

Implementation of Six Sigma Methodology in Construction Industry For Quality Process Improvement

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Abstract - Although Six Sigma has been implemented in the manufacturing and other services industries. This study described the Six Sigma concept as a quality initiative that may be applied in the building industry. The principles, methodology, and metrics of Six Sigma are first discussed. The application of Six Sigma for improving the quality of internal finishes during construction is also explained. For that a case of residential complex consisting of 100 flats is done to find out the defects in plastering. These defects are then evaluated by applying DMAIC methodology of six sigma. Before applying DMAIC, the sigma level is calculated by defects per million opportunities (DPMO). In case study it is found that the defects observed in finishing work (plastering) of residential complex are cracks on plastered surface, improper vertical edges of column, window and door, horizontal edges of column, window and door, air gap in plastered surface, uneven plastered surface, and plastered surface damaged during carrying out other activities. Further these defects are evaluated using DMAIC methodology.

Key Words: Construction Industry, Six Sigma, Quality Improvement, Customer Satisfaction.

1. INTRODUCTION

Construction industry plays a major role in economic growth of any nation. Construction industry is the most booming industry in the whole world. Construction sector is viewed as a service industry which generates substantial employment and provide growth impetus to other manufacturing sectors. Also, construction management and technology are the two key factors influencing the development of the construction sector. Now a days the critical objective of construction industry is to complete the project in time and within the scheduled costs and budget. Along with this need for improving quality and customer satisfaction has received considerable attention in recent years, so the one approach which can fulfil all the requirements of construction industry is using six sigma concepts in construction industry. The six sigma is a quality improvement technique of products in order to ensure customer satisfaction. The result of six sigma will be an increased efficiency, improvement in performance and the control of performance problems thus minimizing defects, risks and deviation.

Six sigma is a quality improvement technique based on statistics was firstly used by Motorola in 1980s by Bill Smith of Motorola to decrease cost, increase quality by improving process and reduce production time. It received little publicity until late 1990s. Six Sigma results the application of a new form of management technique to construction. Essential features of Six Sigma include a clear set of objectives for the delivery process, aimed at maximizing performance for the customer at the project level, concurrent design, construction and the application of project control throughout the life cycle of the project from design to delivery. Six sigma is a quantitative approach for improvement with the goal of limiting defects from any process, specially 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. DMAIC is a data driven technique of six sigma used to improve processes. It brings structure to the improvement process and help teams explore potential solutions, decides a course of action and implement process control. DMAIC is an acronym for Define, Measure, Analyze, Improve and Control. In brief, these 5 steps are as follows.

- **Define (D):** Identify the problem and issues causing decreased customer satisfaction.
- **Measure (M):** Collect data from the process
- **Analyze (A):** Evaluate the current process identify the root causes of the problem
- **Improve (I):** Act on the data to change the process for improvement.
- **Control (C):** Monitor the process to sustain the gain.

1.1 Aim of Study

To study the implementation of six sigma methodology as a quality process improvement in finishing work (plastering work) of residential buildings for better customer satisfaction.

1.2 Objectives

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

1.2 Scope & Limitations

In this study six sigma principles will be applied for internal finishing work (Plastering) of residential project (100-120 Flats) and the sigma level for the same will be calculated from the obtained data. The DMAIC methodology will be adopted to improve the quality of the existing process.

2. LITERATURE REVIEW

A research paper by Thomas Rydzek – The Six Sigma Revolution [1] this research paper explains the basic concept of six sigma and DMAIC methodology. It also explains about the six sigma change agents which are leadership, champions and sponsors, master black belt, black belt, green belt. The author concludes that although the approach is simple, it is by no means easy. But the results justify the efforts expended. It also explains the firms that successfully implement six sigma perform better in virtually every business category, including return to sales, return on investment, employment growth & share price increase.

