Asian Journal of Engineering and Applied Technology (AJEAT)
Vol.3.No.1 2015 pp 30-35
available at: www.goniv.com
Paper Received : 08-05-2015
Paper Accepted: 26-05-2015
Paper Reviewed by: 1. R. Venkatakrishnan 2. R. Marimuthu
Editor : Prof. P.Muthukuma

Implementation of Six Sigma Strategy to Enhance Quality and Performance of Architectural works in Contracted Residential Construction

Muthu Mariappan P[1], Saradha Devi N[2] and Prasanna Kumar S[3]
[1,2]Department of Civil
[1,2]C.A.R.E Group of Institutions, Trichirapalli, India.
[3]Six Sigma Lead, Green Belt - Six Sigma, Madurai, India.
p.muthumariappan@gmail.com[1], saradhadevi1@gmail.com[2], kumar.ae13@gmail.com[3]

ABSTRACT

Construction industry has intricacy in its nature to do a triumphant project because it involves large number of parties as clients, contractors, consultants, stakeholders, shareholders, regulators and others. Among the construction phases the most difficult task is to ensure quality and performance in the execution part. This study develops a framework integrating Quality tools like Pareto chart and Cause and effect diagram as well as Six Sigma strategies like DMAIC and DPMO in a systematic approach with the goal of improving the quality and performance of architectural works in contracted residential construction. A case study of a residential building is taken in which the architectural works are contracted, the Six Sigma methodology have been applied to improve the quality and was checked against the sigma level. Recommendations were made to improve performance as well as to reduce the defects and control measures were also applied for standardisation of contracted construction process.

Key words - Contracted residential construction, Quality tools, DMAIC, DPMO.

I. INTRODUCTION

Construction industry plays a major role in developing and achieving the goals of the society. Construction is one of the largest industries contributing about 10% of the Gross National Product in industrialized countries and also it consumes more resources & money with high rate of wastages. Hence there is a need for process enhancement strategy to control and improve.

In general, there are four types of constructions – Residential Building construction, Industrial construction, Commercial Building construction, Heavy Civil construction. For rapid construction, contracts and sub contracts are made which involves clients, contractors, consultants, stakeholders, shareholders and others. This may sometimes result in poor quality or even failure. The failure of any construction project is mainly due to the problems and failure in performance. The performance of the construction industry is also affected by national economies.

In the fields of civil engineering and architecture, construction is an activity that consists of a building or assembling of infrastructure. Each type of construction project requires a unique team to plan, design, execute and maintain the project. But in contracted construction, only execution and maintenance team are present. Quality construction is a result of using quality materials and implementing standardized process. If a number of construction companies in a country start neglecting the quality aspects in their projects, it starts reflecting on the reputation of the country. Hence we require a performance metric and systematic approach to control quality. Six Sigma provides transparent process and reduce defects. Thus enhancement of quality and performance of contracted construction process will become significant.

This paper will illustrate the research made to develop a procedure enhancing quality of architectural works in contracted multi-storied residential construction project.

II. SIX SIGMA IN QUALITY IMPROVEMENT

Six Sigma is a set of practical methods and tools for process enhancement. It was formulated by Jack Welch in 1986 and he made it fundamental to his business strategy at General Electric in 1995. Today, it is used in many industrial sectors and latest to construction industry. Six Sigma seeks to advance the quality and value of process outputs by recognizing and removing the sources of defects(errors) and to diminish the inconsistency in manufacturing and business courses. It uses a set of quality management techniques, including statistical analysis, and creates a unique infrastructure of people inside the organization. Each and every Six Sigma project processed inside an organization tracks a defined series of steps and has quantified value goals. For example, to lessen process cycle time, to diminish pollution, to reduce costs, to enhance customer satisfaction and to raise profits.

Processes that run with "six sigma quality" around the short term are considered to produce long-term defect grades less than 3.4 defects per million opportunities (DPMO). Six Sigma's inexplicit goal is to elevate all processes, but not only to the 3.4 DPMO level inevitably. Organizations should find out a suitable sigma level grade for each of their most major processes and endeavour to achieve these. As an effect of this goal, it is present on management of the business to prioritize areas of development.

