Analyzing Six Sigma Methodology in Modern Manufacturing Practices

Sami K. Hassan*[1], Mariam F. Suleiman[2]

M.Sc. Scholar, Department of Mechanical Engineering, King Saud University, Riyadh, Saudi Arabia
Assistant Professor, Department of Mechanical Engineering, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia

ABSTRACT

Six Sigma has develop as a most powerful quality improvement methodology in many industries and its significance is growing. This paper represents that the concept of Six Sigma, DMAIC methodology used to implementation of Six Sigma specially for manufacturing industries. And some issues that are acting as most critical successful factors for implementation of Six Sigma by manufacturing industries have been discussed. In this paper the methodology, implementation and benefits of Six Sigma is described. At last some topics for future research are presented.

KEYWORDS: DMAIC Methodology, Normal Probability Distribution , Critical Successful Factors, Process Capability , Critical to Quality Requirements.

I. INTRODUCTION

Six Sigma differs from other quality programs in its top down drive in its rigorous methodology that consists of detailed analysis, decisions based on facts, and a control plan to ensure continuous quality control of a process [7]. Six Sigma was started in Motorola by engineer Bill Smith in the late 1980s in order to address the company‘s chronic problems of meeting customer expectations in a cost effective manner [2]. Six sigma in manufacturing industries has been providing significant benefits, but there is no clarity in procedure regarding the exact parameters for six sigma implementation in industries [1]. All the organizations required to improve their production capabilities and management processes in order to survive long time in the market. This can be achieved by zero defects, improving processes, reduction in process variability, reduction in costs, increased profits, improve product quality and enhance productivity and increasing customer satisfaction [12].

The continuous quest for business improvement philosophies and methodologies like Six Sigma addresses the competitive pressure and challenges that all business sector faces to ensure their sustainability in the global market. Six Sigma is a quality improvement strategy that seeks to find and eliminate cause of defects or mistakes in business processes by focusing on outputs that are of critical importance to customers [6]. As a result, process performance should be enhanced, customer satisfaction should be improved and the bottom-line should be impacted through cost savings and increased revenue.

In statistical terms, Six Sigma means 3.4 defects per million opportunities, where sigma is used to represent the variation about the average of a process. The aim of Six Sigma is to keep the distance between the process average and the nearest tolerance limit to at least six standard deviations and thus reduce variability in products and processes in order to prevent defects. The concept of normal probability distribution curve as shown in figure 1 can be related to the concept of Six Sigma. Jayesh Pathak and Tusar Desai [8] stated that most processes are subject to disturbances that could cause the process mean to shift by 1.5 times standard deviation from the target. Factoring a shift of 1.5 standard deviation in the process mean then results in a 3.4 defects per million opportunities.

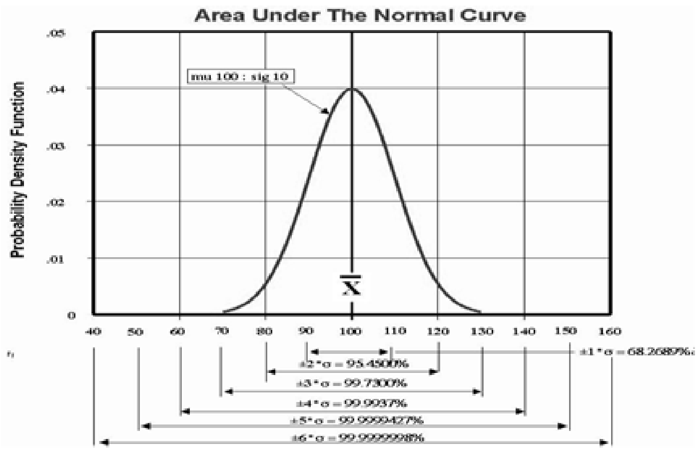

Fig.1 normal distribution curve[18]

II. METHODOLOGY OF SIX SIGMA

Six sigma has two key methodologies:

DMAIC Methodology and DMADV Methodology, both inspired by Deming's Plan-Do-Check-Act Cycle [30].

- DMAIC
- DMADV

- DMAIC:

The DMAIC means Define, Measure, Analyses, Improve and Control. These all work together to create the DMAIC process. This process is incredibly important in six sigma process because it is what helps bring a diverse team together. This is what helps them complete a process or model so that they can share their work and get the job done. DMAIC is used for an existing business process [18], [30].

DMAIC consists of following steps:

- Defining the process improvement goals that are liked with customer demands and the enterprise strategy.
- Measure the current process capability by collecting relevant data.
- Analyse the collected data by verifying cause and effect relationships. Determine all the possible causes of problem and their relationships and make sure all the factors have been considered.
- Improve the current process by the implementing solutions derived in analysis phase using techniques like Design of Experiments.
- Control phase is all about ensuring that any deviations from target are corrected before they result in defects. Set up pilot runs to establish process capability, move on to production, set up control mechanisms and continuously monitor the process [18], [29].

- DMADV:

The DMADV means Define, Measure, Analyse, Design and Verify. Where the DMAIC methodology is used for improve the existing business process. DMADV is used to create new product or process design.