A research paper by Low Sui Pheng & Mok Sze Hui – Implementing & applying six sigma in construction [2] describes the six-sigma concept as a quality initiative that may be applied in the building industry. The principles, methodology, and metrics of Six Sigma are first discussed. The implementation phases as well as the training programs required are explained. A case study of how six sigma was pioneered in an organization in the building industry is presented in this research paper. The finding suggests that management initiatives and support, relevant training, appropriate selection of pilot projects, and commitment by team members are crucial for the successful implementation of six sigma in the organization. The application of six sigma for improving the quality of internal finishes during construction is also explained.

A research paper by Sandeep Bodke, Snehal Nikam, Yogita Phad, Sayali katkade, Kiran Kangane - Quality Improvement in Building Construction Using Six Sigma [3] describes the study on six sigma and quality improvement in building construction using six sigma principles. Quality is improved by using DMAIC methodology of six sigma which help to identify the quality of existing structure by analyzing the

defects that will suggest DFSS for changes that required in current work. In this research paper for applying six sigma in building construction a checklist is prepared for various components. A checklist was prepared for plastering work which covered various points whose quality was checked. In this study the author studied the various factors which affects the quality of construction.

A research paper by Sneha P. Sawant, Smita V. Pataskar - Applying Six Sigma Principles in Construction Industry for Quality Improvements [4] 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's DMAIC concept 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. Various tools are present at each step of DMAIC procedure depending upon the difficulty level.

A research paper by S. Sriram, A. Revathi. - Implementation of six sigma concepts in construction project for ensuring quality improvement [5] paper describes 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 (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). The findings suggest that 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.

3. METHODOLOGY

In study the data is collected from secondary sources such as research paper and internet to study the Six sigma principles, basic concepts of DMAIC methodology and various tools used in DMAIC. A case study of residential complex consisting of 100 flats is done to find out the defects in plastering. For that a checklist is prepared and the defect assessment sheet is prepared in which the possible defects that might occur in plastering work was listed. After collecting primary data from the case study, the sigma level is calculated by using DPMO and then found out defects are mitigated by applying DMAIC concept of six sigma methodology for increasing sigma level and minimizing the defects. After implementing DMAIC and finding out the root causes of plastering defects, remedies are suggested for their control and improvement of plastering process.

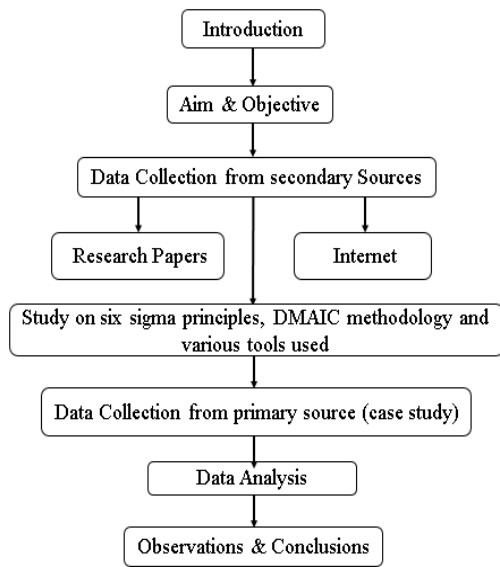


Chart -1: Methodology Flow Chart

3. CASE STUDY

The residential complex has 5 towers of 5 floors, each floor has 4 flats (2bhk). The area of each flat is 556.6 sq. Ft. this residential complex is under construction and the finishing work (plastering) is going on. As the site is currently under construction, so to find out the defects of plastering a checklist was prepared. Once the checklist for defects was prepared the plastering of 80 flats out of 100 were randomly checked. In that 16 flats had plastering defects. following table shows no of defects observed in 16 flats.

Table -1: No. of Defects Observed

No of Defects Observed					
Sr. No	Defects observed	L.R.	Kitchen	B.R-1	B.R-2
1.	Cracks on wall.	4	1	2	3
2.	Uneven Surface of plaster.	1	3	1	-
3.	Vertical Edges of Window, Door & Column.	3	4	6	6
4.	Horizontal Edges of Window, Door & Column.	4	7	4	7
5.	Air Gap between wall and ceiling.	1	2	-	-

6.	Damaged Surface	Plaster	4	2	2	1
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Total no of defects observed – 68.

