

# Implementation of Six Sigma Concepts in Construction Project for Ensuring Quality Improvements

S. Sriram<sup>1</sup>, A. Revathi<sup>2</sup>

P.G. Student, Department of Construction Engineering and Management, SRM University, Kattankulathur, Tamil Nadu, India<sup>1</sup>

Assistant Professor, Department of Civil Engineering, SRM University, Kattankulathur, Tamil Nadu, India<sup>2</sup>

**ABSTRACT:** This paper describes the implementation of Six Sigma concepts in Construction project to meet the quality standards and customer satisfaction. The critical objective of construction industries nowadays is to complete a project within a stipulated time and cost as per the required standards and specifications, minimization of waste and efficient use of resources. Six Sigma principles with an effective methodology in construction industry emphasizes on reducing variation and eliminating the root causes of defects. The basic theory of Six Sigma, Six Sigma principles, DMAIC (Define, Measure, Analyze, Improve, Control) methodology and tools used in each stage of DMAIC methodology has been discussed in this paper. A case study was conducted in a residential building to which Six Sigma principles were applied for internal finishing work (tiling work). A defect assessment sheet has been prepared and the existing sigma level of the process has been found to be 3.37 with corresponding yield of 95.76%. DMAIC methodology has been applied to enhance the quality of the existing process by analyzing the defects, their percentage of occurrence, the possible causes and effect of defects and recommendations to overcome them. The findings will suggest the proper training, management support and minor changes that is required in current work procedure which would help to improve the quality and ultimately enhancing the customer satisfaction which is of prime importance.

**KEYWORDS:** Six Sigma, Six sigma concepts in construction, Six sigma principles, DMAIC methodology, Case study.

## I. INTRODUCTION

Quality Management is defined as any approach used to achieve and sustain a high quality output conforming to requirements and meeting customer satisfaction. The importance of quality improvement and excellent performance in the highly competitive world market lead many organizations, to implement the new philosophies such as pull scheduling and lean principles at their organizations. This paper describes the Six Sigma principle and framework as a quality improvement strategy through the successful business. Six sigma is a quantitative approach for improvement with the major objective being elimination of defects from any process, specifically a numerical goal of 3.4 defects per million opportunities (DPMO). Six sigma is reportedly easier to apply than any other quality management programs because it provides information about the change needed and the programs required to execute the change. The methodology used in this paper is DMAIC, is a five-step improvement process like Define, Measure, Analyze, Improve and Control (DMAIC).

## II. STATISTICAL THEORY BEHIND SIX SIGMA

The Six Sigma concept has been derived from statistical distribution known as “standard normal distribution” illustrated by symmetrical bell-shaped curve. Theoretically this bell-shaped curve has been extensively studied and has been proven very useful as numerous natural continuous phenomena seem to follow it or can be approximated by it.

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The curve represents the total “population” (whatever is measuring) by the infinite series of segments in its both directions. Each segment has been named “Sigma” which symbolize by “ $\sigma$ ” (Greece letter) and its deviation from “mean” ( $\mu$ , average or peak of the bell-shaped curve) in Statistical terms. The considerable part of the curve is the range between  $-3\sigma$  and  $+3\sigma$  due to covering 99.73% of the population where as Six Sigma considers the range between  $-6\sigma$  and  $+6\sigma$  which covers 99.9997% of the data. 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  $\pm 6$  sigma from the mean. Table I shows the overview of Sigma levels and DPMO.

Table I Sigma levels

YIELD	DPMO	SIGMA LEVEL
30.9	690000	1
69.2	308000	2
93.3	66800	3
99.4	6210	4
99.98	320	5
99.9997	3.4	6

### III. DMAIC METHODOLOGY

The DMAIC (Define-Measure-Analyze-Improve-Control) is the classic Six Sigma problem solving process. Traditionally, this approach is to be applied to a problem with an existing, steady-state process or product and/or service offering. DMAIC builds on three fundamental principles:

- Results-focused, driven by data, facts, and metrics.
- Work is project-based (short-term in nature, with length depending on scope and complexity) and project-structured, versus an ongoing process.
- Inherent combination of tools-tasks-deliverables linkage that varies by step in the method.

This approach is more suitable when the current design of the products, services and processes are correct and satisfying the requirements, customers and business.

**DEFINE** - In this step it is necessary to define customer requirements and any things that do not meet those requirements known as defects, define project scope and goals, Identify CTQ (Critical To Quality) characteristics of the process.