Six Sigma projects follow two project methodologies stirred by Deming's Plan-Do-Check-Act Cycle. These methodologies, self-possessed of five phases each, bear the word forms DMAIC and DMADV.

i. DMAIC is adopted for projects meant at enhancing an existing business process.
ii. DMADV is adopted for projects meant at building new product or process designs.

The **DMAIC** project methodology has five phases:

i. **Define** the system, SIPOC map, the both internal and external voice of the customer and their needs, and the project targets, particularly.
ii. **Measure** key features of the current process and gather relevant data.
iii. **Analyze** the data to inspect and verify cause-and-effect associations. Define what the relationships are, and endeavour to ensure that all factors have been measured. Look for root cause of the defect under analysis.
iv. **Improve** or optimize the current progression based upon data analysis using methods such as design of experiments, mistake proofing, and model work to create a new, future state practices. Set up pilot runs to set up process capability.
v. **Control** the future state process to make sure that any variations from the target are corrected before they end in defects. Employ control systems such as statistical process control, visual workplaces, production boards, and continuously observe the process.

A. Sigma levels

The table below gives DPMO values corresponding to various short sigma levels.

TABLE I SIGMA LEVEL RATINGS

Sigma level	**DPMO**	**Percent defective**	**Percentage yield**
1	691,462	69%	31%
2	308,538	31%	69%
3	66,807	6.7%	93.3%
4	6,210	0.62%	99.38%
5	233	0.023%	99.977%
6	3.4	0.00034%	99.99966%

III. RESEARCH METHODOLOGY

The following flowchart indicates methodology adopted for the project

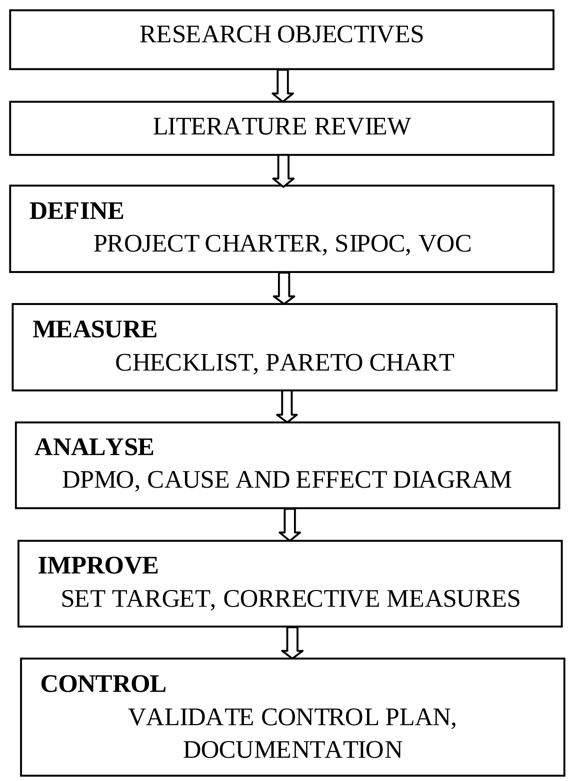

Fig.1. Summary of methodology used in this research

IV. IMPLEMENTING 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. Adopting the DMAIC procedure of six sigma, the quality is improved and then the above procedure is followed to calculate the sigma level, thus the sigma level of quality is expected to be improved. Various quality tools are used at each step of DMAIC procedure depending upon the difficulty level. Also a checklist is prepared for various components as shown in Figure 5. The review is done for each item, the one which meet up the standard necessity is marked as "√" else it is marked as "X". The score is calculated based on the number of "√" over the total number of items measured.

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 10^6. (1)

Based on DPMO, using sigma conversion table (TABLE I) the sigma level is calculated.

CASE STUDY

A residential building comprising of 32 symmetrical flats of 2BHK layout in which architectural works were contracted is considered for study.

A. DMAIC Methodology

By studying various literatures and field survey we have selected some elements like Floors, walls, ceilings, shelves, doors, windows/louvers and components which adversely affect the sigma level of quality in architectural works of a residential building. Out of the above mentioned architectural elements, in this paper we have tried to improve the quality as well as performance of the contracted construction process by using DMAIC methodology.

1) Define:

Project Charter ⇨ SIPOC ⇨ VOC ⇨ CTQ

In this phase we plan how this work gets done and who has responsibility and authority to manage and improve a process by a project charter, SIPOC and VOC analysis are carried out to identify the CTQ's influencing quality in architectural works.

