International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 12 | Dec 2019 www.irjet.net p-ISSN: 2395-0072

Quality Audit of Public Building Project by using Six Sigma Techniques

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Abstract - *Six Sigma is a quality program that, when all is said and done, improves your customer's experience, lowers your costs, and builds better leaders-Jack Welch, expert in Six Sigma program. Six Sigma is a disciplined, data-driven approach and methodology for eliminating defects (driving toward six standard deviations between the mean and the nearest specification limit) in any process from manufacturing to transactional and from product to service. This Project describes the completion of Six Sigma concepts in public sector 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 line of attack in building 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 have been going to discus in this Dissertation. We are going to conduct case study in a public sector to which Six Sigma principles are applied from start to finishing work. We will prepare a defect assessment and will find the existing sigma level of the process with corresponding yield. DMAIC methodology will be 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.*

Key Words*: *Six Sigma, DMAIC methodology

1. INTRODUCTION

The Greek alphabet Sigma has become the statistical symbol and metric of process variation. The sigma scale of measurement is perfectly correlated to such characteristics as defects-per-unit, parts-per-million defectives, and the probability of a failure. Six is the number of sigma measured in a process, which has a target variation of only 3.4 per million as defects under the assumption that the process average could diverge more than the long term by as much as 1.5 standard deviations. Six Sigma can be defined in more than a small number of ways. Six Sigma to be "a program intended at the near-elimination of defect from every item for consumption, development and deal" Six Sigma to be "a strategic initiative to boost profitability, increase market share and improve customer satisfaction through statistical tools that can lead to breakthrough quantum gains in quality." Six Sigma was launched by Motorola in 1987. As a result of a series of changes in the quality area starting in the late 1970s, with strong-minded ten-fold improvement drives. After some internal pilot implementations, Galvin, in 1987, formulated the goal of "achieving Six-Sigma capability by 1992" in a memo to all Motorola employees.

Six Sigma is a system which primarily can improve the quality and consequently the time management of projects. The Six Sigma system has already been implementing in different manufacturing sectors, and providentially it has brought about benefits. It has improved the time, quality and cost running in the projects, according to the Six Sigma Body of Knowledge1, which consists in the process called DMAIC (Define, Measure, Analyse, Improve and Control). However, Six Sigma focuses resting on detecting the errors in the projects, with which it then can create a database to improve the process of the projects.

2. NEED OF STUDY

The execution of six sigma is very less in the construction industry comparing to other industries due to lack of knowledge. The track record of the construction industry is very poor in terms of coping six sigma implementation, resulting in the affection of project objectives like time, cost, quality, & scope.

3. LITERATURE REVIEW

3.1 Applying Six Sigma Principles in Construction Industry for Quality Improvement

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 has been adopted to improve the quality and is checked against the sigma level. The answer suggest that proper training and management support and minor changes inside current work procedure can help improve the quality and ultimately customer satisfaction which is of prime importance.

3.2 Analyze the current lean construction practices

The purpose of this paper is to analyze the current lean construction practices amongst Abu Dhabi construction companies and to develop a practical framework for adopting lean construction techniques and measuring lean performance. An industry survey is used to collect information and data from construction companies in Abu Dhabi area. Collected data and information are organized, analyzed, and used to answer research questions. This study identified and categorized 27 construction wastes in AD construction industry, specified 18 key causes of these wastes, and estimated their extent and impact on project cost, quality, and speed. The study also analyzed the extent and impacts of 23 lean techniques in AD construction industry. The study found that only 32% of surveyed company are currently familiar with and/or already using lean construction techniques and concluded that the industry is in high need for a practical framework, such as the LPDS (bend over Project Delivery System) of LCI (Lean Construction Institute) for adopting lean techniques.

3.3 Implementing and Applying Six Sigma in Construction

This paper states that Six Sigma is a statistical measure used to measure the performance of processes or products against customer requirements. This paper described the Six Sigma concept as a quality initiative that may be applied in the construction 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. The findings suggest that management initiative in addition to 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. Improvement measures taken by a contractor helped to raise the sigma from 2.66s to 3.95s for quality of internal finishes.