**MEASURE** - Identify and collect appropriate data which are relevant to the defects and the process that needs improvement. This step helps to measure the performance of the existing process and its deviation from the actual requirements. The objective of this measurement is to get enough data or information from the process under development. Identify the performance requirements of the process with respect to its CTQ (Critical To Quality) characteristics.

**ANALYZE** - To study and analyze the data collected in the previous step and to find out the root causes of the defects and unsatisfactory performance. This stage involves comparison between the current performances of the existing process with its actual requirements. Once the deviation is measured the problem causing this deviation is identified.

**IMPROVE** - Improve the process by eliminating the defects. Identify the ways to eradicate the existing problem. Verify the inputs that are creating the problem and causing the variation in the outputs and control them. Develop potential solution.

**CONTROL** - It helps to ensure that the problems that are creating variations in the desired outputs are rectified. The new process is implemented under a control plan to achieve the desired results. Measure the performance of the new process under a controlled plan and continually monitor the process to control the quality level of the process.

The objective of this study includes the following:

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- To study the basic principles of six sigma concept and DMAIC (Define, Measure, Analyze, Improve, Control) methodology and various tools used in DMAIC methodology.
- To enhance the quality of an ongoing process (internal finishing work) of a construction project by eliminating defects.
- To meet the quality standards and customer satisfaction by implementing Six Sigma concepts.

Scope of this study:

- The basic theory of Six Sigma, its principles, methodology and various tools used was studied in detail.
- Six Sigma principles was applied for internal finishing work of a project and the sigma level for the same was calculated from the data obtained.
- DMAIC (Define, Measure, Analyze, Improve, Control) was adopted to improve the quality of the existing process.

## IV. METHODOLOGY

The flowchart shown in fig 1 shows the methodology followed in this study.

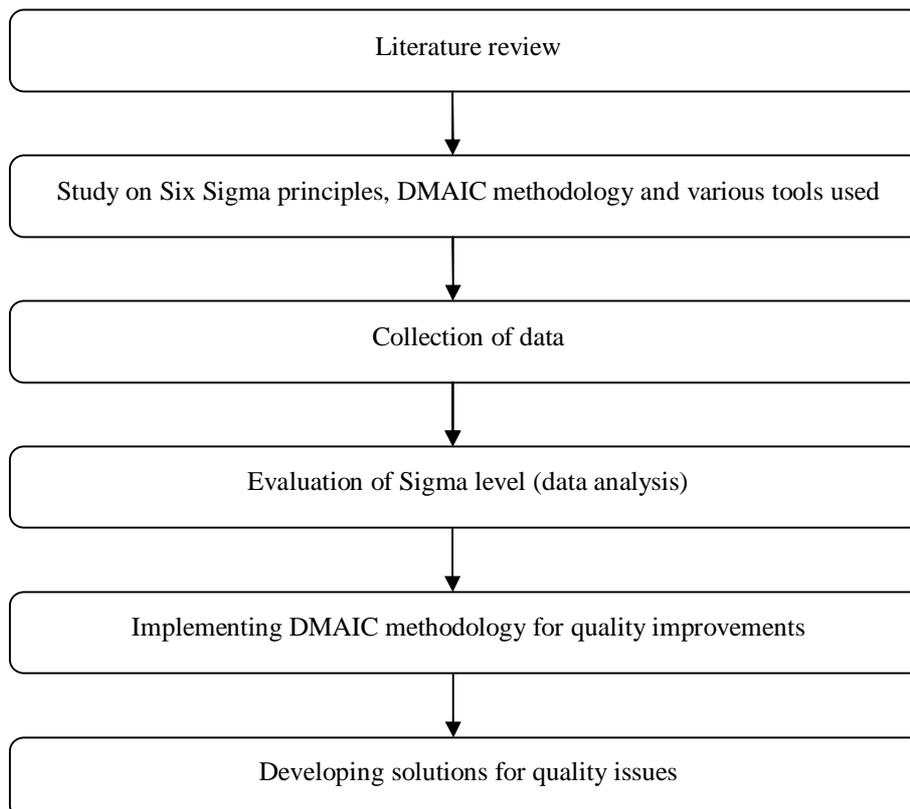


Fig 1 Flowchart for project methodology

## V. IMPLEMENTING SIX SIGMA CONCEPT IN CONSTRUCTION

A case study was conducted on a residential building in which six sigma principles were applied to internal finishing work (tiling works) to enhance the quality of the existing process. A defect assessment sheet was prepared in

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which the possible defects that might occur in tiling works was listed. The assessment was done for each item, the one which met the standard requirement is marked as '✓' else it is marked as 'X' and NA indicates that the item is not applicable. The total number of defects, total number of opportunities for defects in each assessment sheets is calculated and the yield is evaluated as follows:

$$DPMO = \frac{\text{No. of 'X' in data assessment sheet} \times 1000000}{\text{No. of opportunities of defects} \times \text{No. of units}}$$

Based on DPMO, using sigma conversion table (table 1) the sigma level is calculated. Then by using the DMAIC procedure of Six sigma the quality of the ongoing process is improved.