PROJECT CHARTER

Define	
Project Title:	Defect reduction in architectural works.
Problem Definition:	At present Indian construction industry faces series issues because of quality. For rapid progress construction is sub contracted resulting in defects. Unless construction process is standardized it is difficult to meet the customer satisfaction.
Scope & limit:	Architectural works in contracted multistoried residential construction.
Goal:	Improved product quality and customer delivery time.
Tangible Benefits:	Quality Improvement.
Target Benefits:	Better customer satisfaction, Improved quality & delivery time.

Metrics	
Project Start :	November 2014
Project End:	February 2015
Duration:	**4** Months

CTC/CTB	
CTB :	Defects in deliverables-VOC
Drivers:	• Better customer satisfaction in terms of time and quality • Better quality with reduced reworks and defects • Reduced delivery time

The Team	
Project Champion :	Muthu Mariappan P
Guide:	Saradha Devi
6sigma Supporter:	Prasanna Kumar S
Field Supporter:	Maheshwaran M
Support Required:	• Defect measurement data's are required from recent project. • Team support is required for any queries.

Six Sigma Gear
• DMAIC • DPMO • SIX SIGMA RATINGS

Fig.2. Project Charter

SIPOC- Suppliers Input Process Output 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. SIPOC process for Architectural works in a contracted construction is shown below in the Figure 3.

SUPPLIER	INPUTS	PROCESS	OUTPUT	CUSTOMER
BUILDER	1. Drawings 2. Aluminium frames and panels 3. Vitrified tiles 4. Glass 5. Embedding parts 6. Tile cutter and Glass cutter 7. 43 grade white cement 8. Foam grout 9. Fosroc adhesive 10. Potable water 11. Tape measure 12. Carpenter square 13. Tile nippers 14. Contour gauge 15. Notched trowel for spreading adhesives 16. Carborundum paper for smoothing the tile and glass edges 17. Firm sponge 18. Clean cloth	➢ Evaluation of Drawing ➢ Locate and ready the surface ➢ Assembling doors, window and ventilation frames and panels ➢ Check for pattern before positioning tiles ➢ Fitting and placing tiles and doors, windows and ventilation in position ➢ Allow to set ➢ Filling gaps between frame and wall using foam and cement ➢ Embedding parts ➢ Cleaning for smooth operation ➢ Lipping, patti, painting and polishing ➢ After proper setting and curing, the tile must be cleaned and there after proper grouting must be done with tile grout	Fitted doors, windows and ventilations and vitrified tile flooring to use	FLAT OWNERS

Fig.3. SIPOC for Architectural Works

VOC- Voice Of Customers

The term VOC is used to describe customer's needs and their perceptions of the product or service. There are two types of VOC as Internal and External and CTQ's are obtained by this analysis. VOC process for Architectural works in a contracted construction is shown below in the Figure 4.

INTERNAL VOICE OF CUSTOMER		EXTERNAL VOICE OF CUSTOMER	
GOALS AND OBJECTIVE	1. Manufacturing cost must be under budget 2. Enhancing quality 3. Reducing delivery time	VOICE OF MARKET	1. Efficient productivity and delivery on time
VOICE OF PROCESS	1. Unskilled workers, slow motion 2. Lack of worker resources 3. Frequent design changes	CUSTOMERS	1. Lower price 2. High production quality 3. Short duration for production 4. Customer prefer alternation with lower cost
VOICE OF EMPLOYEE	1. Lack of engineers for management 2. Insufficient areas for production 3. Irregular attendance of out sources	COMPETITORS	1. With better production materials and equipments 2. Price competition

Fig.4. VOC Analysis of Architectural Works

CTQ- Critical To Quality

CTQ's are the key drivers for customer satisfaction, they are the critical features and specifications for those products and services and they helps decide where to focus improvement efforts. CTQ's for Architectural works in a contracted construction were obtained and used in creating a checklist to measure the DPMO.

2) Measure:

A checklist is prepared for architectural works which were contracted using the CTQ's, which covers various points and needs to be checked. The checklist as shown in Figure 5 is prepared. The data is filled in the checklist for three – 2BHK 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.

