no two values of the rank are same.

3.2 Causes for Poor Quality of the Work

The parameters that were selected for this purpose were chosen after detail study of various literature work that defined problems for poor quality of end product. The parameters are:

- Improper Project Management
- Unskilled Workers
- Time and Cost Constraints
- Quality of Materials

- Lack of Experience
- Lack in Concentration
- Communication Gap

These are some of the important parameters that was defined for the problems and then they were ranked from 1-7, with 7 being the most important choice and 1 being the least.

3.3 Solutions for the defined Causes

Again with the help of literature and other works various solutions for the defined causes was formulated. The parameters are:

- Better Supervision
- Better Training and Supervision
- Improved Project management
- Better Communication
- Proper Designs
- Better Manpower Management
- Better Quality of Materials

These parameters were further ranked from 1-7, with 7 being the most important choice and 1 the least. The sample Questionnaire that was sent for this part of survey is shown in the figure below (Figure 2).

Fig 2: Sample Questionnaire 2

QUESTIONNAIRE 2

Name:………………………………… Organization with Designation……………………………

Major causes for the poor quality of finishing work (Please Rank From 1- 7 With "7 being the most important influencing factor and 1 the least")

	1	2	3	4	5	6	7
Improper project Management							
Unskilled workers							
Time & Cost constraints							
Quality of materials							
Lack of Experience							
Lack in Concentration							
Communication Gap							

3.4 Normal Distribution of Data

The data obtained for the this part of study by the survey among the civil engineering professionals was checked against the normal distribution of data against a 95% significance level i.e. α value of 0.05. The sample was of 72 data. For the 95% significance level and data set of 72 data, the upper limit of the value stands to be 5.63 and lower limit should be 4.03 (obtained by standard W/S normalcy test table). A total of 120 forms were sent through google docs file and 72 responses were received back, with a response rate of 60%.

3.5 Pareto Analysis

The results were finally analyzed using Pareto's Chart, A Pareto chart or a Pareto analysis is a method or a tool to segregate the vital few from trivial many to determine the most important causes for any problem. Pareto's analysis is also called as 80-20 rule which states that the 80% of the problems are caused by 20% of the factors considering that problems. Pareto Chart is a very important tool in the area of quality control, it helps in finding out the major causes of the said problem and helps in finding out the solutions for the same by focusing on that major causes.

4. ANALYSIS and RESULTS

Above mentioned methodologies were used in the form of case studies of the buildings and in the data collected with the help of survey and were further analyzed by mentioned statistical tools to obtain a definite results.

Case Studies

The studies were done in four different locations and these are mentioned below.

- The first building of the study is at lalitanagar, Kolar, BHOPAL
- The second building for study is at Karod (Near Mandi), BHOPAL
- The third building for the study is at Karod (In front of Mandi) near 80 feet road, BHOPAL
- The fourth building for the study is on Hoshangabad Road, BHOPAL
- The defects and the opportunities along with the calculated sigma level is shown with the help of table below (Table1):

Table 1: DPMO and SIGMA level of Studied Buildings

Building	No. of Opportunities	No. of Defects	DPMO	Sigma Level
Building 1	403	2844	141701.828	2.57
Building 2	709	4592	154339	2.52
Building 3	572	3792	150843.882	2.53

4.1 Normal Distribution

Causes for Poor Quality Work

The data collected for this was analyzed and then was checked whether it is normally distributed in the population. For the analysis purpose W/S method was used in which $q_{critical}$ was determined by the table for 95%

significance level for which the values are mentioned above.

Mean for this data set= 3.819455

Standard Deviation of data set= 0.767309

Calculation of 'q'

Standard Deviation

'q'= 4.9777

Since the value of 'q' lies between 4.03 and 5.63 it can be said that data collected was normally distributed in the population. Its bell curve is shown below:

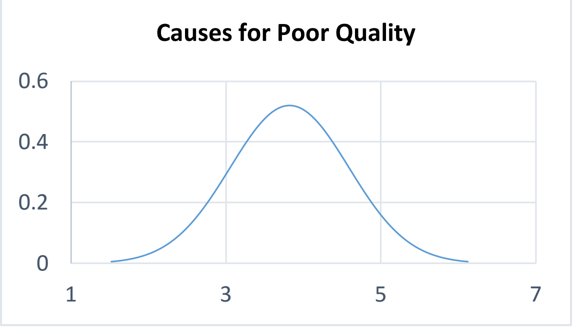

FIG. 3 Normal Distribution Curve for Causes of Poor Quality

Solutions to Improve the Quality of Work

The data collected for this was analyzed and then was checked whether it is normally distributed in the population. For the analysis purpose W/S method was used in which $q_{critical}$ was determined by the table for 95% significance level for which the values are mentioned above.