So, Sigma level is calculated using DPMO, the formula of DPMO is as follows:

DPMO = No. of defects x 1million / no. of units X no. of opportunities per unit.

So as per the case study findings,

- No. of defects = 68 observed
- No. of units = 10,567 checked
- No. of opportunities per unit = 6

$$DPMO = 68 \times 1 \text{ million} / 10,567 \times 6 = 1,072.521.$$

So, based on sigma level table

Sigma level = 3.27.

To increase sigma level, DMAIC of six sigma methodology for eliminating defects is applied.

4. RESULT & TABLE

After calculating the sigma level, the DMAIC methodology was applied to improve the quality of plastering work for improvement of quality process for better customer satisfaction. The DMAIC applied as follows:

Define- Define is the stage where problem is identified & issues causing decreased customer satisfaction. Plastering is the most important part of the finishing job in a building project. But the defects in plastering can spoil all the creativity of building. These defects in plastering need to be repaired as soon as they are observed. In this study a checklist is prepared to find out the defects of plaster in the selected case study of under construction case study of residential building of 100 flats. The defects observed in plastering are cracks on wall, uneven surface of plaster, vertical edges of window, door & column, horizontal edges of window, door & column, air gap between wall & ceiling, damaged plaster surface. The **vertical & horizontal edges of beam, column, window & door** and the **uneven surface of plaster** and **air gap** are caused purely due to **poor workmanship**. The **cracks on plastered surface** are cause due to **poor construction practices - improper preparation of background surface**, damage surface of plaster during working on site - **Lack of supervision, Improper mix of materials, due to rapid drying, Damages to finished plaster surface** during other activities is caused because of **bad supervision from contractor**.

Measure - Measure is the stage where data is collected from process. Measure also helps to identify the most significant factors, shows where to focus efforts and better use of

limited resources to overcome the observed defects. As per the case study findings **70%** of plastering defects are caused because of **poor workmanship**. **15 %** defects caused because of **poor construction practices** - improper mix of material, improper preparation of background surface, rapid drying due to moisture loss. **15%** defects caused because of **bad supervision**.

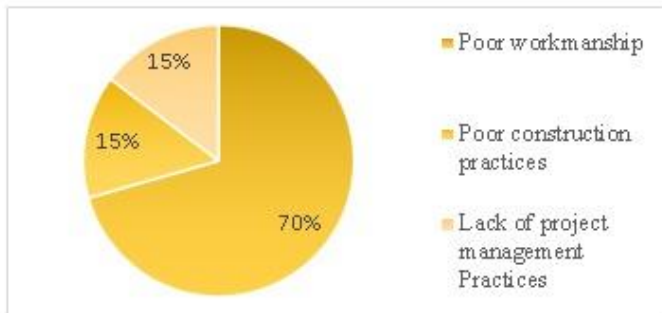


Fig- 1: Causes of defects in Plastering.

Analyze - Analyze is stage where the root causes of the problems or defects are evaluated. For analysing the cause and effect diagram is used. The cause and effect diagram examine why something happened or might happen by organizing potential causes into smaller categories.

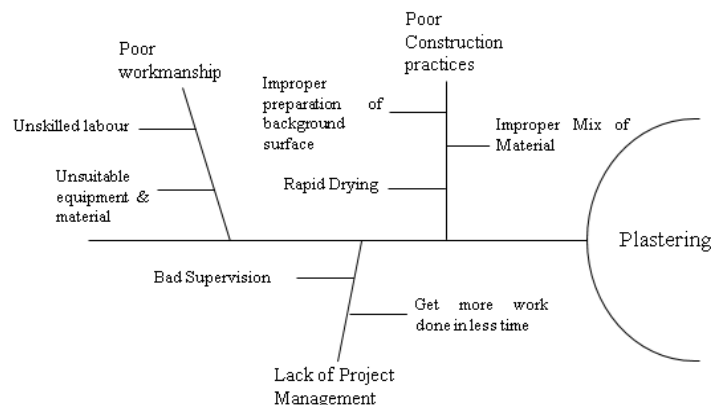


Fig- 2: Cause and Effect Diagram.