4. NEEDS OF SIX SIGMA IN CONSTRUCTION INDUSTRY

Six-Sigma can improve processes by eliminating all types of root causes through a variety of tools. Six-Sigma is a comprehensive method used to help businesses achieve and sustain a healthy level of success. The Six-Sigma system focuses on customer needs, statistical analyses, continuous improvement, and business reinvention. Sigma refers to the amount of inconstancy or variance occurring in a process, and Six-Sigma equates to 3.4 Defects Per Million Opportunities (DPMO). Most defect opportunity measures are translated into the DPMO format, which indicates how many defects, would arise if there were one million opportunities.

DPMO = (No. Of X (Defects) in the data collection sheet / No. Of opportunities of defects ×m No. Of Units) × 1,000,000

Specifically, it 1) helps to identify and eliminate sources of variation in the process, 2) sustains success, 3) sets performance goals for all involved parties, 4) enhances value to customers, and 5) allows businesses to execute strategic change. Define, Measure, Analyze, Improve, Control (DMAIC) is a five-step Six-Sigma improvement model. DMAIC is commonly used by Six-Sigma firms to improve the current capabilities of an existing process. A number of tools and methods can be used in each step of the DMAIC model. The DMAIC's five phases along with examples of the tools applied in each phase are presented in Table.1.

Table.1: Example of tools and methods used in Define, Measure, Analyze, Improve and Control

DMAIC Steps	Examples of tools or methods
Define: Identify the problem and the issues causing decreased customer satisfaction.	Five whys and how System thinking Flowchart
Measure: Collect data from the process	Measurement system analysis (MSA) Benchmark
Analyze: Evaluate the current process, identify the root causes of the problem.	Causes & Effect Diagram Continual improvement Experiment
Improve: Act on the data to change the process for improvement	Pareto Chart, Design of Experiments(DOE) Failure Mode and Effects Analysis(FMEA) Process improvement Variation reduction
Control: Monitor the process to sustain the gains	Management Commitment Control Plan Process behavior chart.

4.1Definitions of Six Sigma

Six Sigma which started by Motorola, had received huge interest by professionals after General Electric and Allied Signal has achieved cultural challenges within their organizations. After these achievement, many books and papers have been published. Some of these studies defined Six Sigma regarding their own perspectives:

- "A disciplined method of using extremely rigorous data gathering and statistical analysis to pinpoint sources of errors and ways of eliminating them"
- "A strategic approach that works across all processes, products, company functions and industries"
- "A business strategy and a systematic methodology, use of which leads to breakthrough quantum gains in product/service quality, customer satisfaction and productivity"

4.2 Six Sigma Methodologies

Six Sigma has two key methods

- DMAIC process (Define, measure, analyze, improve, control).
- DFSS methodology (Design for Six Sigma)

DMAIC is for existing processes which requires significant improvement due to falling below expected quality specification. DFSS as a systematic methodology is for designing new products and/or process at Six Sigma quality levels.

DMAIC methodology and its main steps are explained by and these steps are summarized below.

1. **Stage 1 -** Define, first stages of DMAIC is for team forming, determining the responsibilities of team members, establishing team goals and review the process steps, basic steps are

i. **Define the problem:** Problem should be based on measurable data and specific

ii. **Identify the customer:** Identification of the customer includes the analyses of problem impacts and a detailed analysis of COPQ (Cost of poor quality).

iii. **Identify CTQ characteristics:** Identification of CTQ (Critical to quality) is the determination of the important issues for customers.

iv. **Map the process:** A visual representation of the existing process should be prepared in order to look beyond functional activities and core process.

v. **Scoping the project:** Reduction of project scope is the main focus of this step. Determination of specific project issues, a problem statement and brainstorm session are the purposes of scoping the project.

2. **Stage 2 -** Measure, second stage of DMAIC, is for having a plan for data collection, preparing a sufficient data sample and preliminary analysis of this sample. In this stage, Six Sigma team analyzes current performance through valid data in order to understand improvement opportunities and identify KPIV.

i. **Identify measurement and variation:** Types, sources, causes and detailed impacts of variation on process should be defined by the establishment of measurement.

ii. **Determine data type:** Six Sigma team should define data types that will be collected. The main focus is to decide what kind of data and knowledge required for process improvement.

iii. **Develop a data collection plan:** Data collection plan provides data collection responsible and data displaying formats.

iv. **Perform measurement system analysis:** Graphical and baseline analysis should be performed through MSA (Measurement System Analysis) in order to be sure that data collection plan works accurately and collected data are confidential.

