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APPLICATION OF SIX-SIGMA FOR PROCESS & QUALITY IMPROVEMENT OF BUILDING CONSTRUCTION: A CASE STUDY

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Abstract- Construction industry in developing countries like India is often characterized with low productivity and poor quality. And since in last few decades there has been significant rise in customer awareness towards quality. Construction industry therefore understood the effectiveness of quality management systems and the importance of quality improvement and need of excellent performance. One such key innovation of Six Sigma involves absolute professional strategies of quality management functions for improving the process in construction. Six-sigma was firstly introduced by assembling industry in the 1980s and became popular as a process improvement method. Anything which does not meet the requirement is deemed to be called as 'Defect' in construction industry and here Six Sigma plays a pivotal role in meeting the quality requirements. This paper describes the implementation of Six Sigma strategies in Construction project to improve the quality of output of a process and customer satisfaction. The basic theory methodology of Six Sigma principles, DMAIC (Define, Measure, Analyze, Improve and Control) and tools were used in each stage. A case study of Row housing construction was selected to which Six Sigma principles are to be applied. Questionnaires survey was conducted from the Site Engineers, Contractors, Consultants and Project managers. Later, based on the findings will suggestions of proper training, management support and minor changes that are required in current work procedure which would help to improve the quality and ultimately enhancing the customer satisfaction which is of prime importance were given..

Keywords- Six-sigma, Performance improvement, Defect, DMAIC, DPMO.

I. INTRODUCTION

Inefficient or non-existent quality management processes results in significant expenditure of time, money and resources, also both human and material are wasted each year. In an attempt to improve their market competitiveness, some organizations are beginning to monitor the performance of construction processes. The purpose of this study is to explore the process of implementing six-sigma in construction industry using a qualitative case study methodology. Questionnaire survey of the construction firms was done collected through in depth interviews and analyzed. Later, based on the findings it was concluded that six Sigma implementation leads to higher level of customer focus. Six-sigma is a methodology having quantitative approach for improvement with the objective of constraining imperfections from any process, extraordinarily a numerical objective of 3.4 deformities for every million chances (DPMO). In order to familiarize both researchers and practitioners on how to implement Six Sigma method and its potential benefits, this paper describes various outcomes of Six Sigma process methodology applied for Row house construction. Outcome of six-sigma was the improved productivity of construction, reduced process variability, enhanced interaction between project teams and reduced project delays. The methodology it utilizes is a five stage improvement process: Define Measure, Analyze, Improve and Control (DMAIC). Six-sigma is more exceptional, centered and detail than some other quality improvement procedures.

1.1 Purpose and Objective of the Research –

1. To examine the six-sigma idea.
2. To check extent of knowledge prevailing among the construction professionals about the effective utilization of six-sigma.
3. Applying DMAIC system of six-sigma procedure on building construction work.
4. To enhance quality of an ongoing process of a construction project.
5. Compare six-sigma results of standard strategy for working and six-sigma philosophy.

1.2 Scope of the investigation –

There is a need in construction industry to have more case studies clearly presenting the application of six-sigma within each domain in a proposed framework. Appropriate definition of all critical items in any construction project, and commitment of all the people involved helps to lead the overall Six Sigma program successfully in construction industry. Practical works in future researches can evaluate this claim and add effective comments and recommendations on this essay.

II. RELATED WORK

1. Pande and Holpp (2002) carried out study on Six Sigma as (1) a factual proportion of the execution of a process or an item; (2) an objective that ranges close for execution improvement effectively; and (3) forming an organization to accomplish enduring business initiative and world-class performance.
2. Celep Oguz, John Hutchison and Seungheon Han carried out implementation of lean six sigma in concrete panel production (2002). This study aims to investigate how Six Sigma and Lean principles are implemented together on construction projects by considering a case study to measure the process capability index (Cp) also to measure the performance of Six Sigma efforts. The paper tries to support the claim with the help of a case study where Lean and Six Sigma are used simultaneously.
3. Dean T.Kashiwagi (2004) characterized the application of six-sigma by using data and statistical analysis to measure and improves the projects performance. Also to increases profit by eliminating defects.
4. Neha Bagdiya, Sneha Sawant (2013) adopted Six sigma to reduce defects and improve quality in RCC members. A case study in Pune was selected to find out the causes of construction defects. A checklist was prepared for case study in which defects in all the RCC members and the percentage defects were found out.
5. Deepanjali Patil, Pushpanjali Patil (2015) Used Six Sigma methodologies for Road construction work. DMAIC and DPMO methodology of Six Sigma was adopted in this study. Although Six Sigma is a relatively new quality initiative, the results of this case study show that it can be implemented and can minimize the defects.

