International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 03, March-2019

APPLICATION OF SIX-SIGMA TOOL AT BRIDGE SITE

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Abstract— Six sigma has been successfully implemented in many manufacture and business sectors for quality and production improvement but it is new to construction sector and this philosophy is to reduce the defects in the construction. In order to improve the productivity of construction projects and achieve reliable workflow, it is necessary to quantify the eventual goals for the target process assessment_ This study explores whether Six-Sigma principles that were originally and widely applied to the manufacturing industry can be applied to the construction industry or not. The Six-Sigma takes attention to the quality that customers are concerned with and also contribute to achieve efficiency and reduce costs. As the infrastructure is very vast topic to study, so the study will be carry out on the bridge construction. Here an attempt has been made that the theories regarding the Six-Sigma tool are practically implemented in the construction industry. Here, this tool is applied at the bridge construction site. In this research work, the number of defects at the site were found out using the checklist and interviews to get the current Sigma level that came to be 2.81 and it was later improved by using the DMAIC methodology of Six-Sigma. After finding the current Sigma value, recommendations were given along with the repair measures.

Keywords— Six Sigma , Quality Control , Construction Industry , DMAIC

INTRODUCTION

Six Sigma is a highly disciplined process which helps to focus on developing and delivering near-perfect products and services which is required in today's world. Six Sigma strategies seek to improve the quality of the output of a process by identifying and removing the causes of defects and minimizing variability in manufacturing, construction and business processes. The diagram of conceptual six-sigma quality control is shown in Figure 1 which is below. If normal value for a process is located at the midpoint between upper and lower limit, each one is 6σ away from the normal value. In short, the range of no defect is ±6σ from the normal.

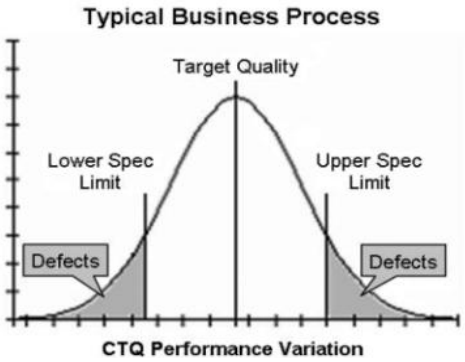

Fig. 1: The concept of six-sigma

The purpose of this study is to analyze Six Sigma within construction context in the infrastructure and evaluate its features through the literature and improve the quality.

I. LITERATURE REVIEW

According to S. Sriram , A. Revathi, the implementation of Six Sigma concepts in Construction project to meet the quality standards and customer satisfaction. The basic theory of Six Sigma, Six Sigma principles, DMAIC methodology and tools used in each stage of DMAIC methodology has been discussed in this paper. A case study was conducted during a residential building to which Six Sigma principles were applied for internal finishing work (tiling work). DMAIC methodology has been applied to the existing process to enhance the quality by analyzing the defects, their percentage of occurrence, the doable causes and effect of defects and recommendations to overcome them.
Sarathkumar K and Loganathan R aimed on developing a project questionnaire model based on the theory of Six-Sigma. They tried to improve the painting work, tile work and brick work of a building by using DMAIC methodology.

Kuo-Liang Lee and Yang Su showed that a 1-cm spacing between the board and the main structure effectively reduced cracks. After applying this innovative finding and following the control plans, the customer dissatisfaction of case company decreased from 87% to 11%, accordingly.

Megan Florent Tchidi , Zhen He & Yan Bo Li explores practical solutions for construction process and quality improvement by using prefabricated composite structure (PCS) based on Six Sigma method. The D-M-A-I-C method of Six Sigma has been applied to conduct the analysis of the construction process, to get the essential factors to improve and thus to achieve higher customer satisfaction. It improves the construction process, quality resistance to various performances and proposes the most effective mix proportion. Based on measurement and construction process analysis from Six Sigma black belt consultant, construction managers, Engineers, clients, architects, the model helps to search out and eliminate critical defects and failure before they occur in the process.

Frank T. Anbari and Young Hoon Kwak provides a brief overview of the Six-Sigma management method and its use in project management. They have presented the methodologies used in managing Six-Sigma projects for both-process improvement and new development projects. They have discussed the challenges and obstacles in the application of the Six-Sigma method. They have also identified the success factors for Six-Sigma. According to their findings, the main factors influencing the success of Six-Sigma projects include management commitment, organizational involvement, project governance, project selection, planning, implementation methodology, project management and control, cultural change and continuous training.

Low Sui Pheng and Mok Sze Hui carried out the case study at the Housing and Development Board (HDB), Singapore. Six-Sigma was applied to improve the quality of internal finishes where improvement measures taken by Contractor A helped to raise the Sigma from 2.66σ to 3.95σ.

Seung Heon Han, Ho Dong Ryu, Myung Jin Chae, Han Him Kim, Do Yon Kim, Sun Hee Kim explored the feasible solutions for the construction performance improvement by use of the Six-Sigma principle. They carried out a case study of the standard unit activity groups. In-depth comparative analysis was done on the present way of the performance improvement and the advantages of the Six-Sigma principle over the traditional techniques were identified and noted. It was then concluded that the Six-Sigma method had brought more benefits in generating the optimized solution sets from initial performance indices as the target processes became complicated and extended during the time frame. The authors suggested that an advanced methodology should be developed for the financial feasibility analysis to achieve the aforementioned objectives, before implementing Six-Sigma principle to a real project.`