v. **Collect the data:** Collected data should be proper and provide enough information to Six Sigma team in order to determine root causes of the problem

3. **Stage 3 -** Analyze, thirds stages of DMAIC is for finding the root causes of defects, right approach styles to data and improvement opportunities

   i. **Perform capability analysis:** Baseline capability should be realized in order to understand performance level of the process.

   ii. **Select analysis tools:** Six Sigma team should control the graphical analysis and decide which tools will be used in order to find the details of variation and performance.

   iii. **Apply graphical analysis tools:** A visual performance indications should be realized through graphical analysis techniques.

   iv. **Identify sources of variation:** Statistical tools are used in order to define the variations sources. The main focus in this step is to find and repair significant variations.

4. **Stage 4 -** Improve, fourth stages of DMAIC, is for designing, implementing and validating the improvements. This stage includes FMEA (Failure Mode and Effect Analysis), a preliminary cost/benefit analysis and preparation of necessary actions, basic steps are

   i. **Generate improvement alternatives:** Focus of this step is to define, generate and evaluate the possible improvements.

   ii. **Create a "should be" process map:** Mapping of best improvement opportunities should be realized by Six Sigma team.

   iii. **Conduct FMEA (Failure Mode and Effect Analysis):** This analysis is used in order to make the situation analysis of "before the failure".

   iv. **Perform a cost/benefit analysis:** Cost/Benefit analysis is the comparison between expected benefits and improvements costs.

   v. **Conduct a pilot implementation:** The implementation of planned improvements should be conducted on a small scale.

   vi. **Validate improvement:** Sigma values before and after "Improve Stage" should be compared in order to understand the effect of process improvement.

5. **Stage 5 -** Control, last stage of DMAIC, is for the institutionalization of process/product improvements and following performance. This is a transition phase of process from Six Sigma team to original executers under detailed control plan, basic steps are

   i. **Mistake-proofing:** Remove the error possibilities is the main focus of this step. It is important to remove errors before provoking defects in the process.

   ii. **Long-term MSA (Measurement System Analysis):** Data collection should be distributed over the long-term in order to measure and monitor inputs/outputs of process improvements through Measurement System Analysis.

   iii. **Appropriate and applicable charts (statistical process control):** Graphical representation of process should be realized in order to control processes with lower and upper limits.

   iv. **Reaction plan:** That is a detailed plan of controlling issues and necessary actions if the revised process is no longer under control.

   v. **The new or revised SOPs (standard operating procedures):** Six Sigma team should periodically revise the existing documents and procedures in order to reflect improvements results.

4.3 Metrics & Belt System

Six Sigma metrics measures defects rate without considering the complexity of the products and processes. Sigma concept as an international quality measurement technique was started by Motorola and better processes with few defects rates have higher sigma values.

Table.2: Basic Sigma Conversion Table

Basic Sigma Conversion Table		
Yield = Percentage of items without defects	Defects per million opportunities (DPMO)	Sigma Level
30.9	690000	1
69.2	380000	2
93.3	66800	3
99.4	6210	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 6 210.

Belt System which is a hierarchy between experts, is another challenge created by Six Sigma. Six Sigma team members are: Executive Leader, Executive Champion, Deployment Champion, Project Champion, Master Black, Black and Green Belt. The definitions of belts are,

- **Master Black Belts (MBBs):** have high level understanding of the Six Sigma projects, and DMAIC/DFSS. They can mentor Green Belts.
- **Black Belt (BB):** includes on-site project and off-site classroom activities and its training takes five months.
- **Green Belts (GB):** who have the basic knowledge of Six Sigma and DMAIC/DFSS work with Black Belts. Training of Green Belts takes approximately seven weeks.