2.1 SIX-SIGMA METHODOLOGY: DMAIC

Six-sigma uses its basic continuous improvement methodology known as DMAIC (define, measure, analyze, improve, control) aims to enhance the efficiency of the existing processes and increase customer satisfaction.

1. Define: In this step it is necessary to define customer requirements, as anything that do not meet those requirements is known as defect, so in this step determine key processes, key roles and team charter, also define project goals and scope, and estimate the risks and financial impact.

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

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

4. Improve: Identify alternative solutions and methods based on the knowledge derived from above analysis step. Also study and assess the potential solutions to distinguish the most successful improvement solution. Implement that successful method.

5. Control: Establish a control plan in order 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

2.2 DPMO

Six Sigma metrics does not take in account the complexity of the processes while measuring defects rate and the concept processes with few defects rates have higher sigma values (Pheng and Hui, 2004) after becoming an international quality measurement technique was started by Motorola.

Table-1: Basic sigma conversion table

Basic Sigma Conversion Table		
Yield=Percentage of items without defects	Defects per million opportunities (DPMO)	Sigma Level
30.9	690 000	1
69.2	380 000	2
93.3	66 800	3
99.4	6 210	4
99.98	320	5
99,9997	3.4	6

For instance; four sigma level mean that product satisfies requirements at 99, 4 % of the time and products numbers with defects are 6210 (Table-1). Six-sigma uses the statistical metrics and techniques to measure the processes performance and rate the defects in order to obtain high quality at 6-sigma level at the low price, and teaches involved team appropriate tools to analyze their performance and improve the way of business. 3.4 ppm was used as the target level of the Six Sigma principle by Motorola which signifies only 3.4 defects/million parts or operations. Six-sigma is a systematic strategy that leads the employees and processes to maintain and control the processes to achieve high performance.

III. CASE STUDY

A) Awareness of process improvement (Six-sigma) in market:

The purpose of checking awareness of Six-sigma in market is to know the need of process improvement methodology in the construction context. For this purpose some questions regarding their own concepts of quality, cost, productivity, efficiency, customer satisfaction, Six Sigma are asked to 40 people of construction field in market from Dhule and nearby zones (Maharashtra).And the overall views of are mentioned in the form of ratings in charts below;

