International Journal of Advances in Software Engineering & Research Methodology– IJSERM
Volume 1 : Issue 3 *[ISSN 2374– 1619]*
Publication Date : 30 September, 2014

Applying Six Sigma Principles in Construction Industry for Quality Improvement

[Sneha P. Sawant[1]and Smita V. Pataskar[2]]

Abstract **– Six Sigma is a Quality improvement technique that has being implemented in manufacturing and other industries. Six sigma is new to construction industry. This paper describes the basic theory of Six Sigma, principles, methodology and various tools used. A case study of a residential building is taken in which the Six Sigma principles are applied for internal finishing work, the Six Sigma methodology has been adopted to improve the quality and is checked against the sigma level. The findings suggest that proper training and management support and minor changes in current work procedure can help improve the quality and ultimately customer satisfaction which is of prime importance.**

Keywords **-Quality Control; Construction industry; Construction management, DMAIC procedure**

I. Introduction

Quality Management is defined as any approach used to achieve and sustain a high quality output by conforming to requirements and meeting customer satisfaction. Six sigma is a quantitative approach for improvement with the goal of eliminating defects from any process, specifically a numerical goal of 3.4 defects per million opportunities (DPMO). Six sigma is reportedly easier to apply than many other quality management programs because it provides information about the change needed and the programs to execute the change.

The strategy it uses is a five-step improvement process: define, measure, analyze, improve and control (DMAIC). This process is deeply integrated with the overall goals of the organization and, as such, requires top down implementation. Six sigma is more intense, focused and detailed than any other quality improvement techniques.

Six Sigma was first used in 1985 by Bill Smith of Motorola to decrease cost, increase quality by improving process and reduce the production time.

1. Sneha Sawant
Student of Master of Engineering; Dr. D. Y. Patil College of Engineering, Pune. India.

2. Smita Pataskar
Professor, Department of Civil Engineering, Dr. D. Y. Patil College of Engineering, Pune, India.

II. Statistical Theory Behind Six Sigma

Six Sigma is a statistics based methodology and relies on the scientific method to make significant reductions in customer defined defect rates in an effort to eliminate defects from every product, process and transaction. The Six Sigma principle can be represented on a normally distributed product quality distribution curve. When the mean is located at the center of the normal distribution curve, the lower and upper limits are six times the standard deviation (sigma) from the center line. In other words the range of lower and upper limit defect is +/- 6 sigma from the mean.

Table.1 illustrates the rate of defects per million opportunities in different sigma levels.

TABLE 1: OVERVIEW OF SIGMA LEVELS AND DPMO

Yield	DPMO	Sigma Level
30.9	6,90,000	1
69.2	3,08,000	2
93.3	66,800	3
99.4	6,210	4
99.98	320	5
99.9997	3.4	6

III. Basic Framework of Six Sigma Principle - Based Management

According to the paper presented by Seung Heon Han, Myung Jin Chae, Keon Soon Im, Ho Dong Ryu[1] named "**Six Sigma Based Approach to Improve Performance in Construction Operations**" the six sigma principle concept can be applied to the construction process control within the basic framework of CTQ inputs, DMAIC procedures and output measures as shown in figure below,

FIGURE 1: BASIC FRAMEWORK OF SIX SIGMA

Performance Indicators (Input CTQ)	Six Sigma Application Procedure DMAIC	Indices of Performance improvements (outputs)

DMAIC Procedure

As per paper published by Muharrem Firat Yilmaz[3] named **"Six Sigma within Construction Context"** Six Sigma is a continuous improvement methodology which known as DMAIC (define, measure, analyze, improve, control) aims to enhance the efficiency of the existing processes and increase customer satisfaction through designed products and services. DMAIC framework is a integration of several techniques such as QFD (quality function deployment), SPC (statistical quality control), DOE (design of experiments), and FMEA (failure mode and effects analysis) in a logical direction. This approach is more suitable when the current design of the products, services and processes are correct and satisfactory regarding to the requirements, customers and business. This methodology offers structured framework in following steps to establish systematic continuous improvement.