Mean for this data set= 3.904762

Standard Deviation of data set= 0.74136817

Calculation of 'q'

Standard Deviation

'q'= 5.26696

Since the value of 'q' lies between 4.03 and 5.63 it can be said that data collected was normally distributed in the population. Its bell curve is shown below:

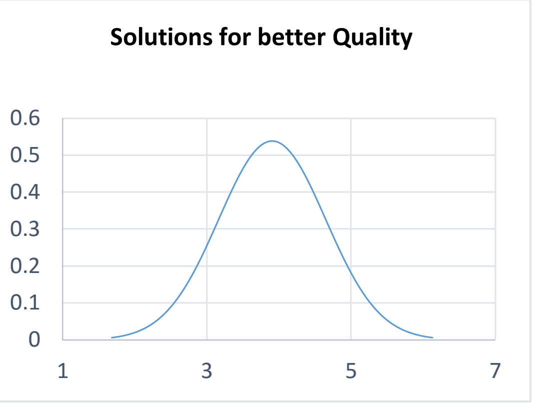

FIG. 4 Normal Distribution Curve for Solution for Better Quality

4.2 Spearman Rank Correlation

The collected data was ranked in the order of their mean and the correlation value was therefore calculated. The Ranked parameters are shown in the Table 2 & 3 respectively.

TABLE 3: Causes of Poor Quality Work

Parameters	Mean	Rank
Time & Cost constraints	3.416667	5
Quality of materials	4.652778	2
Improper project Management	4.041667	4
Unskilled workers	4.736111	1
Lack of Experience	4.263889	3
Lack in Concentration	3.083333	6
Communication Gap	2.541667	7

TABLE 4: Solutions to Improve the Quality Work

Parameters	Mean	Rank
Improved Project Management	3.972222	5
Better training and Education	4.694444	1
Better Supervision	4.430556	2
Better Quality of materials	4.277778	3

Better Communication	4.027778	4
Better manpower management	3.680556	6
Proper Design	2.25	7

The parameters under both were ranked in the order of their mean and then the value of Spearman rank Correlation was further calculated by applying the formula:

Since all the ranks are different hence this formula is being used.

Using the value of 'd_i^2'as 10 and value of 'n' as 7 in the above mentioned formula the value of spearman rank correlation was found out to be '0.821429'. A high value of correlation i.e. near to 1 shows a good level of correlation between the considered parameters.

4.3 Pareto Analysis:

Pareto's Analysis was done to determine the 20% of the important causes that give rise to 80% of the problems of poor quality according to the survey results. This is shown in Table 5 below.

TABLE 5: Pareto Analysis

S.No	Parameters	Frequency	Cumulative	Percent
1	Unskilled workers	23	23	32%
2	Quality of materials	12	35	49%
3	Lack of Experience	12	47	65%
4	Improper project Management	8	55	76%
5	Time & Cost constraints	7	62	86%
6	Communication Gap	7	69	96%
7	Lack in Concentration	3	72	100%

The above table shows the number of responses that were made in the different parameters under the head of frequency. Further, their cumulative frequency was calculated with the percentage of them too to show which parameters are more responsible for the (80%) poor quality work.

The major causes that were found out are:

- Unskilled workers
- Quality of materials
- Lack of Experience
- Improper project Management

This is also shown with the Pareto Chart below:

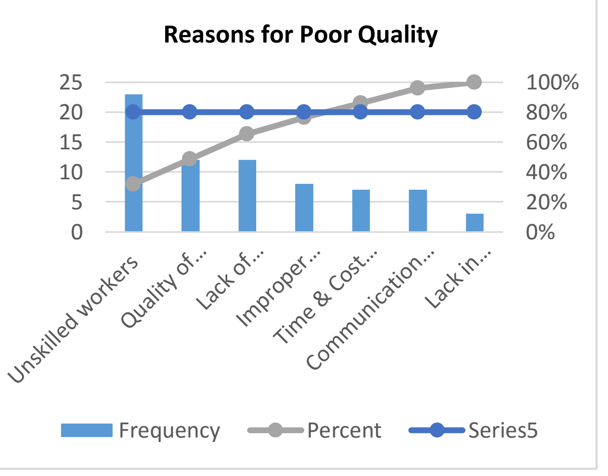

FIG. 5: Pareto Chart for Poor Quality

The solutions that were earlier identified were used (the most important ranked according to survey) in the last case study of a multi storey building to see whether the quality of work done improves or not. The used Solutions are mentioned below:

- Better training and Education
- Better Supervision
- Better Quality of materials
- Better Communication

The fourth and the final study for this work was conducted at a building on Hoshangabad Road, BHOPAL, a 7 storey building was in its finishing stage when this study was done and a total of 27 two BHK flats were studied in this.

Total Number of Defects was calculated as = 245

Total Number of opportunities was calculated as = 4266

DPMO= 57430.8486

<u>Corresponding Sigma Level = 3.08</u>

The solutions that were formulated were when used in the construction process of the above building showed an increase in sigma level of 3.08 which was earlier hovering around 2.50 mark.

5. CONCLUSION

In the study done here, the principles of Six Sigma are used in the internal finishing work with the aim to have a better quality of internal finishing work. The entire work done here is based on the DMAIC methodology of six sigma. By applying the above methodology of six sigma the quality of the finishing work improved, which was earlier hovering around 2.50, reached to 3.08, so and it can be said that if these principles are applied regularly in the construction works the quality of the work done would definitely improve and finally a better level of construction and a better quality of end product can be produced.

TABLE 6: DPMO and SIGMA level of Studied Buildings

Building	No. of Opportunities	No. of Defects	DPMO	Sigma Level
Building 1	403	2844	141701.828	2.57
Building 2	709	4592	154339	2.52
Building 3	572	3792	150843.882	2.53
Building 4	245	4266	57430.8486	3.08

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