LOCATIONS		FLOORS					WALLS					CEILINGS					SHELVES					DOORS					WINDOWS/LOUVERS					COMPONENTS				
		Jointing	Finishing	Alignment & Evenness	Cracks & Damages	Hollowness	Jointing	Finishing	Alignment & Evenness	Cracks & Damages	Hollowness	Jointing	Finishing	Alignment & Evenness	Cracks & Damages	Roughness	Joints & Gaps	Cracks & Damages	Alignment & Evenness	Finishing	Accessories Defects	Joints & Gaps	Material & Damages	Alignment & Evenness	Functionality	Accessories Defects	Joints & Gaps	Material & Damages	Alignment & Evenness	Functionality	Accessories Defects	Joints & Gaps	Material & Damages	Alignment & Evenness	Functionality	Accessories Defects
Hall	Wall 1																																			
	Wall 2																																			
	Wall 3																																			
	Wall 4																																			
Kitchen	Wall 1																																			
	Wall 2																																			
	Wall 3																																			
	Wall 4																																			
Bedroom	Wall 1																																			
	Wall 2																																			
	Wall 3																																			
	Wall 4																																			
C.Toilet	Wall 1																																			
	Wall 2																																			
	Wall 3																																			
	Wall 4																																			
M.Bedroom	Wall 1																																			
	Wall 2																																			
	Wall 3																																			
	Wall 4																																			
M.Toilet	Wall 1																																			
	Wall 2																																			
	Wall 3																																			
	Wall 4																																			
Balcony	Wall 1																																			
	Wall 2																																			
	Wall 3																																			
	Wall 4																																			
No. of Defects																																				
No. of Checks																																				
Total Number of Defects																																				
Total Number of Checks/Opportunities for defects																																				

Fig.5. Checklist to Measure Defects in Architectural works

The summary of data collected from the architectural works of three 2BHK flats is as shown below:

TABLE II DATA COLLECTED USING CHECKLIST

S.No	Flat	Defects	Opportunities
1	BLOCK 1A	61	460
2	BLOCK 1B	63	460
3	BLOCK 1C	62	460

Therefore,
DPMO = (186/ (3 X 460)) X 1,000,000
DPMO = 1,34,780
Based on the Sigma conversion table,
$\sigma = 2.60$
Thus, we can identify that the performance of the contractor is of 2.60 sigma level with yield of 86.52% and defect rate is 13.48%. Let us set a target sigma level to be 3.5.

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. Figure 6 below shows us the Pareto Analysis for Architectural works in construction.

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?

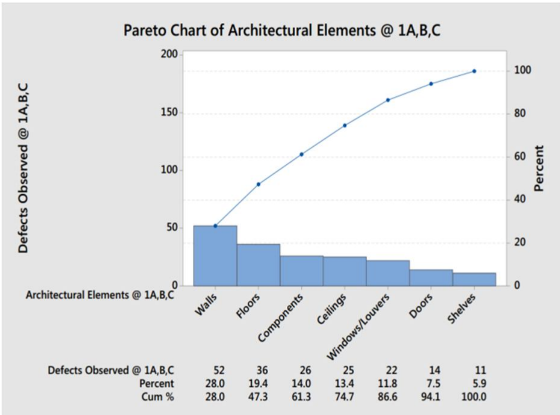

Fig.6. Pareto Analysis for Architectural works

3) Analyse:

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.

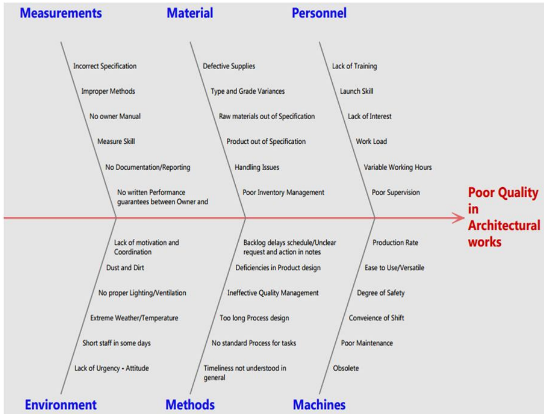

Fig.7. Cause and Effect diagram for Architectural works

4) *Improve:*

According to the ‘Preventive and Corrective Actions Guidelines’ specified by R.M. Baldwin the Corrective Action is defined as, a term that covers the process of act in response to product problems, customer complaints or other non-conformities and fixing them.