Define. In this step it is necessary to define customer requirements and any things do not meet those requirements known as defect, determine key processes, key roles and team charter, define project goals and scope, and estimate the risks and financial impact.

Measure. Identify and collect the appropriate data which are relevant to the defects and the processes need improvement. Measure the processes performance and establish the measurement system based on Six Sigma techniques and tools.

Analyze. Study and analyze the data collected in previous step to find out the root causes of the defects and unsatisfactory performance.

Improve. Identify alternative solutions and methods based on the knowledge derived from analyze step, study and assess the potential solutions to distinguish the most successful improvement solution. Implement that successful method.

Control. Establish a control plan to ensure that expected improvement has been achieved, and the knowledge and experiences have been documented and shared to remain at attained high level performance.

IV. Implementing and Applying Six Sigma in Construction

In this paper we shall see how six sigma is applied in construction, for this we shall consider a residential building and try to improve the quality of internal finishing work. For this a checklist is prepared for various components as shown in TABLE 2. The assessment is done for each item, the one which meets the standard requirement is marked as '√' else it is marked as 'X' and a '-' indicates that the item is not applicable. The score is computed based on the number of '√' over the total number of items assessed. The yield is then calculated as follows:

DPMO = (No. of 'X' in data collection sheet/ No. of Opportunities of defects X No. Of Units) X 1,000,000.

Based on DPMO, using sigma conversion table (TABLE 1) the sigma level is calculated. Then using the DMAIC procedure of six sigma the quality is improved and then the above procedure is followed to calculate the sigma level, the sigma level of quality is expected to be improved by the above procedure.

Various tools are present at each step of DMAIC procedure depending upon the difficulty level. In this paper we shall use the following tools at each step of DMAIC methodology.

Define – SIPOC – Suppliers Input Process Output Customer
Measure – Pareto Diagrams
Analysis – Cause and Effect Diagram
Improvement – Corrective Action
Control – Control Plan

Case Study

A residential building comprising of 18 buildings of 2BHK flats is considered for study. A checklist is prepared for internal finishing work, which covers various points whose quality needs to be checked. The checklist as shown in TABLE 2, is prepared. The data is filled in the checklist for three – 2BHK apartments which comprise of 144 flats. The one which conforms to standards are marked as '√' else 'X'. The number of 'X' leads to defects and total number of checks leads to opportunities.

The summary of data for the three buildings is as shown below:

Sr. No.	Building	Defects	Opportunities
1	B	619	18336
2	C	545	18336
3	D	570	18336
	Total	**17334**	**55008**

Therefore, DPMO = (17334/55008) X 1,000,000

DPMO = 31522.68

Based on the Sigma conversion table,

σ = 3.36

Thus, we can conclude that the current performance of t0he company is of **3.36 sigma level**. Let us set a target sigma level to be **4.5**

mentioned activities, in this paper we have tried to improve the quality of flooring by using DMAIC methodology.

1. Define: SIPOC – Suppliers Inputs Process Outputs Customers

Whenever we want to start any process improvement activity, it is important to get the high level understanding of the process. SIPOC helps us to agree the boundaries of what we will be working. Shown below in the TABLE 3 is the SIPOC process for flooring using vitrified tiles.

