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Implementation of Six Sigma in Indian Manufacturing Industries

Mr. Mohit Chhikara
m.s.chhikara@gmail.com

Dr. M. S. Narwal
Associate Professor
DCRUST, Murthal.

Mr. Pradeep Dahiya
M.Tech Research Scholar
DCRUST, Murthal.

Abstract:- Six Sigma is the concept of improving the quality by reducing process variations, making continuous improvements, reducing defect rates and improving the processes. The Definitions & Concepts of Six Sigma have been changing since its evolution as per the requirements of time & market conditions. Initially, the concept of Six Sigma focused on defect reduction, then on cost reduction along with value addition and now on value creation, improving the process-capability making the process more reliable along with reducing eight wastes of industry & improving the competitiveness of a product with least possible costs incurred on it. This study presents the literature-review of the works already done in the field of Six Sigma Implementation by the various authors till now. The findings of this paper will be the basis of my further research in this field by developing appropriate research methodology needed to achieve the objectives set by me for my research work.

Keywords: Six Sigma, Quality, Process Variations, Continuous Improvements, Defect Reduction, Cost Reduction, Value Creation, Process Capability, Competitiveness.

1. INTRODUCTION

Mathematically, 'Six Sigma' represents Six Standard Deviations (plus or minus) from the arithmetic mean. As a program, it presents a "structured and systematic approach" to process improvement, aiming at reduction of defect rate to 3.4 defects for every million opportunities (Harry and Schroeder, 2000; Henderson and Evans, 2000).

Hammer (2002) simplified the definition of Six Sigma as a project based methodology to solve specific performance problems recognized by an organization. Linderman *et al.* (2003) emphasized the need for a common definition of Six Sigma and defined it as 'An organized and systematic method for strategic process improvement and new product and service development that relies on statistical and scientific methods to make dramatic reductions in customer defined defect rates'. However over the years, number of studies has projected Six Sigma as change management approach at strategic level, beyond its initial statistical definition.

Bremer *et al.* (2006) offered three common definitions for Six Sigma:

- 1) A metric that assists with managing process variation, key performance indicators and continuous improvement initiatives;
- 2) A methodology that offers a consistent model and approach to team-based problem solving; and
- 3) A management system that helps executive leadership drive, metric based governance system across the enterprise.

However, Schroeder *et al.* (2008), have opinioned that many of the definitions of Six Sigma found in the literature are very general and do not provide elements — or factors (variables, constructs, concepts) and defined "Six Sigma as an organized, parallel-meso structure to reduce variation in organizational processes by using improvement specialists, a structured method and performance metrics with the aim of achieving strategic objectives".

According to Zhang *et al.* (2011), it is nearly impossible to develop formal conceptual definition of Six Sigma because it is driven by the changing needs of the organization and consultant needs to always offer something new and distinctive. It is evident from the fact that, **“Six Sigma continues to draw tools and concepts such as Kano Analysis from marketing research, change management from Organisation Behaviour, Supply Chain Optimization from operations research and Hosin Planning from Toyota”**.

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.

Companies may choose from the existing variations of this base definition while deploying Six Sigma in order to customize it to their situation. The Deployment Strategy may be different among them & also within, at various levels of organizations.

1.2 Background

Since the first appearance of man on earth, mankind has an everlasting need for growth and improvement besides its survival. In ancient times, the major two foci for improvement were athletics and agriculture. Business environment received similar focus for improvement since its inception. The story began around 100 years ago when Frederick Taylor concluded that the best way to improve productivity was to segregate the execution of work from its planning and improvement processes used for execution (Taylor, 1911). However, in the era of industrialization, the roots of modern improvement programs can be traced back to initiatives undertaken by several companies during the later-half of the 19th century. During this period, employee-driven improvements and incentive programs brought about positive changes in the industrial environment (Schroeder and Robinson, 1991). In the later half of 20th century, more than 69 quality related initiatives were reported (Dedhia, 2005).