One of the significant reason of poor workmanship is Unskilled workman. The Factors which are responsible for skilled labour shortage in construction industry now a days is because of lack of vocational training & education, lack of motivation & incentives, skilled labour migrate overseas, change in skill requirement, poor working environment. Another reason for poor workmanship is use of unsuitable tools & equipment's. one of the reason for damaged equipment & tools is the improper handling of them. The reasons of poor construction practices are improper mix of material, improper preparation of background & rapid drying. Another reasons for defects are bad supervision and getting more work done in less time.

Improve – Improve is the step where the ways are identified to eliminate the defect by developing the solution for defects. The problem of unskilled labour or lack of skilled labour is there because lack of education and vocational training, lack of motivation and incentive, change in skill requirements or new technology, because of unfair wages the workmen are migrating overseas. As most of workers are seasonal, migrants' workers from poor agricultural states, so they don't have the proper knowledge about the activity of construction. So, it is necessary to provide the workman with proper training of construction activities before starting that activity. Also, some vocational training programs should be arranged for them to get more knowledge about construction activities. The vocational education and training system have crucial role in supporting with the matching of the skills needed by industry with the skills offered by the labour. As per on survey the 10 % of skilled workman migrate overseas to gulf countries in most cases for getting higher wages. Also because of delay in payment by contractor, the workman feels unsatisfied and migrate to another site. So, by giving them payments on time we can stop them by migrating. Also appreciating them by giving incentives and by providing them proper site safety & environment we can stop their migration.

Another problem of poor workmanship of use of unsuitable tools and material can be improved by properly using and keeping them in proper place so that they will not get damaged. The tool needs to be cleaned after use of them. So, for supervising these activities we can appoint a supervisor apart from contractor will check those things. The problem of poor construction practices such as improper mix of materials, improper preparation of background surface and rapid drying can be improved by following the proper producer of plastering specified by Indian standard codes. By using the mix of 1:4 or 1:6 we can prevent defects.

Proper preparation of background surface is necessary for the adhesion of bond between background and the plaster, so needs to be cleaned properly, should have required roughness. If the surface is smooth, then it should made rough by wire brushing. Also, to obtained rough surface, a mortar 1 cement: 1 to 3 coarse sand by volume prepared to a wet consistency may be forcibly dashed or to the surface (spatter dash treatment) by suitable means on to a hard surface like concrete. Rapid Drying can be prevented by, watering the base coat at least one day before plastering, by keeping the fresh surface wet & cool for at least 15 days, the surface should be kept semi wet as per the exact requirement. Also, by implementing proper project management practices and keeping track of activities time to time we can mitigate the defects of plastering.

Control - Control is the step where we prepare a control plan. Control plan will help us to check on the various preventive measures which will help us to achieve the desired result. Control plan is a description of the

procedures, checks or assigned activities with respect to specifications, marking and performance. To control all the activities, it is necessary to provide the proper checklist to follow the procedure and the contractor and supervisor should supervise their work properly. Also, by following the proper project management rules we can control the delays of project completion.

Also, by providing following measures as quality control plan, we can reduce and control the defects.

Table -1: Quality Control Plan

Quality Control Plan	
1. By Issuing a written, site specific quality control document.	We can share this with everyone involved in the project – from architect to suppliers, to set expectations, outline responsibilities and align goals right from the start.
2. By forming a quality control committee.	This will include key members of our site staff and subcontractors to give everyone a sense of ownership and to make sure that team is covering all aspects of our work.
3. By holding pre activity meetings.	As professionals lose almost two full working days each week solving avoidable issues and searching for related information. Holding meeting only allows everyone to review specs together but they also are a great forum for clarifying issues and preventing misunderstanding.
4. By conducting constructability reviews.	Led by the designer and contractor, these reviews will help anticipate and alleviate field problems.
5. By performing regular inspections.	According to some estimate, construction rework can account for between 2% and 20% of a typical projects contract amount. We can avoid that costly outcome by assessing the quality of the workmanship and identifying errors before they lead to major problems and rework.