External consultants are mostly experienced trainers and take roles on establishment and management of first deployment plan. The hierarchy relations between belts are

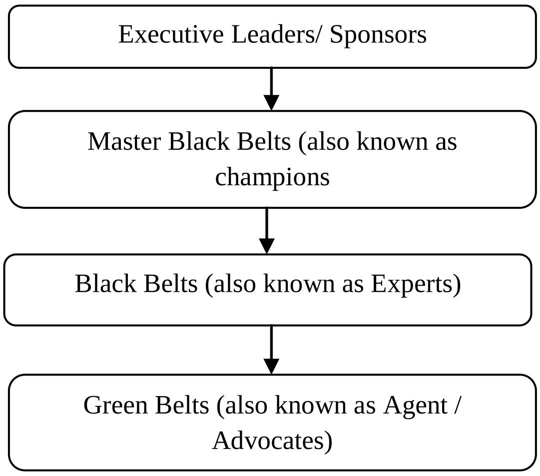

Chart - 2: The Structured approach of Six Sigma & Belt Relations

5. PROBLEM STATEMENT AND METHODOLOGY

5.1 Problem Formulation

Six Sigma is a system which primarily can improve the quality and consequently the time management of projects. The Six Sigma system has already been implemented in different industry sectors, and fortunately it has brought about benefits. It has improved the time, quality and cost management in the projects, according to the Six Sigma Body of Knowledge1, which consists in the process called DMAIC (Define, Measure, Analyse, Improve and Control) However, Six Sigma focuses on detecting the errors in the projects, with which it then can create a database to improve the process of the projects.

5.2 Methodology

Six Sigma has two key methodologies:

1. DMAIC: It refers to a data-driven quality strategy for improving processes. This methodology is used to improve an existing business process.
2. DMADV: It refers to a data-driven quality strategy for designing products & processes. This methodology is used to create new product designs or process designs.

5.3 DMAIC Methodology

This methodology consists of the following five steps.

Define --> Measure --> Analyze --> Improve -->Control

- Define: Define the problem or project goal that needs to be addressed.
- Measure: Measure the problem and process from which it was produced.
- Analyze: Analyze data and process to determine root causes of defects and opportunities.
- Improve: Improve the process by finding solutions to fix, diminish, and prevent future problems.
- Control: Implement, control, and sustain the improvements solutions to keep the process on the new course.

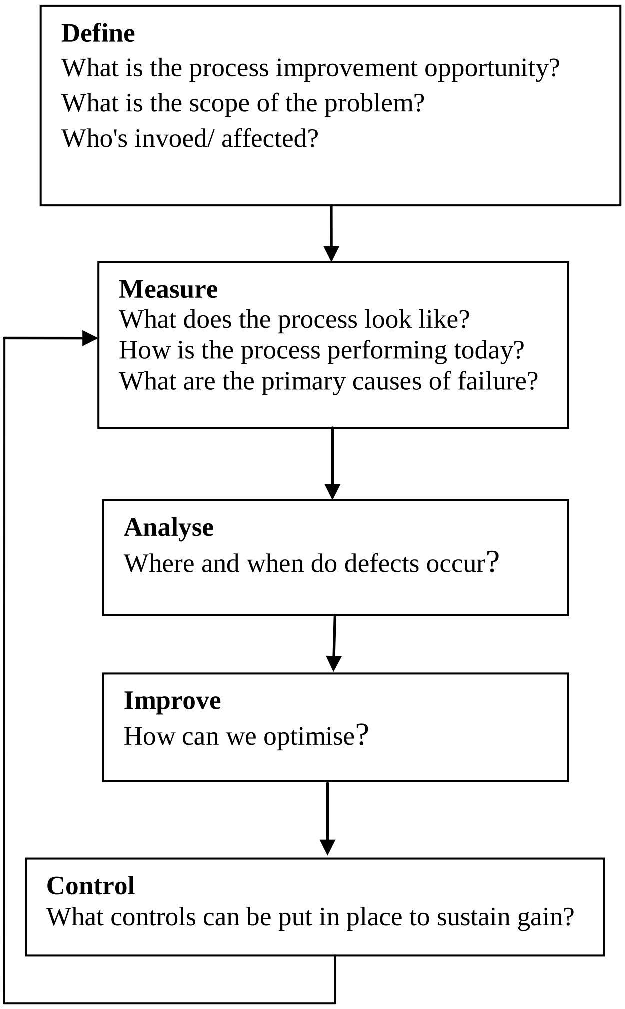

Chart - 3: Six-sigma's structured methodology – DMAIC

6. RESULTS AND DISCUSSION

Table.3: Theory of Constraints (TOC)