According to Montgomery (2005), Six Sigma has been very successful and is rather the most successful business improvement strategy developed in during the last 50 years. Management experts like Walter Shewhart, Joseph Juran, and W. Edwards Deming who championed the cause of Total Quality, brought the idea of Continuous Process Improvement as a Formal Methodology to the Limelight (Evans & Lindsay, 2008). An Example of Early Process Improvement methodology is the Deming Cycle of PDCA (Plan-Do-Check-Act).

Over the decades, the need for continuous improvement within the organization became imperative. For this purpose, a number of continuous improvement methodologies were developed based on a basic concept of process improvement, waste minimization, production system and quality improvement. Presently, its application has extended beyond manufacturing industries to service, government, public sector, healthcare and non-profit organizations. The fact is further reinforced by the survey report published by Dyn Corp that Six Sigma is the most effective quality improvement technique (Dusharme, 2012). This survey further revealed that the concept of Six Sigma is rated high as compared to many other process improvement techniques.

1.3 History and Evolution

Willmott (1995) & Grint (1997) opinioned that any supposedly new or emergent approach to business improvement has a historical ancestry of underlying assumptions. According to Grint (1997), this history has definite influences over the current development of such approaches. Many authors believe that by the end of 1986 Bill Smith, a reliability engineer and scientist at Motorola's communication division coined the word 'Six Sigma' and presented his ideas to Robert Bob Galvin, the Chairman of Motorola (Pande *et al.*, 2000, Park, 2003;). Galvin was quite impressed by the name 'Six Sigma', as it sounded like new Japanese car and he needed something new to draw Global attention. Galvin could visualize the merits of the concept and officially launched 'Six Sigma' in that year. He proposed 'Six Steps to Six Sigma' for process improvement and 'Mechanical Design Tolerancing' to achieve 3.4 Defects per Million Opportunities (DPMO). 'Six-Sigma' is more of an evolutionary development programme in the science of continuous improvement that combines the best element of many earlier quality initiatives (Folaron and Morgan, 2003).

Gupta (2005) presented the growth of Six Sigma over the years in the form of S-Curve (Figure 1.1). This graph depicts the birth, exploration, evolution and growth of Six Sigma along with its different stages of development.

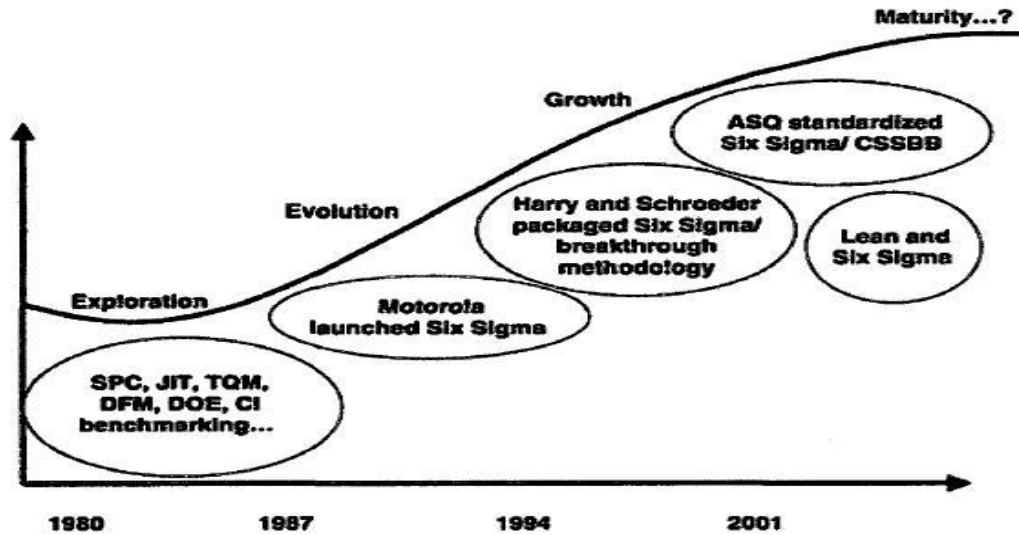


Figure 1.1: S-Curve (Gupta, 2005)

During the initial period of implementation, the focus was solely on the statistical aspects of Six Sigma. The unique combination of “change management and data-driven methodologies” which transformed Six Sigma Process from simple quality measurement and process improvement tool to what it is perceived today, as a New Break-through business strategy, is the brain child of two Motorola executives, Mikel Harry & Richard Schroder. They also developed strategies and deployment guidelines for a Variety of Industries.