TABLE 2: CHECKLIST FOR FLOOR TILING WORK

Building / Flat No : - _____

Sr. No.	Points Description	Rooms									
		LR	Pas	Kit	UT	Bed1	Bed2	TL 1	TL 2	Ter	Remark
1.	**Tiling Work**										
a	**Floor Tiling Work**										
1	Flooring Tiles & Skirting fixed properly.										
2	Color/shade variation uniform in floor tiles.										
3	Floor tiles and skirting are thoroughly cleaned.										
4	Cracks observed in flooring/Skirting.										
5	No loose patches (Voids) in Flooring after knocking.										
6	Butt filling/ grooves/ offset of skirting uniform.										
7	Skirting are in line & level and right angles at										
	Corners and around column offsets.										
8	Flooring joints matched properly.										
9	Proper slope maintained for all floors.										
10	No water logging in flooring after pouring water.										
11	Windows/ ventilators in toilets properly finished with wall tiles.	NA	NA	NA	NA	NA	NA			NA	
12	Proper slopes towards nahani trap given at all	NA	NA	NA	NA	NA	NA				
	places.										
13	Proper tile drop at bath/toilet/balcony terrace given	NA	NA	NA	NA	NA	NA				
	1/2" or one tile thickness level drop recommended										
	in balcony/ toilets from rooms/ passage floor level.										
14	Cutouts for water taps properly finished.	NA	NA			NA	NA			NA	

DMAIC Methodology

By studying the checklist we have selected some activities like flooring using vitrified tiles, dado tiling, wooden doors, terrace water proofing using brick bat which adversely affect the sigma level of quality. Out of the above

2. Measure: Pareto Charts

Each construction activity is a set of various dependent activities; Pareto chart helps to identify the most significant factors, shows where to focus efforts and allows better use of limited resources. Chart (FIG 2) below shows us the Pareto Analysis for flooring using vitrified tiles.

A Pareto Chart can answer the following questions:

- What are the largest issues facing our team or business?
- What 20% of sources are causing 80% of the problems?
- Where should we focus our efforts to achieve the greatest improvements?

3. Analyze: Cause and Effect Diagram

Cause and Effect diagram helps us to visualize in a graphical manner the outcome and various factors that influence that outcome. It graphically illustrates the relationship between a given outcome and all the factors that influence the outcome.This type of diagram is sometimes called a "fishbone diagram" because of the way it looks.

TABLE 3: SIPOC ANALYSIS FOR VITRIFIED TILE FLOORING

Suppliers	Inputs	Process	Outputs	Customers
Builder	Vitrified tiles 43 grade cement Fosroc adhesive Tile grout Potable Water Tape measure Carpenter Square Contour gauge Notched trowel for spreading adhesive Tile nippers Pointed Plasterer's trowel Tile cutter Carborundum paper for smoothing the tile edges Firm sponge Clean cloth	1. The surface where tiling work is to be done must be clean and free from dust, paint, grease, scraps, oil etc. 2. If the bed surface has been left dry for long time then it must be washed and made sufficiently cured. 3. Bed mortar must be prepared by using cement and crushed sand in the proportion of 1:8 along with water to make consistence paste, use this paste to make a bedding of 20 – 30 mm thickness after checking the levels through 4 corners of the area. 4. Apply a mixture of cement slurry and fosroc tile adhesive on the bed mortar, the proportion of fosroc is 300 ml per bag of cement. 5. Clean back of the tile with damp cloth if dusty. 6. Tiles are placed at right angles with respect to one side of the room. 7. Kindly look at the back of the tile and follow any one laying pattern as shown below:  8. Never place the tiles in this pattern:  9. Use of 2 – 5mm of spacers is recommended. 10. For proper bonding press the tiles gently with the wooden mallet do not use iron hammer or any heavy material to press the tile. 11. After fixing the tiles, the extra mortar etc. should be cleaned with wet cloth or sponge and allow to set and curing must be done for 7 days. 12. After proper setting and curing, the tile must be cleaned and there after proper grouting must be done with tile grout. **Inspection Checklist:** 1. Jointing: All joints are properly filled. 2. Finishing: Mortar stains or paint drips should not be seen and must have consistent color tone. 3. Evenness: Surface are even (not more than 3mm over 1.2 m). Level to proper falls in wet areas like kitchen and toilets, no ponding should occur at any part of floor. Lippage between 2 tiles should not be more than 1mm. 4. Cracks and Damages: No chips, cracks and other visible damage must be observed. 5. Hollowness: No hollow sound when tapped with hard object.	Finished Floor surface	Flat owners.