In this paper the following tools are used in each stage of DMAIC methodology,

Define - SIPOC (Suppliers Input Process Output Customer)

Measure - Pareto chart

Analyze - Cause and Effect diagram

Improve - Brainstorming (Recommendation for corrective action)

Control - Control plan

## VI. CASE STUDY

A residential building comprising of 8 flats with 3 BHK flats was considered for this study. A checklist (assessment sheet) was prepared for tiling work, which covers various points whose quality was checked as shown in table II.

Table II Assessment sheet

S. No	Defects	Bathroom -1	Bathroom - 2	Master bathroom	Kitchen
1	Uneven surfaces or lippage				
2	Right angles at corners				NA
3	Hollow sound				
4	Cracks observed in tiling				
5	Staining (Stainmarks)				
6	Colour/Shade variation				
7	Skirting are in line, level and at right angles at corners				NA
8	Bad pointing (grouting of joints)				
9	Damages due to plumbing and sanitary fittings				
10	Proper slope maintained for floors to prevent water logging				NA
	No. of defects				
	No. of checks				

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The summary of data for eight 3BHK flats is shown below in table III.

Table III Summary of data

S.No	Flat No.	Defects	Opportunities
1	101	12	37
2	102	8	37
3	103	6	37
4	104	6	37
5	201	7	37
6	202	10	37
7	203	9	37
8	204	7	37
	Total	65	296

Therefore,  $DPMO = 65 / (296 \times 8) \times 1,000,000$

$$DPMO = 27,449.32$$

Based on Sigma conversion table,

$$\sigma = 3.37$$

Yield = 95.76% (Percentage of items executed properly by contractors is 95.76%).

### DMAIC Methodology

After evaluation of Sigma level, DMAIC methodology was applied to improve the quality of tiling works as follows,

#### 1. Define: SIPOC (Suppliers Inputs Process Outputs Customers)

- In Six Sigma, SIPOC is often used in the define phase of DMAIC as it clearly understands the purpose and the scope of a process.
- It shows a organized structure consisting of Suppliers of the process, Inputs to the process, Process the team is improving, Outputs of the process, Customers who receive the process output.
- With this tool, an organized view of your work process and SIPOC structure was built that helps the process owner and those working on the process to clarify the primary elements of a process and agree the boundaries of what they will be working. SIPOC diagram for wall tiling and floor tiling are shown in the table IV and V.

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Table IV SIPOC analysis for Vitrified wall tiling

Supplier	Inputs	Process	Output	Customers
Builder	1.Vitrified tiles 2. 43 Grade OPC 3.Mortar pan 4. 2mm spacers 5.Laticrete grout 6.Measurement box for Volume batching (30cmx30cmx37.5cm) 7.Spade for mortar mixing 8.Trowel 9.Straight edge 10.Spirit level 11.Tile cutter 12.Wooden Hammer 13.Bal Endura Adhesive	1. Select and stack tiles adjacent to the work 2. Clean the laitance, set mortar/concrete if any on base surface 3. Proper check to be done on the level of plaster and only after clearance is given, tile marking should be done 4. Mark the tile pattern on the plastered surface as per drawing to predefine the positions of electric and plumbing points 5. Then handover the area to plumbing and electrical agency for chasing and laying of plumbing lines and MEP works 6. After the plumbing and electrical lines are laid and clearance is provided from them, then only the tiles should be laid so that there is no wastage and damage of tiles. 7. Fix the tiles with tile adhesive (3mm thickness) on the plastered wall surface 8. Do gentle tapping with wooden mallet such that each tile is properly embedded with the adjoining tile 9. Joints should be thin and straight and check the joint pattern as per drawing 10. Grout the tile joints after 7days of installation and remove spacers before grouting. 11. Thoroughly clean the surface with mild hydrochloric acid and water	Finished wall surface	Flat Owners