Six-Sigma has undergone “Three distinct phases of evolution” over the years (Figure 1.2). The first generation (1987 to 1994) focused on reduction of defects, the second generation (1994 to 2000) emphasized on cost reduction and the third generation (2000 onwards) focused on Value-Creation for the Enterprise (Harry & Crawford 2005; Montgomery 2005).

A Successful Generation III Enterprise is not going to stop its preceding Generation I and II activities. Those are still essential, but value creation requires an expanded emphasis on Six Sigma with the deployment of new methods and techniques. Motorola was a live example of a successful Generation I company, while General Electric and Honeywell characterized Generation II. Quite a few organizations are trying to embrace Generation III Six Sigma. Difficulties with both first and second generation efforts are that, they could not address some of the larger issues for commercial success. The missing ingredient is the concept of value creation that Generation III addresses (Harry and Crawford, 2005).

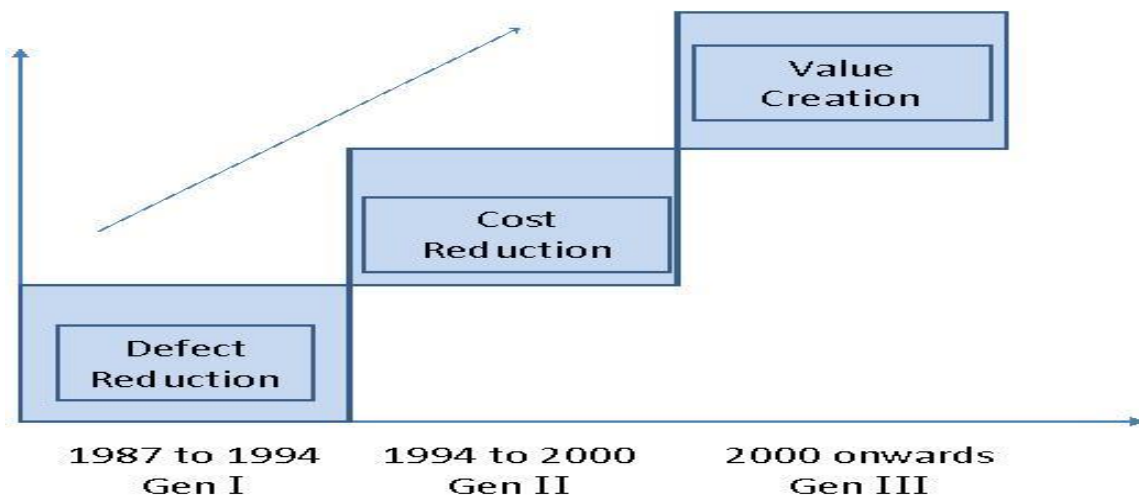


Figure 1.2 Phases of Evolution of Six Sigma Concept

1.4 Six Sigma Project

- The Project Management Board of Knowledge, including Project Management Institute’s (PMI) Standards Committee defines Project as “Temporary Endeavour undertaken to create Unique Product or Service”.
- Turner (1992) defines **Project** as “an Endeavour in which human, material & financial resources are organized in novel way, to undertake a Unique Scope of Work of given specification, within constraints of Cost & Time, so as to achieve Unitary Beneficial Change, through the Delivery of quantified & Qualitative Objectives”.
- **Six Sigma is a Process Improvement Project** which can be defined as “a systematic approach for improving

Organizational performance that consists of specific practices, tools, techniques and terminologies and implemented as a set of improvement projects. Both TQM & SIX SIGMA Projects can be called as 'Process Improvement Projects'. However in TQM literature, Projects have been differentiated on the basis of their scope (Juran, 1989). Projects with an objective to meet the specific process related issues are classified as little q (quality) projects, whereas the one with a broader scope are classified as Big Q projects can be considered as Six Sigma projects since they attempt to improve the customer satisfaction and try to achieve corporate level objectives.