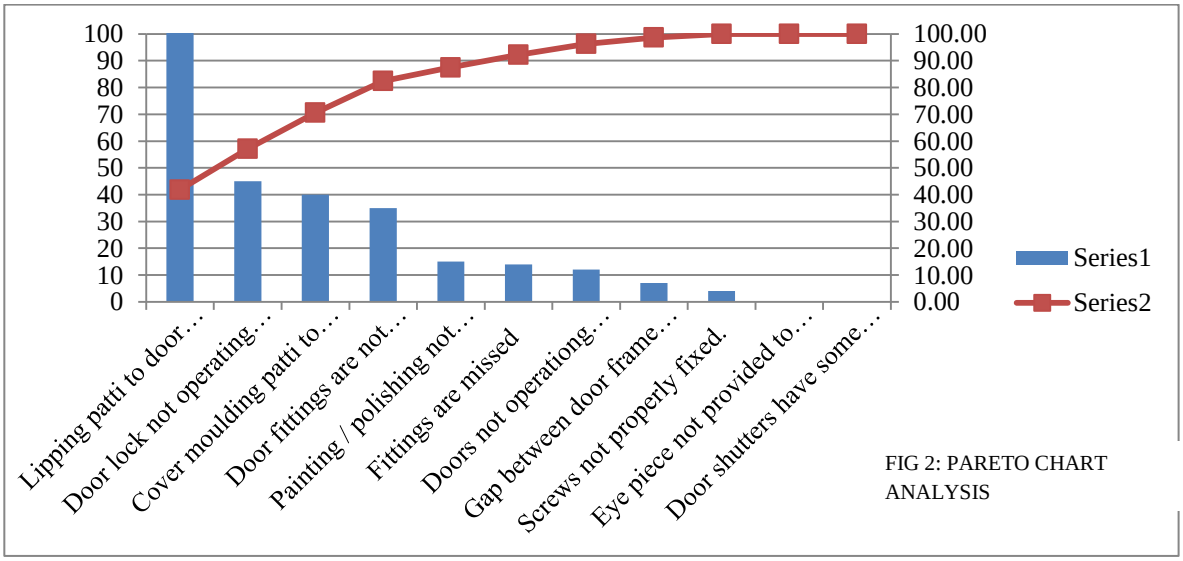

FIG 2: PARETO CHART ANALYSIS

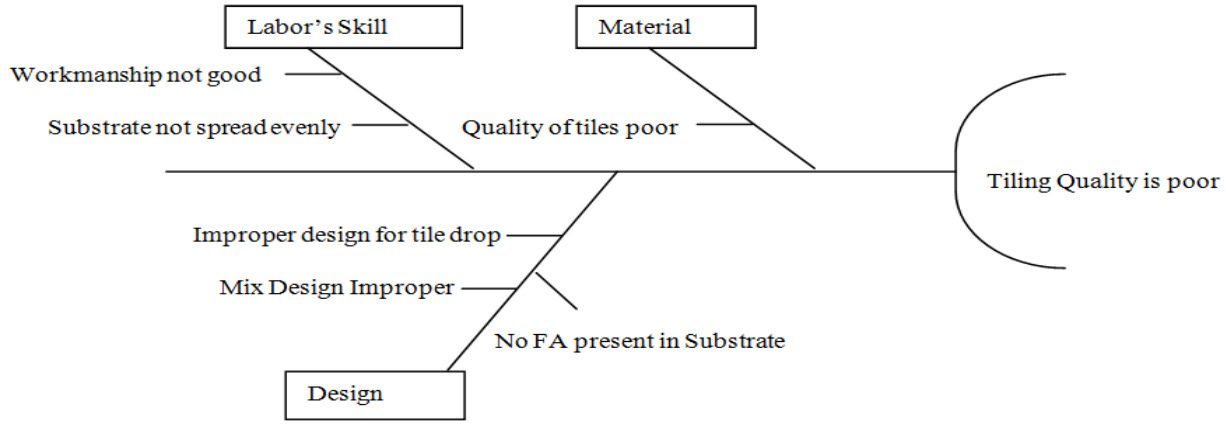

FIG 3: CAUSE AND EFFECT DIAGRAM FOR VITRIFIED FLOORING

4. Improve: Corrective Action

As per the '**Preventive and Corrective Actions Guidelines'** given by R.M. Baldwinthe Corrective Action is defined as, a term that encompasses the process of reacting to product problems, customer complaints or other nonconformities and fixing them.
The process includes:
• Reviewing and defining the problem or nonconformity
• Finding the cause of the problem
• Developing an action plan to correct the problem and prevent a recurrence
• Implementing the plan
• Evaluating the effectiveness of the correction.

Thus, from the above analysis following corrective actions were taken:

i) Skilled labors were employed and proper training was given to them.
ii) The Mix design for substrate was revised from 1:8 to 1:4:4 were there was 1 part of Cement, 4 parts of Fine aggregate and 4 parts of Coarse aggregate.
iii) Tiles of better quality were used.

5. Control : Control Plan

Control plan will help us to keep a check on the various preventive measures which are taken to achieve the desired result. As per the '**Guide to Control Plans'**a control plan is the documented description of those procedures, checks or assigned activities necessary to verify that production units continue to conform to the type approval requirements with regard to specification, marking and performance.The aim of the control plan information is to show that the appropriate level of control exists in relation to those aspects of the product, which are critical to its continuedcompliance. Thus we shall use the checklist which is prepared earlier as a control plan.

Conclusion