Sr. No	Theory of Constraints (TOC)	Total	Mean	SD
1	We frequently use Current Reality Tree (CRT) as problem analysis tools when looking for core problems.	69	2.76	1.42
2	We frequently use Conflict Resolution Diagram (CRD) to generate solutions to difficult problems.	75	3	1.55
3	We frequently use Future Reality Tree (FRT) to validate proposed changes.	69	2.76	1.33
4	We frequently use Prerequisite Tree (PT) to plan the implementation of changes.	71	2.84	1.37
5	We frequently use Transition Tree (TT) to implement changes.	69	2.76	1.30
6	TQM is a management philosophy and practice to ensure effective and efficient use of all available resources.	74	2.96	1.54
7	TQM aims to make customer satisfaction as the focus of a business.	71	2.84	1.46
8	Teamwork and participation are important for achieving a continuous improvement culture.	68	2.72	1.43
9	Training and education are vital elements with respect to TQM implementation.	79	3.16	1.46
10	Statistical techniques (such as Statistical Process Control, Design of Experiments, etc.) are important to ensure consistency of product and process quality.	76	3.04	1.34
11	Supplier involvement is vital in supporting quality improvement.	69	2.76	1.33
12	Management leadership, commitment and support determine the success of new change initiatives.	62	2.48	1.36
13	Management must provide adequate resources in every aspect of the business.	70	2.8	1.32
14	A work environment, which is conducive for improvement, is created through management-worker partnerships.	72	2.88	1.39
15	Initiatives such as Kaizen, suggestion schemes, quality circles, etc. will motivate employees to participate in quality improvement.	74	2.96	1.43

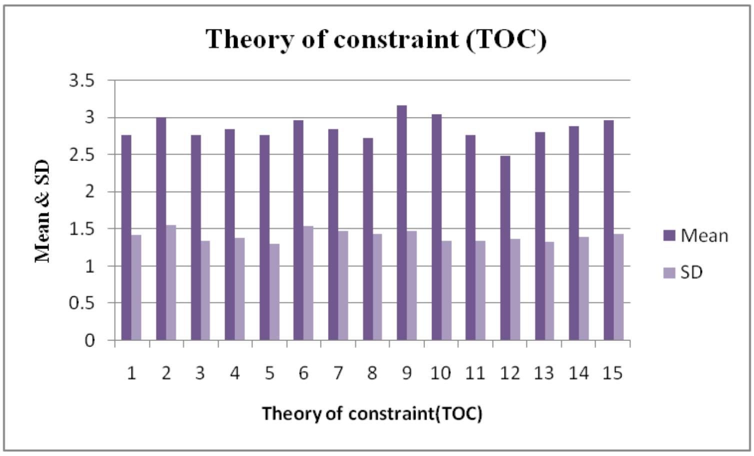

Fig - 1: Theory of Constraint (TOC)

Table.4: Management Leadership

Sr. No	Management Leadership	Total	Mean	SD
1	Top management ensures that every employee knows the company's mission and business objectives.	65	2.6	1.22
2	Top management strongly promotes staff involvement in quality management and improvement activities.	72	2.88	1.27
3	Managers and supervisors empower employees.	77	3.09	1.58
4	Communication links are established between employees and top management.	72	2.88	1.42
5	Top management takes care of employee well being (e.g. welfare, health and safety provision, etc.).	62	2.48	1.26
6	Company fulfils its social responsibilities (such as environment friendly operation, charity to school, etc).	77	3.08	1.50

Fig - 2: Management Leadership

Table.5: Resource Management

Sr. No	Resource Management	Total	Mean	SD
1	Human resource ability considered in improvement activities.	66	2.64	1.15
2	Employees are given information and training they need to do the job effectively.	74	2.96	1.34
3	Employees are given tools they need to do the job effectively.	77	3.08	1.35
4	Sufficient financial resources provided to support improvement activities.	72	2.88	1.56
5	Company manages its material resources effectively.	67	2.68	1.38