- Famous Quote from Jack Welch, Former CEO, GE Company, **“The best Six Sigma projects begin not inside the business but outside it, focused on answering the question: How can we make the customer more competitive? What is critical to the customer’s success? Learning the answer to that question and learning how to provide the solution is the only focus we need.”**

1.5 Deployment of Six-Sigma Projects

- In practice, Six Sigma projects are deployed / executed in 5 phases generally comprising of **“Define–Measure–Analyze–Improve–Control (DMAIC)”**, where DMAIC focuses on eliminating defects by reducing variability in operation.
- The original Six Sigma process developed for problem-solving at Motorola was MAIC, devoid of D: Define.
- Presently, DMAIC is mostly used as Unique Problem-Solving Process in Manufacturing Sector. Foster (2007) claimed a Common Process for implementing improvement tools named as DMAIC Methodology, which is similar to Edward Deming’s “Plan-Do-Check-Act (PDCA)” PROBLEM-SOLVING Approach.
- Where DMAIC focuses on eliminating defects by reducing variability in operation, **DFSS (Design for Six Sigma)** focuses on preventing defects by optimizing transformation of what is wanted and perceived in the customer domain to what can be produced in engineering and operation domain (Ferryanto, 2005).
- Not all Six Sigma projects produce bottom-line benefits, many produce only local improvements (Pyzdek, 2003) and about 20 per cent of projects are cancelled (Eckes, 2001). Besides, since different potential areas of improvement compete for scarce resources, organization should select Six Sigma projects in such a way that they are closely tied to the business goals and strategy (Ingle and Roe, 2001). It has also been seen that poorly selected and defined projects not only lead to delayed results, but also fail to realise the targeted improvement.
- R&D, Manufacturing & Service are 3 major domains of most of the companies across the globe. According to Park (2003), Six Sigma in the R&D part is called “Design for Six Sigma (DFSS),” “Manufacturing Six Sigma” in manufacturing and “Transactional Six Sigma (TSS)” in the service sector.
- Snee and Hoerl (2003) have proposed a high level road map for Six Sigma Deployment. They presented a deployment road map which has proved its efficacy in a number of different circumstances. It shows how to get started, manage the important aspects of the initiative, maintain the momentum over time, and eventually how to scale down the initiative and institutionalize Six Sigma. All organizations deploying the Six Sigma have to undergo each of the phases, although each of them will progress through these phases differently.
- Over the years, many researchers have studied Six Sigma Programs & identified many Critical Success Factors impacting the deployment of Six Sigma (Coronado & Antony, 2002; Mc Adam & Evans, Gijo & Rao, 2005). All the Factors are Essential & should be taken in account while successfully implementing Six Sigma.
- According to Zhang *et al.* (2011), the focus of Six Sigma research has shifted over time. While earlier research focussed on technical issues, more recent studies have addressed broader deployment issues such as project management mechanisms and its performance implication.
- ‘Project Selection’ is considered to be one of the Key Factors contributing to the Successful Deployment of Six Sigma in all the Phases. ‘Project Selection’ should be completed within reasonable time span (4-6 Months) to deliver Tangible (Quantifiable) Business Benefits in Financial Terms or Enhanced Customer Satisfaction.
- Other necessary CSFs necessary for the Successful Deployment of Six Sigma Projects in Industries have been identified & discussed in the chapter of literature-review.

1.6 Motivation of Study

- Although Positive Results from Six Sigma Programs galore, but such endeavors also have their fair share of criticism for failing to deliver performance benefits.
- The earlier literature which was predominantly based on descriptive accounts of organizational applications have increasingly been complimented with empirical studies which attempt to link theory and practice with more critical analysis (Choo *et al.*, 2007; Nonthaleerak and Hendry, 2008; Linderman *et al.*, 2003; Buch and Tolentino, 2006). Though empirical studies pertaining to the implementation of Six Sigma have been reported by researchers from many developed countries, similar kind of studies, especially expert opinion studies, need to be carried out in developing countries like India in order to understand various issues affecting Six Sigma implementation.