We have seen how various factors have high impact on the quality of the construction. These factors must be identified as early as possible so that the quality can be improved. Detailed methodology has been implemented based on Six Sigma principles which give us systematic approach to identify and improvise the current process. Six Sigma also provides scale to measure whether the quality has been improved or not.

References

1. Paper presented on **Six Sigma-Based Approach to Improve Performance in Construction Operations** Seung Heon Han, M.ASCE1; Myung Jin Chae, Ph.D., P.E.; Keon Soon Im, P.E.; and Ho Dong Ryu
2. Paper presented on **Six Sigma within Construction Context As a Quality Initiative, Performance Indicator/Improver Manangement Strategy** by Muharrem Firat Yilmaz
3. **Benefits, obstacles and future of Six Sigma approach** by Young Hoon Kwak and Hrank T. Anbari.
4. **Implementing and Applying Six Sigma in Construction** by Low Sui Pheng and Mok Sze Hui
5. **The Application of Six Sigma Approach in Construction: A Case study for improving Precast Production Management** by Lu-Maan Chang, Chun-Hung Chao, Ya-Hui Lin
6. **Implementing Lean Six Sigma: A Case study in concrete panel production** by Celep Oguz, Yong-Woo Kim, John Hutchison and Seungheon Han.
7. **Improvement Process for Rolling Mill through the DMAIC Six Sigma Approach** by Kunal Ganguly.
8. **Quality Management Tools for each Six Sigma's DMAIC.**
9. **Wikipedia -** http://en.wikipedia.org/wiki/SIPOC
10. http://www.discover6sigma.org/post/2007/06/sipoc/
11. http://www.instituteforwihealth.org
12. **https://balancedscorecard.org/Portals/0/PDF/c-ediag.pdf**
13. '**The Application of Cause and Effect Diagram in Sepahan Oil Company**' by Masoud Hekmatpanah.
14. **APPLICATION OF SIX SIGMA METHOD TO EMS DESIGN**' by Miroslav RUSKO, Ružena KRÁLIKOVÁ.
15. '**Preventive and Corrective Actions Guidelines'** given by R.M. Baldwin.