II. CONCEPT OF SIX-SIGMA

Six-Sigma is a quality management philosophy that aims at process improvement by applying statistical process control to reduce variations in the product which help to minimize the defects. The word *Sigma* which has come from statistical term that measures how far a given process deviates from perfection. At early 1980s, the first initiator of the Six Sigma concept was led by the Motorola Corp that lead the organization successfully through the implementation of the Six Sigma principles. Most people consider that Six Sigma is a purely statistical methodology but in practice, the term Six Sigma level means 3.4 defects per million opportunities or success rate of 99.999660 percentages. Six Sigma's purpose is to reduce the variance and variability in the processes, so to provide clients-consumers of the organization, products or services which are more reliable and with fewer errors and defects. Six-Sigma is basically statistics based methodology and relies on the scientific method to make significant reductions in customer defined defect rates in an effort to eliminate that defects from every product, process and transaction. The principle of Six-Sigma can be studied with the help of normally distributed product quality distribution curve where the mean is located at the center of the normal distribution curve, the lower and upper limits which are six times the standard deviation (sigma) from the center line of the curve. In other words the range of lower and upper limit defect is +/- 6 sigma from the mean of the curve. Six Sigma can be applied in two ways viz. D-M-A-I-C which are Define, Measure, Analyse, Improve and Control and the other is D-M-A-D-V which are Define, Measure, Analyse, Design and Verify. It should be noted that DMAIC is used for projects aimed at improving an existing business process whereas DMADV is used for projects aimed at creating new product or process designs.

Table-1 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. METHODOLOGY

The main purpose of this study is to present the advantages and to find the various trends of Six-Sigma. The research strategy was made by selecting the research papers in which successful implementation of Six-Sigma in Construction Industry was presented and documented. Research papers from various international journals were

studied. It involved searches from the well-known research databases like Google scholar, ASCE Journals, Inderscience and Science direct. The search was carried out in the journals of these websites with key word as "Six-Sigma in Construction Industry".

Here the DMAIC method of Six-Sigma is implemented :-

DEFINE - In this step, customer requirements are defined here and any things that do not meet those requirements are termed as defects. Here, the project scope, goals along with the identification of CTQ (Critical To Quality) characteristics of the process.

MEASURE - Identifying and collecting the appropriate data which are relevant to the defects and the process that needs improvement. This step measure the performance of the existing process and its deviation from the actual requirements. The objective of this measurement is to get enough data and information from the process under development. Identifying the performance requirements of the process with compare to its CTQ (Critical To Quality) characteristics along with finding the existing sigma level.

ANALYZE - To study and analyze the collected data in the previous step and to find out the root causes of the defects and unsatisfactory performance which are leading in it. This stage involves comparison between the current performances with the existing performance. Once the deviation is measured the problem causing the deviation are identified.

IMPROVE - Improving the process by eliminating the defects which are identified. To eradicate the existing problem and thus verify the inputs which are creating the problem and causing the variation. To control the outputs of the process by developing potential solution of the problems. To give out preventives measures and solutions along with the recommendation.

CONTROL - It helps to ensure the problems that are creating variations in the desired outputs are rectified. The new process is implemented under a well defined control plan to achieve the targeted results. To take the validations of the authority and measuring the new sigma level along with monitoring the results. Continuously monitoring the process to control the quality level of the process.

IV. DATA COLLECTION

A case study was conducted on a bridge site in which six sigma principles were applied to the structural members of the bridge to enhance the quality of the existing process. A defect assessment sheet was prepared in which the possible defects that might occur in members was listed. . The assessment was done for each member, the one which met the standard requirement is marked as '□□□' else it is marked as 'X'. 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 = No. of 'X' in data assessment sheet x 1000000
No. of opportunities of defects x No. of units

Based on the value of DPMO and using the sigma conversion table (table 1), the sigma level is calculated. The summary of data for the each structural members are shown below:-

Sr.No	Member	Defects	Opportunities
1	Pile-cap	27	186
2	Pier	43	186
3	Pier-cap	25	186
4	Girder	74	744
5	Deck slab	18	186
6	Seismic arrester	64	366
	Total	**251**	**1854**

Therefore , DPMO = 251/(618*3) X 1,000,000

DPMO = 135383

Based on Sigma conversion table,

$\sigma = 2.81$

Yield = 86.46 %

Thus , the current Sigma level of the bridge is 2.81 which is not acceptable.

V. RECOMMENDATIONS

As the sigma level is less than 3 so work is to be done on it. so the recommendations for the defects are listed below which can be applied to get the improved six sigma level.

1. Cracks should be filled up with the sealant.
2. Use proper tools and equipments.
3. Joints should be properly filled.
4. Adequate supervision.
5. Excess oil should be avoided.
6. Concrete grout paste should be prepared and applied in the affected area to fill it completely.

VI. CONCLUSION

This work recognizes that vast literature was obtained on six sigma philosophy, which gives a wide idea of present practices and researches carried in this field. Six sigma philosophies which are widely accepted by manufacturing/production industries and it is also possible to implement this in the construction industry with required modification. One of the major challenges which are faced by the construction firms or the organization is to deliver the product within the given time frame without compromising in the quality of the product. Execution of works with the standard quality requirements reduces rework and hence reduce the cost for it. There are various factors which have high impact on the construction quality of the bridge. These factors must be identified as early as possible so that quality can be improved. DMAIC method of six sigma is applied here. Now, here the current sigma level of the bridge was find out with the help of the checklist and it was 2.81 which is not acceptable. The root causes for the defects in the bridge were identified. For this defects, recommendations were be given. DMAIC will be helpful to increase quality and quantity at the same time and it will affect technical and financial success of project significantly. After the recommendation which are suggested here the sigma level is targeted between 3 to 3.5 which can be achieved within the scope of application.

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