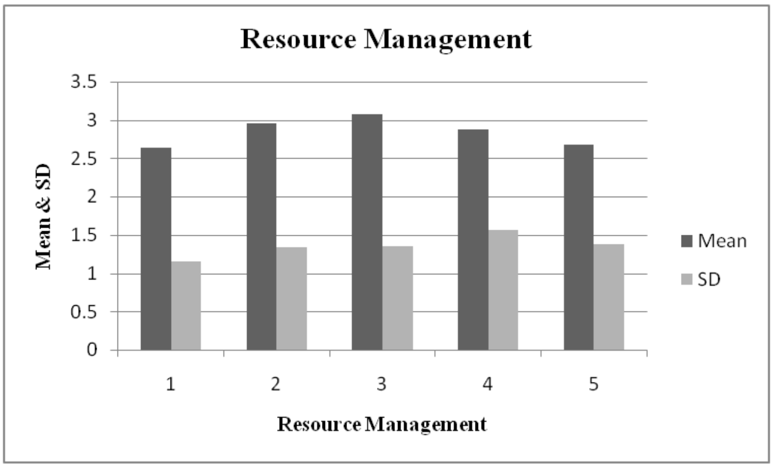

Fig - 3: Resource Management

Table.6: Measurement and feedback

Sr. No	Measurement and Feedback	Total	Mean	SD
1	Customer satisfaction level are measured and monitored.	67	2.68	1.41
2	Information on quality and customers are collected and analyzed.	72	2.88	1.30
3	Information on operational and financial performances are collected and analyzed.	77	3.08	1.44
4	Employees' views are listened to and acted upon.	72	2.88	1.54
5	Employee performance are measured and recognized.	74	2.96	1.40

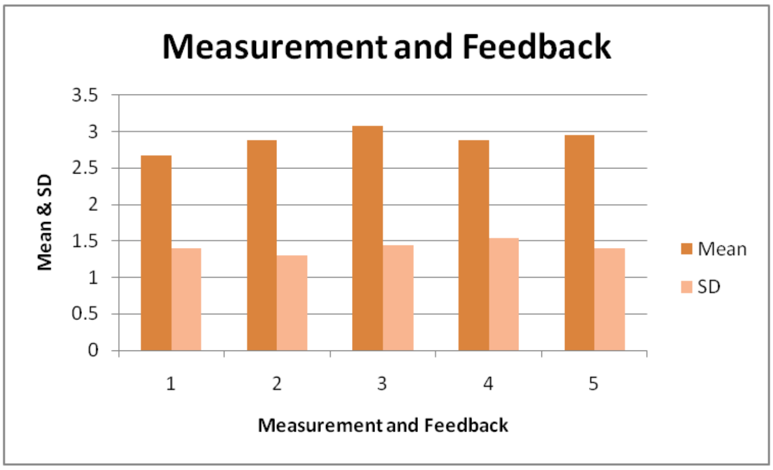

Fig - 4: Measurement and Feedback

Table.7: Continuous Improvement

Sr. No	Continuous Improvement	Total	Mean	SD
1	There is a quality improvement coordinating body (e.g. quality steering committee).	65	2.6	1.12
2	Improvement teams are active in all departments.	79	3.16	1.21
3	Quality improvement tools and techniques are widely used.	74	2.96	1.54
4	The company practices continuous improvement of all its products, services, and processes.	71	2.84	1.46

Fig - 5: Continuous Improvement

Table.8: Supplier Quality Management

Sr. No	Supplier Quality Management	Total	Mean	SD
1	Suppliers are selected on the basis of quality aspects.	68	2.72	1.28
2	Company ensures that suppliers can maintain high technical standards and meeting quality specifications.	67	2.68	1.25
3	Company regularly conducts suppliers' quality audits.	71	2.84	1.46
4	Company works closely with suppliers toward long term partnership and improvement.	69	2.76	1.51
5	Suppliers provide relevant quality records and data.	73	2.92	1.38

Fig - 6: Supplier Quality Management

Table.9: Systems and Processes

Sr.No	Systems and Processes	Total	Mean	SD
1	Systems and procedures for quality assurances are implemented.	67	2.68	1.22
2	Internal data collection system is established.	73	2.92	1.19
3	Market information and feedback system is established.	70	2.8	1.53
4	The employees involved in different processes know how to evaluate them.	76	3.04	1.49