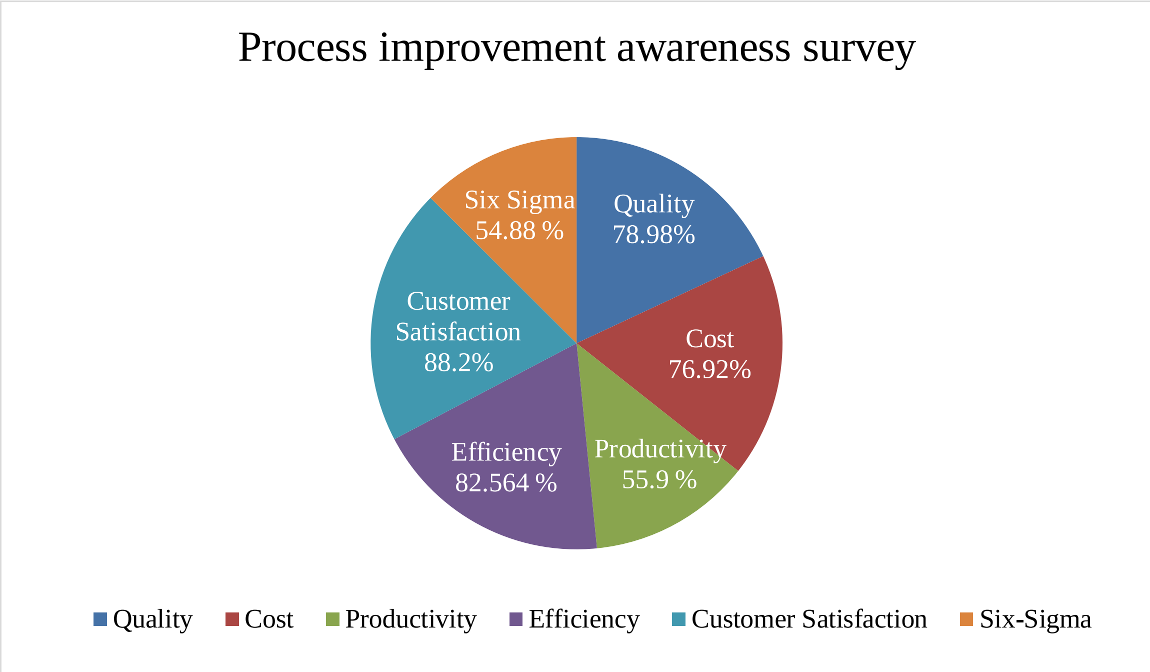

Fig.1: Market survey about need of process improvement

B) Applying six-sigma for internal finishing work of "Row house" construction:

A case of how Six Sigma might be applied for enhancing the quality of construction of "Row house" in Dhule city is presently portrayed. Residential building comprises of 4 row houses and all four row houses are nearly identical and were named as A1, A2 and B1, B2 and selected for study. The agenda is using process improvement techniques in construction industry is to produce something with equal or better quality with lower cost i.e. to improve the quality of internal finishes (such as plastering, painting, flooring ,painting and false ceiling) for row house construction. A checklist covering various points whose quality needs to be checked is prepared for internal finishing work. The factors that are checked for various internal finishing items as shown in table. The assessment is done for each internal finishing item, the one which affirms to specification above 80% is marked as **''1''** or else below 80% are it is marked as ''**0**'' and a "**--**" indicates that the item is non-applicable. The score is computed based on the number of ''**0''** over the total number of items assessed. The number of ''**0**'' leads to number of defects and the number of ''**1**'' total number of checks leads to opportunities, it is necessary to decrease the frequency of defects related to quality of construction as to wipe out poor execution of work and reduce mishaps. For this reason some of following factors that importantly needed to be checked are chosen.

i) Regular method of internal finishing work of "Residential building" construction: For Building A1.

Sr.No	ROOMS	LIVNG ROOM				KITCHEN				WC				BATH			
	Factors to be checked	WALL 1	WALL 2	WALL 3	WALL 4	WALL 1	WALL 2	WALL 3	WALL 4	WALL 1	WALL 2	WALL 3	WALL 4	WALL 1	WALL 2	WALL 3	WALL 4
1 Brickwork	Non uniform lap	1	0	1	1	0	0	1	1	0	1	1	1	1	0	1	1
2	Deviation from verticality or alignment	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	0
3	Spalling of brickwork	1	1	1	1	1	1	1	0	1	1	0	0	1	0	0	1
4	Unleveled brick courses	1	1	0	1	1	0	1	1	0	1	1	1	0	1	0	1
5	Uneven edges	1	0	1	1	1	1	1	0	1	1	0	0	1	0	1	1
6	Gaps in the mortar bed	0	1	1	0	1	1	1	0	0	1	0	1	1	0	0	1
7 Plastering	Cracks on plastered surface	1	0	0	1	1	0	1	1	1	0	1	1	1	0	0	1
8	Swelling of small patches on plastered surface	0	1	1	1	0	1	0	1	1	1	0	1	1	1	1	0
9 Flooring	Raised corners	1				1	--		1	1	1	0	1	1	0	1	0
10	Adhesion failures	1				0	--		1	0	1	0	1	0	1	1	1
11	Dirty joints if any	0				0	--		0	1	0	1	0	0	0	1	1
12	Hollow sounds	1				1	--		1	0	1	1	1	1	1	1	0
13 Painting	Uneven finish(brush marks)	1	1	1	0	1	0	1	1	0				1			
14	Flashing	1	0	0	1	1	1	0	0	1				1			
15	Fading	0	1	1	1	1	0	1	0	1				1			
16	Blooming	0	1	0	1	1	1	0	1	1				0			
17 False ceiling	Too many Joints	1				--				--				--			
18	Plug in gaps	1				--				--				--			
19	Finishing	0				--				--				--			
No. of Defects		16				18				18				19			
No. of Opportunities		55				56				52				52			
TOTAL NO. OF DEFECTS														71			
TOTAL NUMBER OF CHECKS/OPPORTUNITIES FOR DEFECTS														215			