DMADV consists of following steps:

- Defining the process improvement goals that are liked with customer demands and the enterprise strategy.
- Measure is a phase to identify characteristics that are Critical To Quality and collect data to measure them.
- Analyse to develop and design alternatives, create a high-level design and evaluate design capability to select the best design.
- Design details, optimize the design, and plan for design verification. This phase may require simulations.
- Verify the design, set up pilot runs, and implement the production process [18], [30].

Table 1. objective and tools of six sigma methodology.

Define	**Measure**	**Analyse**	**Improve**	**Control**
Objective Define the problem statement	Objective Measure current production	Objective Analyse the root cause of the problem	Objective Improve current process reduce root cause effect	Objective Control process to improve productivity
Tools 1. Project charter 2. Timeline chart 3. SIPOC map 4. CTQ table 5. Change management plan	Tools 1. Data collection plan 2. Detailed process flow chart 3. Process capability 4. Current sigma level	Tools 1. Cause and effect diagram 2. Cause validation 3. FMEA (before)	Tools 1. Solution implementation plan 2. Before after analysis chart 3. Baseline Vs. achievement	Tools 1. Process management & control plan 2. Response plan 3. Monitoring chart for future control 4. Audit plan 5. Audit checklist

Tool and techniques used in six sigma

Associates uses different types of tools and techniques related to quality in various phases of six sigma. Below are just a few of them:

- Charts and Graphs

Usually, the first and best way to analysis measures of a process is to create a picture of the data. Charts and graphs are really nothing more than visual displays (pictures) of data. It is obvious that looking at a pie chart or a line graph is a lot more meaningful and convenient than reading tables of numbers. And when comparison is needed charts and graphs are best to use, because of them one can make discoveries that the numbers themselves would hide. Charts and graphs are of various types, each offering a bit different picture of the data. A Black Belt will usually use at least a couple of these in one project [18]. Following are some of the most commonly used types of charts and graphs:

- Control Chart
- Pareto Diagram
- Cause-and-Effect or Fishbone Diagram
- SIPOC Diagram
- Tree Diagram
- Run Chart
- Check sheets and Spread sheets
- Matrix Diagram
- Flow Chart
- Scatter Diagram
- Histogram

All the tools are discussed below in detail:

- Control Chart

A control chart is simply a run chart to which two horizontal lines called control limits are added, the upper control limit and the lower control limit. Control limits are chosen statistically so that they are highly probability (greater than 0.99) that points will fall between these limits if the process is in control. Control charts only give the signal when the process trends to go out of control and cannot determine the source of the problem. As problem-solving tools, control charts allow operators to identify quality problems in processes as they occur [3], [5], [9], [11], [12], [21], [23], [24], [26], [27].

- Pareto Diagram

Pareto analysis is a technique based on the Pareto principle of the vital few and the trivial many. The Pareto principle is also called the 80-20 rule. This simply means that in any process product or transaction 80 present of problems are due to 20 present of causes. A Pareto diagram is a bar chart that illustrates the frequency of recurrence or the cost of a set of items. The items are shown in the descending order of importance from left to right [3], [9], [18], [26], [27].

- Cause-and-Effect or Fishbone Diagram

This is a diagram which gives the relationship between quality characteristic and its factors. It is a pictorial presentation in which all possible causes and their effects are displayed. A problem can be due to a variety of reasons or causes. The solution to the problem becomes similar and easier if only true causes for the problem can be identified. The cause and effect diagram was introduced by Kaoru Ishikawa of Japan. It is the simple, graphical method for presenting a chain of causes and effects and for sorting out causes and organising relationships between variables. Because of its structure, it is often called fish bone diagram [3], [5], [9], [11], [12], [18], [19], [21], [22], [26].

- SIPOC Diagram

SIPOC is an acronym for Supplier, Input, Process, Output, and Customer. SIPOC is used in the Define phase of DMAIC and is often a preferred method for diagramming major business processes and identifying possible measures. The SIPOC diagram is used to show major activities, or sub processes, in a business process, along with the framework of the process, represented by the Suppliers, Inputs, Outputs, and Customers. A SIPOC diagram is used to help define the boundaries and critical elements of a process without getting into so much detail that the big picture is lost [11], [12], [18], [19], [21].

- Tree Diagram

A tree diagram maps out the paths and tasks necessary to complete a specific project or reach a specific goal. This technique is used to seek answers to such questions as - What sequence of tasks will address this issue? A structure tree is used to show the links or hierarchy of the ideas brainstormed. By using tree diagram goals and possible solutions can be connected by using a structure tree. One can also use this approach to tie major customer needs, such as good value, to more specific requirements, such as low installation cost, low maintenance cost, and so on [18].

- Run Chart

Run chart monitors performance of one or more processes over time to detect trends, shifts or cycles. It allows a team to compare performance before and after implementation of a solution to measure its impact. It focuses attention on truly vital changes in the process. Pareto charts and histograms don't show you how things are changing over time. That's the job of a run, or trend, chart [18], [21], [23], [24], [26].