Table V SIPOC analysis for Vitrified floor tiling

Supplier	Inputs	Process	Output	Customers
Builder	1.Vitrified tiles 2. 43 Grade OPC 3.Mortar pan 4. 2mm spacers 5.Laticrete grout 6.Measurement box for Volume batching (30cmx30cmx37.5cm) 7.Spade for mortar mixing 8.Trowel 9.Straight edge 10.Spirit level 11.Tile cutter	1. Select and stack the tiles adjacent to the work. 2. Clean the laitance, set mortar/concrete if any on base surface 3. Provide a proper base before starting tile work 4. Tile should be embedded in cement mortar mix ratio 1:6 ,the bedding is made 30 to 50mm thickness after checking the levels through 4 corners of the area 5. Cement slurry should be spread by using minimum cement about 2Kg/Sq.m over cleaned surface and cement paste should be spread using minimum cement about 4.5 Kg/Sq.m over cement mortar beds 6. Use wooden hammers to tap the tiles in position	Finished floor surface	Flat Owners

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	12. Wooden Hammer	<p>7. Where full tile cannot be accommodated, the required size tile can be cut and sawn and installed to the true line</p> <p>8. While fixing the tiles care to be taken for firmly securing the tile in base mortar, because after finishing the hollow sound could not be found by tapping with wooden mallet</p> <p>9. Clean the joints with coir brush to remove mortar and dust</p> <p>10. Grout the tile joints after 7days of installation and remove spacers before grouting.</p> <p>11. Thoroughly clean the surface with mild hydrochloric acid and water</p>		
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### 2. Measure: Pareto charts

- A Pareto chart depicts the frequency with which certain event occurs. It is a bar graph where each frequency (or frequency range) is shown in a descending order of importance of data from left to right.
- Using a Pareto chart, helps us to concentrate or focus on the factors that have greatest impact.
- A Pareto chart can answer the following questions,
  - What are the largest issues, our team is facing?
  - What 20% of the sources are causing 80% of the problems?
  - Where should we focus our efforts to achieve the greatest improvements?

The following figure 2, illustrates Pareto chart analysis for tiling works.

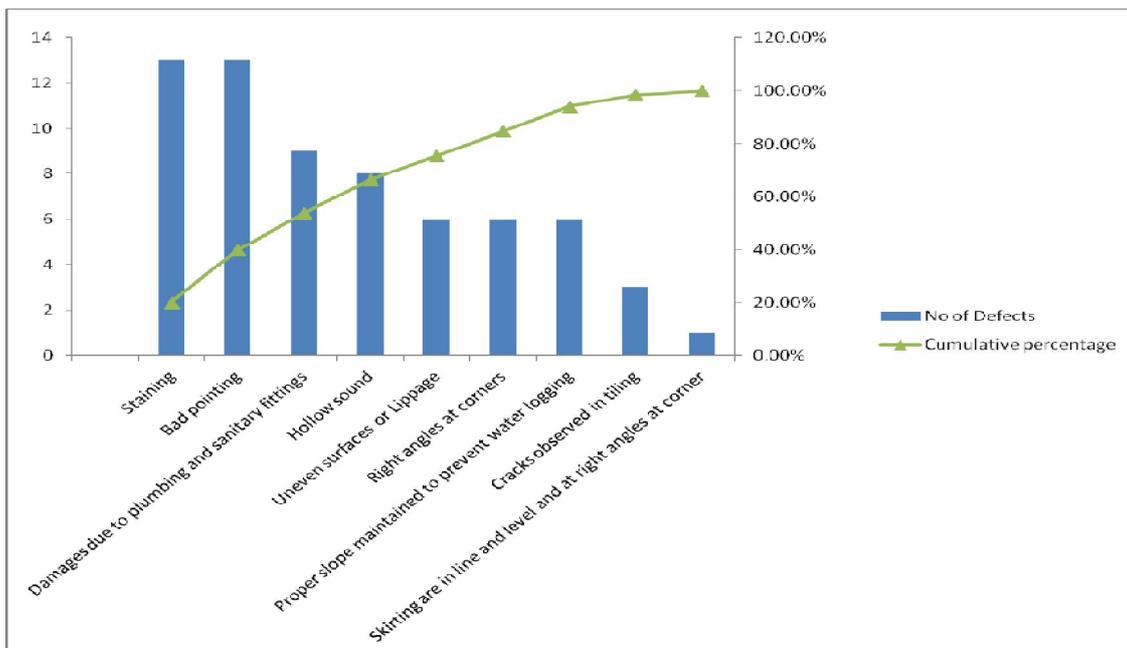


Fig 2 Pareto chart analysis for wall and floor tiling

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### 3. Analyze: Cause and effect diagram

- It graphically illustrates the relationship between a given outcome and all factors that influences that outcome.
- This type of diagram is called as fishbone diagram because of the way it looks. The following figure 3, illustrates the fishbone diagram for tiling wall and floor tiling.