Calculations for Sigma value:

The DPMO (defects per million opportunities) formula is used:

DPMO= (No. of defects) / (No. of opportunities*No. of units)*1,000,000

The DPMO relating to the internal finishes of building A1 unit recently completed by Contractor was then calculated based on the data collected and presented in Table 1

DPMO= (No. of ''X'' in the data collection sheet)/ (No. of opportunities of defects*No. of units) *1,000,000

DPMO= (71)/ (215*1)*1,000,000= 330233

Based on the sigma conversion table in Table-1, the equivalent sigma for 330233 DPMO was approximately **2.0 σ** and according to belt holders it was decided that **2.0 σ** was not acceptable where quality of internal finishes is concerned. So a decision was made to apply six-sigma on Building B1 which is identical to building A1 to improve the quality of work.

ii) Applying six sigma method on internal finishing work of "Residential building" construction: For Bldg B1.

Sr.No	ROOMS	LIVNG ROOM				KITCHEN				WC				BATH			
	Factors to be checked	WALL 1	WALL 2	WALL 3	WALL 4	WALL 1	WALL 2	WALL 3	WALL 4	WALL 1	WALL 2	WALL 3	WALL 4	WALL 1	WALL 2	WALL 3	WALL 4
1 Brickwork	Non uniform lap	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	Deviation from verticality or alignment	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
3	Spalling of brickwork	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	Unleveled brick courses	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	Uneven edges	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
6	Gaps in the mortar bed	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
7 Plastering	Cracks on plastered surface	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1
8	Swelling of small patches on plastered surface	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1
9 Flooring	Raised corners	1				1	--		1	1	1	1	1	1	1	1	1
10	Adhesion failures	1				1	--		1	1	1	0	1	1	1	1	0
11	Dirty joints if any	0				1	--		1	1	1	1	1	1	1	1	1
12	Hollow sounds	1				1	--		1	1	1	1	1	0	1	1	1
13 Painting	Uneven finish(brush marks)	1	1	1	1	0	1	1	1	1				1			
14	Flashing	0	1	1	1	1	1	1	0	1				1			
15	Fading	1	1	1	1	1	0	1	1	1				1			
16	Blooming	1	1	0	1	1	1	1	1	0				1			
17 False ceiling	Too many Joints	1				--				--				--			
18	Plug in gaps	1				--				--				--			
19	Finishing	1				--				--				--			
No. of Defects		05				05				03				04			
No. of Opportunities		55				56				52				52			
TOTAL NO. OF DEFECTS														17			
TOTAL NUMBER OF CHECKS/OPPORTUNITIES FOR DEFECTS														215			

Calculations for Sigma value:
The DPMO (defects per million opportunities) formula is used:
DPMO= (No. of defects) / (No. of opportunities * No. of units) * 1,000,000

DPMO= (No. of ''X'' in the data collection sheet)/ (No. of opportunities of defects*No. of units) *1,000,000
DPMO= (17) / (215*1)*1,000,000=79070
Based on the sigma conversion table in Table 1, the equivalent sigma for 79070 DPMO was approximately **3.0 σ**

Remark: By comparing both the above processes we get the increase of **1.0** σ in building B1 by application of DMAIC technique of six-sigma methodology.

IV. CONCLUSION

1. From market and literature survey it is concluded that there is a desperate need of execution of work with quality in the construction context and it can be done by process improvement.
2. By considering standard strategy for working for improving the quality of internal finishes by minimizing defects with DMAIC method of six-sigma by comparing two processes, we got the increase in sigma value of **1.0 σ.**
3. Though six-sigma is new concept in building construction work, it is seen that by using operational principles it can be implemented to any kind of construction work.

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