6. By checking the quality of material while accepting.	When receiving materials, we can complete a quality control inspection to ensure only approved products are accepted and items have not been damaged while
7. By keeping records of approvals and verifications	Project managers should get formal owner verifications and secure approvals of workmanship. This can be done by either by hiring third party inspectors.

4. CONCLUSION

In this the study, it is seen how various factors have high impact on the quality of the construction. These factors must be identified as early as possible so that 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. 7% uneven surface, 27 % improper vertical edges of column, window and door, 32% improper horizontal edges of window, door, 4% air gap in plastered surface, and 15 % damage plastered surface during carrying out other activities are observed. Further the sigma level is calculated using DPMO, the calculated sigma level was 3.27. After applying DMAIC it is observed that these 70% defects are caused because of poor workmanship, 15 % because of poor construction practices and 15 % because of lack of project management practices. So, these issue which are leading to plastering defects are tried to minimize by applying DMAIC which will directly increase the sigma level of quality. After evaluating the defects by applying DMAIC is observed that the lack of skilled labour or unskilled labour, use of unsuitable equipment's and tools is leading to the poor workmanship, improper preparation of background surface, improper mix of material and rapid drying these issues are leading to poor construction practices and also other issues such as lack of supervision by contractor and lack of project management practices leading to the defects which are deteriorating the quality of finishing work (plastering) of residential project. Deteriorating of quality of finishing work will lead to poor customer satisfaction. But by using six sigma methodology which is the set of management technique and tool for better improvement of quality process can help in identifying and minimizing defects earlier which will improve the customer satisfaction which will also improve the productivity of construction industry.

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REFERENCES

1. Frank T. Anbari, "Success factors in Managing six sigma Projects", Research Gate, January 2004.
2. General specifications for plastering & painting manual.
3. IS 1661:1972, Indian Standard, "Code of Practice for Application of Cement & Cement Lime Plaster Finishes".
4. Low Sui Pheng, Mok Sze Hui, "Implementing & Applying Six Sigma in Construction", Journal of Construction Engineering & Management, Issue – July/ August – 2004.
5. "Quality Assurance for Cement Plastering", CAMTECH/C/2006/ Plastering/ 1.0, Issue November – 2006. Thomas Pyzdek, "The Six Sigma Revolution", [http:// www.pyzdek.com/ six sigma revolution.htm](http://www.pyzdek.com/six-sigma-revolution.htm), Issue – 12/21/ 2000.
6. S. Sriram, A. Revathi, "Implementation of Six Sigma Concepts in Construction Project for Ensuring Quality Improvements", International Journal of Innovative Research in Science, Engineering & Technology, vol-5, Issue – 4th April 2016.
7. Sandeep Bodke, Snehal Nikam, Yogita Phad, Sayali Kathade, Kiran Kangane, "Quality Improvement in Building Construction Using Six Sigma", ISOR – JMCE, PP 01-05.
8. Shantanu Sathe, Dr. Satish B. Allampallewar, "Application of Six Sigma in construction", ijirset, vol.6, Issue – 11, Nov 2017.
9. Sneha P. Sawant, Smita V. Patasakar, "Applying Six Sigma Principles in Construction Industry for Quality Improvement", ICAET -2014.
10. Thomas Pyzdek, "The Six Sigma Revolution", [http:// www.pyzdek.com/ six sigma revolution.htm](http://www.pyzdek.com/six-sigma-revolution.htm), Issue – 12/21/ 2000.
11. Young Hoon Kwak, Frank T. Anbari, "Benefits, Obstacles, and Future of Six Sigma Approach, Technovation 26 (2006).