The process includes:

- checking and defining the problem or non-conformity
- Finding the reason of the problem
- Formulating an action plan to correct the problem and avoid a recurrence
- Implementing the action plan
- Evaluating the potency of the correction made.

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

i. Better quality materials meeting specifications should only be used.
ii. Recommended to review the past performances of contractor before contracting the works as well as to review the quality track records of supplier before making orders for raw materials and components that are to be used in project.
iii. Written performance guarantees and incentives based on Six Sigma levels.
iv. Detailed plan and manuals should be provided by owners to avoid incorrect routings.
v. Encourage contractor to supervise all his ongoing works more closely to conform the level of skill to quality standards.
vi. Recommended proper trainings to new employees and safety meeting to all employees in site.
vii. Breakdown of schedules, assignment of workmanship in works for better time management.
viii. Check for conformance on before and after stage of an activity.
ix. Ensure housekeeping activities in all projects.

5) *Control:*

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 mentioned as the documented description of those process, checks or assigned activities required to verify that production units continue obeying the rules to the type approval desires with respect to specification, marking and performance. The aim of the control plan information is to prove that the proper level of control exists in relation to those features of the product, which are critical to its sustained compliance.

The validation of improvement measures taken where examined with sigma level for flat Block-1D, hence we used the checklist which is prepared earlier as a control plan.

BLOCK 1D- 7 Defects out of 460 opportunities are observed after the improvement actions were taken.

Therefore,
DPMO = (7/ (460)) X 1,000,000
DPMO = 15,217
Based on the Sigma conversion table,
$\sigma = 3.66$

Thus, we can conclude that the current performance of the contractor is 3.66 sigma levels with yield of 98.48% and defect rate is 1.52% which is more than the fixed target. Let us by now set a target to achieve yield of 99.99966%

V. CONCLUSION

Various factors influencing contracted construction process performance are identified from a case study using a detailed structured checklist and developed a framework to enhance quality as well as performance of architectural works in contracted multi-storied residential construction projects 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. It is recommended for future research to develop a modelling system in order to measure performance of contractor/subcontractor in construction projects.

REFERENCES

[1] Adure, Gautam S and Shusma S. Kulkarni. (2012) ‘Process improvement in construction industry through six sigma approach’- Global Journal of Engg. & Appl. Sciences, Vol.2, No.1, pp.49-55.

[2] Ahmed S. Agha. ‘Total Quality Management In Construction Industry’.

[3] Dean Kashiwagi, Nathan Chong, Marcos Costilla, Frank McMenimen and Charles Egbu. (2004) ‘Impact of six sigma on construction performance’- 20th Annual ARCOM Conference, Vol. 1, 13-23.

[4] Dudgikar.C.S., Er. M.B. Kumthekar, Er. S.R.Khot. (2012) ‘Development of ERP Module for Quality Management in Construction Industry’ - International Journal of Electronics and Communications (IJEC), Volume –1, Issue – 1, pp 29-40.

[5] Luh-Maan Chang, Chun-Hung Chao, Y a-Hui Lin. (2010) 'The Application of Six Sigma Approach in Construction: A Case Study for Improving Precast Production Management'.

[6] Marija Andjelkovic Pesic, Nada Barac and Gorica Boskovic. (2013) 'Possibilities for the six sigma concept implementation in small enterprises' – Technics technologies education management, Vol. 8, No. 1, pp. 309-314.

[7] Mehmet Tolga Taner. (2013) 'Critical Success Factors for Six Sigma Implementation in Large-scale Turkish Construction Companies' - International Review of Management and Marketing Vol. 3, No. 4, pp.212-225.

[8] Priyanga.V and Ambika.D. (2014) 'Study on Factors Influencing Construction Process Performance' - International Journal of Advanced Research in Civil, Structural, Environmental and Infrastructure Engineering and Developing, Volume: 2 Issue: 2, pp. 85-89.

[9] Seung Heon Han, Myung Jin Chae, Keon Soon Im and Ho Dong Ryu. (2008) 'Six Sigma-Based Approach to Improve Performance in Construction Operations' - Journal of Management in Engineering, Vol. 24, No.1, pp. 21-31.

[10] Sneha P. Sawant and Smita V. Pataskar (2014) 'Applying Six Sigma Principles in Construction Industry for Quality Improvement', Proc. of the Intl. Conf. on Advances In Engineering And Technology - ICAET-2014, pp. 407-411.