- Check sheets and Spread sheets

Check sheets are forms used to collect and to organize data. Ideally, check sheets are designed by a Black Belt and/or team and have two key objectives:
- To ensure that the right data is captured, with all necessary facts included, such as when it happened, how many, and what customer. We call these facts stratification factors.
- To make data gathering as easy as possible for the collectors.
Check sheets can vary from simple tables and surveys to diagrams used to indicate where errors or damage occurred. Spread sheets are the place where check sheet data is collected and organized. A well-designed spread sheet makes it much easier to use the data [3], [5], [11], [18].

- Matrix Diagram

Matrix diagram are spread sheets that graphically display relationships between ideas and activities in such a way as to provide logical connecting points between each item. It is one of the most versatile tools in quality planning [18].

- Flow Chart

A flowchart is used to show details of a process, including tasks and procedures, alternative paths, decision points, and rework loops. A flowchart can be depicted as a as is map showing a process as it currently works or as should-be map showing how it ought to work. The level of detail will vary, depending on the objective. Many Black Belts now use software to draw their flowcharts [18].

- Scatter Diagram

Scatter diagrams are used to determine whether relationship really exists between two process two process characteristics and the direction of the relationship. A scatter diagram graphically illustrates the relationship between variables, typically based on quantitative data. They reveal bi-variety relationships, which are relationships between pairs of variables, such as number of defects per batch against changes in the speed of production line, or production time per unit against hours of training [18].

- Histogram

A histogram, another type of bar chart, shows the distribution or variation of data over a range: weight, cost, size, length of time, age and so on. For instance, we know that a big chunk of our pizza deliveries are late, but we do not know how late or even how early they arrive. So, over several days or weeks, you could measure the time in minutes it takes to deliver pizzas to customers and then plot that data. In analysing histograms, you can look for the shape of the bars or the curve, the width of the spread, or range, from top to bottom, or the number of humps in the bars. If you plot customer requirements on a histogram, you can quickly see how much of what you do is meeting or not meeting customers' needs. How much of what you do is meeting or not meeting customers' needs [18].

Statistical Process Control:

SPC is the application of statistical techniques to determine whether the output of a process conforms to the product or service design. In SPC, control charts are used primarily to detect production of defective products or services or to indicate that the production process has changed and that products or services will deviate from their design specifications unless something is done to correct the situation [3], [5], [9], [11], [12], [18], [21], [23], [24], [26], [27].

Quality function deployment (QFD):

QFD originally stood for Quality function deployment. Years ago when quality departments were generally much larger, quality engineers were “deployed” to customers to rigorously probe the customers’ needs. The engineers then created series of forms that transition those needs into a set of actions from the supplier. The simplified QFD attempts to accomplish the same task in a condensed manner.
If you were limited to use one six sigma tool you would use the simplified QFD. It is useable on any type of problem, and it should be used on every problem. It takes relatively small amount of time and gets much buy-in from customers. QFDs don’t always get the respect they deserve because they don’t look complex. But they are very powerful tool [29].

Failure mode effect analysis:
A simplified FMEA is used in conjunction with the simplified QFD. It is the opposite side of the same coin and it is equally important. Analytical Technique that Identifies Future Failure Modes of a Product/Process and Plans for its Elimination.
Steps of FMEA:
(1) Recognize & Evaluate Potential Failure of Product/Process and its Effects,
(2) Identify that Actions Could Eliminate or Reduce the Chance of
Potential Failures,
(3) Document the Process [2], [29].

Design of experiment:
In an optimized process, all the inputs are at settings that give the best and most stable output. To determine these optimum settings, all key process input variables must be run at various levels with the results then analysed to identify which setting give the best results. The methodology to perform this optimization is called a simplified Design of experiments (DOEs) [7], [12], [14], [19], [29].

Tool and techniques used in different phases of DMAIC:

Tools and techniques used in define phase:
Project charter [12], [27].
SIPOC model [11], [12], [19], [21], [27].
Voice of Customer (VOC) [19], [22], [24], [27].
Process flow [23].
Tools and techniques used in measure phase:
Pareto chart [23].
Process flow chart [12], [24], [26].
Statistical Quality Control (SQC) tools [27].
Tools and techniques used in analysis phase:
Pareto Chart [3], [9], [26], [27].
Brainstorming [21], [27].
Root Cause Analysis [3], [5], [9], [11], [12], [19], [21], [22], [26], [27].
Five-Why Analyse Technique [9], [27].
Failure mode and effect analysis [2], [27].
Hypothesis Testing [20].

Tools and techniques used in Improvement phase:

Pareto diagram [5].
Taguchi’s Design of experiment [7], [12], [14], [19], [27].
Brainstorming [21], [27].
ANOVA [7], [12], [14], [27].
Analysis of variance [7].
Tools and techniques used in control phase:
Statistical Quality Control (SQC) charts [3], [5], [9], [11], [12], [21], [23], [24], [26], [27].

III. CONCLUSION

More research in the area of Six Sigma is still necessary to contribute to the concept and practice of implementation of Six Sigma and conceptual frame work for process improvement model to reduce waste and create value in the manufacturing industries.

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