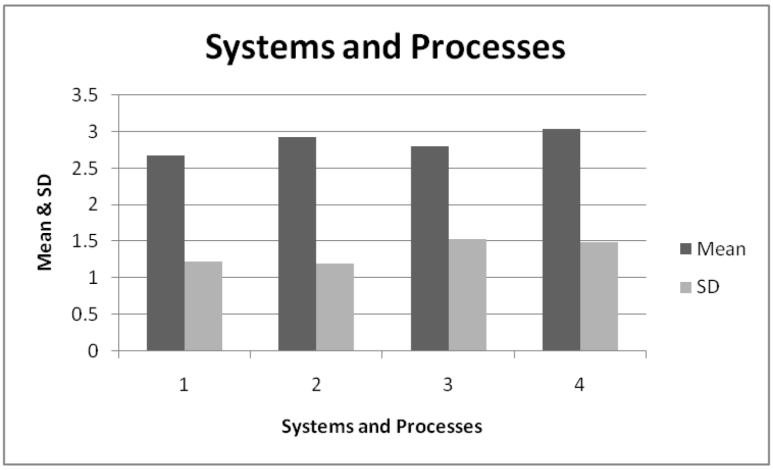

Fig - 7: Systems and Processes

Table.10: Education and Training

Sr.No	Education and Training	Total	Mean	SD
1	Top management always updates their knowledge.	71	2.84	1.37
2	Employees are trained for job related skills.	74	2.96	1.24
3	Employees are trained on total quality concepts.	76	3.04	1.40
4	Continuous learning is provided through education and training.	74	2.96	1.34

Fig - 8: Education and Training

Table.11: Work Environment and Culture

Sr.No	Work Environment and Culture	Total	Mean	SD
1	A pleasant environment exists in all working areas.	68	2.72	1.51
2	Positive values such as trust, honesty, hardworking, are fostered by management.	70	2.8	1.38
3	Teamwork and involvement are normal practices in the company.	72	2.88	1.45
4	The company adopts 'Employee satisfaction' initiatives (such as suggestion schemes, profit sharing, etc.).	73	2.92	1.47

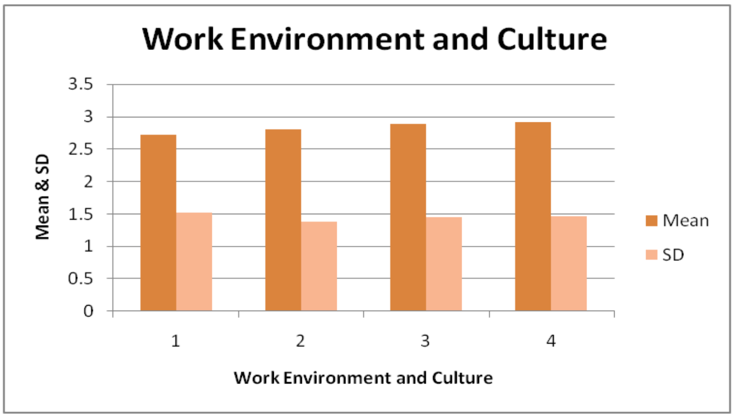

Fig - 9: Work Environment and Culture

Table.12: Total Quality Management Results

Sr. No	Total Quality Management Results	Total	Mean	SD
1	Customer satisfaction has shown improvement.	74	2.96	1.43
2	The numbers of products/service defects, errors, or failures found by the customer have decreased.	66	2.64	1.38
3	The number of customer complaints has decreased.	80	3.2	1.47
4	Our financial results have been improving.	80	3.2	1.41
5	Our quality program has improved our business performance in general.	72	2.88	1.30
6	Our company has developed a culture that emphasizes quality.	65	2.6	1.32
7	The number of employees participating on quality teams has increased.	72	2.88	1.51
8	Employee satisfaction has increased.	69	2.76	1.39
9	Employee turnover has decreased.	73	2.92	1.44
10	Partnership with suppliers has improved quality of purchased parts.	70	2.8	1.35
11	Do you consider your TQM program successful?	77	3.08	1.47