- Zu *et al.* (2010) have extensively studied 226 US manufacturing plants to establish the cultural aspects of implementation of Six Sigma. Similar kinds of studies in developing countries need to be investigated.
- While the impact of organizational culture on TQM has been extensively studied in the literature, little research has been done to examine the implementation of Six Sigma relating to culture, despite the recognized importance of organizational culture for Six Sigma adoption and deployment (Antony, 2004; Goffnett, 2004).
- Of late, an expert opinion study has been reported by Timans *e al.* (2009) to identify Six Sigma Tools and Techniques in US. An expert opinion study of similar nature for Indian industries will certainly be beneficial to both industry and academia to suggest frame work for its implementation and carry out further research in this field.

2. LITERATURE-REVIEW

2.1 The purpose of this literature-review is:

1. To identify the existing work to form a theoretical foundation for understanding the concerned domain.
2. To gain some insight about which domain is relevant in order to position the research.
3. To review existing work in the selected domain to gain an understanding of the statues & progression of that work in future

2.2 Observations from Some Major Research Papers/Journals Studied

Table 2.1: Observations from some major research Papers/Journals

Authors	Year	Observations
Coronado and Antony	2002	12 Critical Success Factors (CSFs) necessary for Successful Deployment of Six Sigma Projects
Kwak and Anbari	2006	Divided CSFs into four categories: Management involvement and organizational commitment; Project Selection, Management and control skills; Encouraging and accepting cultural change; Continuous education and training
Ben Clegg et al.	2009	Various CSFs necessary for the Successful Implementation of Six Sigma Projects
Dr. P. Ramasubramanian	2012	Concepts of Champions, Master Black Belts (MBB), Black Belts (BB), Green Belts (GB) and Team members (TM), in perspective of Six Sigma Technology
Celep Oguz et. al.	2012	Process Capability Index (Cp) as Six Sigma Process Indicator
Everton Drohomerecki et. al.	2013	Study of DMAIC methodology & Various Techniques/Methods to implement it
Qun Zhang et al.	2013	Commonly used Techniques for Six Sigma Deployment
Mohit Taneja and Arpan Manchanda	2013	Six Sigma Implementation in Small & Medium Enterprises (SME's)
Hassan Rangriz et al.	2014	Influential factors on Six Sigma implementation are: Lack of relevant knowledge, difficulty of maintaining results advantages, complicatedness of processes, lack of clarity of the processes output, lack of focus on client, lack of senior managers support, lack of sufficient sources, resistance against change, lack of improving reflection, lack of professional trainings, lack of enough time for implementation of Six Sigma
Riddhish Thakore et al.	2014	DFSS process & its Tools, Benefits & Limitations of adopting Six Sigma
Kunal Ganguly	2015	Utilisation Of Dmaic Approach For Case Study In An Integrated Aluminum Company, Improvement Process For Rolling Mill Through The Dmaic Six Sigma Approach
Anup Kumar Rajak et al.	2016	Key tools, RDMAIC, Product management and process through a statistical method for delighting the customers is a modern approach in Lean Six Sigma

2.3 Deployment Process of Six-Sigma Projects

- In practice, Six Sigma projects are deployed / executed in 5 phases generally comprising of “**Define–Measure–Analyze–Improve–Control (DMAIC)**”, where DMAIC focuses on eliminating defects by reducing variability in operation.
 - DMAIC, a five phase closed-loop problem solving pattern that eliminates unproductive steps, and applies technology for continuous improvement. DMAIC is generally used on business process that fails to meet customer requirements.
- 1) **Defining** and understanding the critical requirements, key factors and expectations of the customer which affects the process output.
 - 2) **Measuring** the process and relevant data to the process primary through Six Sigma metrics.
 - 3) **Analyzing** the causes of defects and sources of variation using statistical quality control tools.
 - 4) **Improving** the process by deriving in the analysis phase the most critical source of variation.
 - 5) **Controlling** and monitoring the process variations using a statistical process strategy to sustain the gains and improvements.