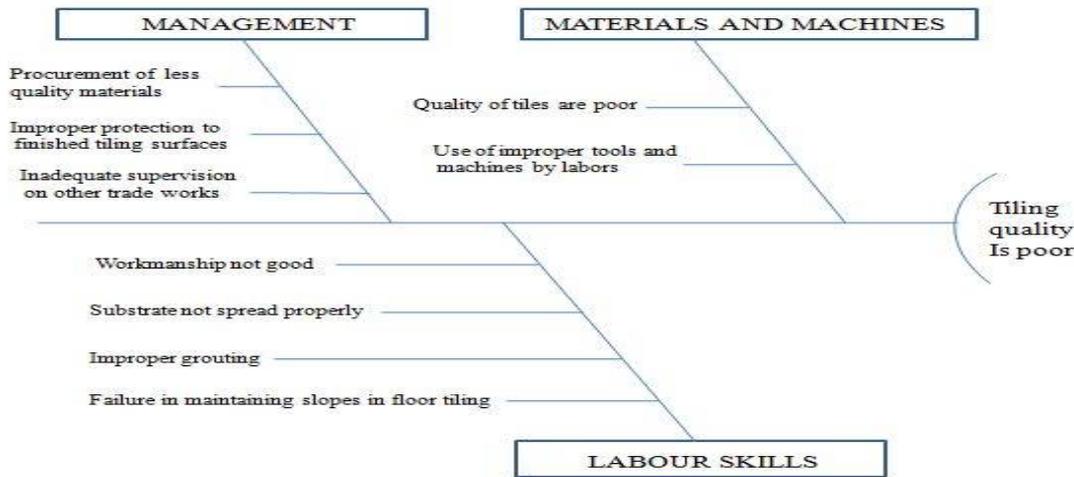


Fig 3 Cause and effect diagram for wall and floor tiling

### 4. Improve : Brainstorming

Effective brainstorming can be accomplished by following simple brainstorming do's and don'ts with your team. A brainstorming session is a tool for generating as many ideas or solutions as possible to a problem or issue. It is not a tool for determining the best solution to a problem or issue. Based on brainstorming some of the recommendations are made in order to prevent recurrence of defects as shown in the table VI.

Table VI Recommendations to overcome defects

S.No	Defects	Recommendations
1.	Uneven surfaces or lippage	a. Proper surface preparation b. Correct tile thickness c. Use proper tools d. Ensure tiles are even and level using spirit level e. Proper protection
2.	Cracks	a. Provide proper protection b. Adequate supervision on other trade works c. Avoid poor handling ,cutting of tiles and direct impact.
3	Hollow sound	a. Ensure proper and uniform spread of tile adhesive and mortar b. Tap with wooden mallet after installation of tiles as a check for hollow sound.
4	Bad pointing	a. Select suitable grouting material b. Joints should be properly filled c. Tiles surface to be properly cleaned after installation
5	Staining	a. Proper protection to the tiles surface b. Avoid spillage c. Adequate supervision

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## 5. Control: Control plan

Control plan will help us to monitor on the various preventive measures which are taken to achieve the desired outcome. The aim of control plan is to show that appropriate level of control exists in relation to the defects which are listed out earlier. The assessment sheet (checklist) which has been prepared earlier can used a control plan.

## VII. CONCLUSION

One of the major challenges faced by the construction firms is to deliver the product within the stipulated time without compromise in Quality. Execution of works with the Standard Quality requirements reduces rework and hence the cost for it. There are various factors which have high impact on construction quality. These factors must be identified as early as possible so that quality can be improved. In this paper tiling work of a residential building has been studied and sigma level has been evaluated. DMAIC methodology has been implemented based on Six Sigma principles which give a systematic framework to identify the impact of defects, their root causes and ways to reduce them. DMAIC can be helpful to increase quality and quantity at the same time and it will affect technical and financial success of project considerably. Briefly, Six Sigma, as a quality initiative, that aims to reduce defects and variations in processes using statistical measurements, process design and quality control analysis in order to increase (external/internal) customer satisfaction.

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