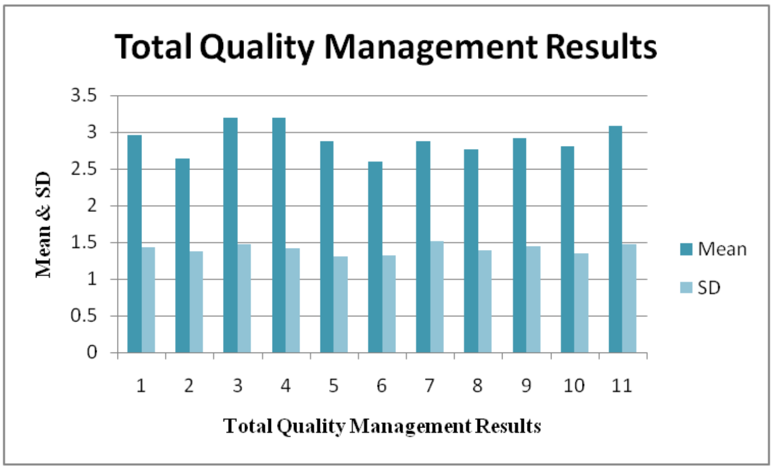

Fig - 10: Total Quality Management Results

Table.13: Barriers to TQM

Sr.No	Barriers to Tqm	Total	Mean	SD
1	Lack of understanding.	73	2.92	1.44
2	Lack of preparation	66	2.64	1.32
3	Resistance to change	67	2.68	1.44
4	Lack of vision.	74	2.96	1.34
5	Lack of top management commitment.	78	3.12	1.54
6	Lack of customer focus.	67	2.68	1.44
7	Lack of resources.	68	2.72	1.43
8	Lack of systems and structures for TQM activities.	71	2.84	1.49
9	Availability to training.	74	2.96	1.46
10	Training with no purpose.	68	2.72	1.24
11	Costly consultancies, training programs.	75	3	1.29
12	Lack of rewards and recognition.	74	2.96	1.40
13	Lack of effective measurement criteria.	78	3.12	1.45
14	Lack of evaluation procedures and benchmark indices.	62	2.48	1.26

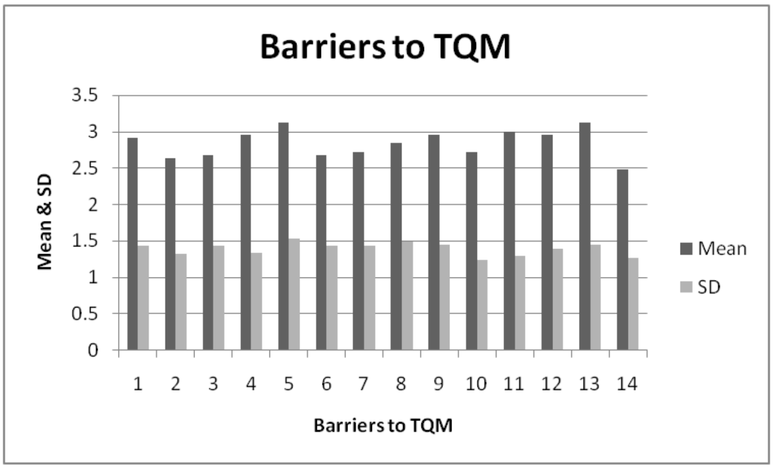

Fig - 11: Barriers to TQM

7. CONCLUSIONS

Six sigma philosophy is widely accepted by manufacturing industries and it also possible to implemented in construction industry with little fragment modify more research work is required in this field, so great scope of research is accessible for new researchers in this field. Past case study reveal that it required team efforts involving top management and every worker in the organization to fully employ the philosophy. However, realization among consultant, engineers and employees concerning six sigma in construction should be produced. From various literatures conclusion author feel that, uses of six sigma in construction industry under different situation plays significant role. In current years there has been a lot of attention in the request of Six Sigma principles. Several papers have been presented on this subject substantiating the meaning of adopting Six Sigma to improve process performance.

One of the challenges of Six Sigma is to reach results quicker than other improvement methods. Even though some researchers evaluate Six Sigma as a new management approach, it can be said that adoption of Six Sigma to construction context can be realized by combination of existing quality initiatives and Six Sigma. In this thesis, after the completion of the entire works, the following benefits will be obtained:

- Use replacement,
- Reduce or recycle,
- Eliminate the unnecessary things,
- Doing different tasks at the same time,
- Easy work flow, Develop collaboration,
- Introduce cross training,
- improve the level of inspection,
- concentrate on preventive maintenance of tools and equipment,
- Institutionalize,
- Develop accident plans,
- Reduce the number of components,
- present job site displays to publicize project information,
- Remove negotiator.

8. FUTURE SCOPE

Six Sigma can be implemented in different types of construction projects and site environment such as: transportation, water, power plant, structure, industrial and residential projects. That's why; this research will not focus on any special project types. Furthermore, this study will attempt to cover site and office based operations of construction projects. Considering the mentality difference between project managers, site and office engineers, it is important to reflect their ideas and perspectives about process improvement.

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