Table 2.2 Process of Six Sigma Deployment (Source: Kumar and Sosnoski (2009))

Phase No.	Phase	Tools & Techniques
1	D – Define	Pareto analysis; Project charter
2	M - Measure	Descriptive statistics; Process capability analysis
3	A – Analyze	Detailed process map; Fish-bone diagram
4	I – Improve	Experimentation; New process
5	C – Control	Statistical process control

2.4 Methods & Techniques used for Identification of Six Sigma Projects

- **Kano Analysis**
The Kano-model is a theory of product development and customer satisfaction developed in the 1980s by Professor Noriaki Kano, which classifies customer preferences into five categories, which are, Must-be Quality, One-dimensional Quality, Attractive Quality, and Indifferent Quality & Reverse Quality.
- **Value Stream Mapping**
Value stream mapping usually employs standard symbols to represent items and processes, therefore knowledge of these symbols is essential to correctly interpret the production system problems. Value stream mapping is a lean-management method for analyzing the current state and designing a future state for the series of events that take a product or service from its beginning through to the customer. At Toyota, it is known as "material and information flow mapping". It can be applied to nearly any value chain. Using the Method,
 1. Planning and preparation. Identify the target product family or service. Create a charter, define the problem, set the goals and objectives, and select the mapping team. Socialize the charter with the leadership team.
 2. Draw while on the shop floor a current state value stream map, which shows the current steps, delays, and information flows required to deliver the target product or service. This may be a production flow (raw materials to consumer) or a design flow (concept to launch). There are 'standard symbols' for representing supply chain entities.

3. Assess the current state value stream map in terms of creating flow by eliminating waste.
4. Draw a future state value stream map.
5. Work toward the future state condition.

- **Theory of Constraints (TOC)**

The **theory of constraints (TOC)** is a management paradigm that views any manageable system as being limited in achieving more of its goals by a very small number of constraints. There is always at least one constraint, and TOC uses a focusing process to identify the constraint and restructure the rest of the organization around it. TOC adopts the common idiom "a chain is no stronger than its weakest link". This means that processes, organizations, etc., are vulnerable because the weakest person or part can always damage or break them or at least adversely affect the outcome.

- **Hoshin Planning**

Hoshin Kanri is a system for strategic planning that:

1. Selects a key objective.
2. Aligns implementation plans at all levels.
3. Implements, reviews, and improves the plan on an ongoing basis.
 - The process of hoshin planning follows Deming's PDCA (**Plan-Do-Check-Act**) cycle. In fact, PDCA is an influential tool that was used to create Hoshin Kanri. PDCA is a generic method for continuous improvement, which are what hoshin planning aims to be.

- **Cost of Poor Quality (COPQ)**

Cost of poor quality (COPQ) or poor quality costs (PQC), are costs that would disappear if systems, processes, and products were perfect.

COPQ was popularized by IBM quality expert H. James Harrington in his 1987 book *Poor Quality Costs*. COPQ is a refinement of the concept of quality costs. In the 1960s, IBM undertook an effort to study its own quality costs and tailored the concept for its own use. While Feigenbaum's term "quality costs" is technically accurate, it's easy for the uninitiated to jump to the conclusion that better quality products cost more to produce. Harrington adopted the name "poor quality costs" to emphasize the belief that investment in detection and prevention of product failures is more than offset by the savings in reductions in product failures.

- **Critical Total Quality (CTQ)**

Critical total quality (CTQ) is one of process performance indicator used in previous Six Sigma projects (Han et al 2008). In implementing Six Sigma principle, CTQ is a main indicator in the phases of DMAIC (Han et al 2008). This method adopts the process capability index (Cp) to measure the performance of Six Sigma efforts on the reliability of panel production rate.

Cp can be calculated using the following equation (Montgomery 2004):

$$\text{Cp (process capability index)} = (\text{USL} - \text{LSL}) / (6 \times \text{STDEV})$$

Where, USL = upper specification given; LSL = lower specification given;

STDEV = standard deviation of the data.

Process capability indices are constructed to express more desirable capability with increasingly higher values. The Cp value recommended for new process is 1.5 (Montgomery 2004).

- **Quality Function Deployment (QFD)**

It is a "method, wily to transform qualitative user demands into quantitative parameters, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process." as described by Dr. Yoji Akao, who originally developed QFD in Japan in 1966, when the author combined his work in quality assurance and quality control points with function deployment used in value engineering.

QFD is designed to help planners focus on characteristics of a new or existing product or service from the viewpoints of market segments, company, or technology-development needs. The technique yields charts and matrices. QFD helps transform customer needs (the voice of the customer [VOC]) into engineering characteristics (and appropriate test methods) for a product or service, prioritizing each product or service characteristic while simultaneously setting development targets for product or service.

- **Strategic Deployment Plan**

‘Strategy Deployment’ aims to formulate clear corporate objectives and goals, disseminating and aligning those objectives throughout all levels of the organization, and then creating plans of action to achieve those objectives.

- **Voice of Customer**

The voice of customer is very important in identification of Projects for Six Sigma Deployment. The voice of the customer identifies needs and requirements that feed into project selection. Because customer’s behavior is a key to strategy and process design, their insights drive the value levers and mapping, and they define value-added services and products. Additionally, through their use of products and services, they provide ongoing feedback and help the company identify new product development opportunities.

Customer feedback reveals issues and requirements that feed into the weights and measures used to identify high-value projects. These value levers then feed into the project selection criteria, screening, scope and prioritization steps.

- **Surveys (Suppliers, Customers)**

Surveys help in knowing the market’s demand about any project through different people’s feedbacks who are expert of their fields. A successful business knows its customers – who they are, what their expectations are and what they think of the products or services. More importantly, a successful business continually improves its processes, reassesses its ability to meet customer needs, and gathers customer data to keep well appraised of changing customer needs and expectations.

There are many different types of customer data and many ways for a business to obtain it. Some customer data is available to virtually any business in the form of complaints, returns and refunds. Additional customer data can be obtained through surveys, focus groups, face-to-face interviews and feedback cards. And all of these can be used to identify Six Sigma projects to improve customer satisfaction.

2.5 Methods & Techniques used for selection of Six Sigma Projects

- **Programming Methods**

The mathematical approach is commonly used for larger projects. The constrained optimization methods require several calculations in order to decide on whether or not a project should be rejected. Programming methods are best for such cases and these methods provide faster & accurate results.

- **Scoring and ranking**

There are number of approaches to ranking projects, which include, assigning projects a point value, assessing the risk of a project, reviewing the project context, Using double or single elimination and ranking a project according to your organization’s mission and values.

- **Real Option Analysis**

Copeland and Antikarov (2001) have formally defined Real Option as: **“A real option is the right, but not the obligation, to take an action at a predetermined cost called the exercise price, for a predetermined period of time”**. Real Options analysis offers an attractive alternative to the existing valuation methods as it explicitly accounts for the value of future flexibility in decision-making (Trigeorgis, 1996). Hence the option values of the projects not only act as a real value of the project, but also augment the flexibility in decision making.

- **Data Envelop Analysis**

Data envelopment analysis (DEA) is a nonparametric method in operations research and economics for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision making units (or DMUs). Although DEA has a strong link to production theory in economics, the tool is also used for benchmarking in operations management, where a set of measures is selected to benchmark the performance of manufacturing and service operations. In the circumstance of benchmarking, the efficient DMUs, as defined by DEA, may not necessarily form a “production frontier”, but rather lead to a “best-practice frontier” (Cook, Tone and Zhu, 2014). DEA is referred to as "balanced benchmarking" by Sherman and Zhu (2013).

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