POLITECNICO DI MILANO

SCHOOL OF INDUSTRIAL AND INFORMATION ENGINEERING

MASTER OF SCIENCE IN MANAGEMENT

SIX SIGMA IMPLEMENTATION IN MANUFACTURING SECTOR

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ABSTRACT

The organization successes mostly depends on the customer satisfaction and loyalty these are the pillars of any organization's success. The companies are trying to improve product and services to get the customer satisfaction, loyalty, decrease costs and to get more profit. In order to reach their goals the organization's are using advanced methodologies like six sigma.

Six sigma is used in various sectors like manufacturing, service, financial, health care, information technology and other sectors. In this paper we focus only on the manufacturing sector. This paper explains the methodologies of six sigma, determining the tools and techniques used during DMAIC phases, success factors of six sigma, KPI's of six sigma and comparison of implementation of six sigma in manufacturing sector by considering 5 companies listed as follows

• TATA MOTORS

• FORD

• GENERAL MOTORS

• NAVISTAR

• TOYOTA

We would also determine the problems faced in the implementation of the six sigma and benefits occurred by the implementation of six sigma in those five organizations.

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1.INRODUCTION

"6Sigma is a quality program that, when all is said and done, improves your customer's experience, lower the costs, and make better leaders". - Jack Welch. Jack welch implement ed 6Sigma as a central business strategy and benefited $2.5 billion per year at General Electric and Motorola, Honeywell, ABB, Bombardier, Sony etc. from the big list. Coming to service organizations this powerful strategy was embraced by big organizations like JP Morgan, American Express, Lloyds TSB, City Bank, etc. even though applications of 6Sigma are still limited. In most of the organizations, 6sigma is a measure of quality those who continuously put efforts to reach perfection. 6Sigma was first introduced by Bill Smith while working as a senior engineer and scientist in communication division, as a solution for the problems of high warranty claims at Motorola in 1986. This benefited Motorola not only with achieving 6sigma quality level but also, the focus was on reducing defect rate in the process with help of powerful, practical and statistical tools and techniques. This leads to better productivity, customer satisfaction, better quality of service, decreased the cost of operations and costs of poor quality etc. M Harry formerly is accredited with the development of the 6sigma concept in the late 1980s (Maguire, 1999). Motorola was honored with the Malcolm Baldridge Award in 1988. Motorola had spent $170 million on worker's education and training and saved $2.2 billion in terms of costs of poor quality.

2.SIX SIGMA MEANING

Six sigma is a system of statistical tools and techniques concentrated on eliminating the defects and reducing process variability. Six Sigma become the statistical symbol and measure of the standard deviation. standard deviation is a measure of the variation of the dispersion. The sigma scale of measure is correlated to characteristics such as defects-per-unit, parts-per-million defectives, and the probability of failure. 6 is the number of sigma's measured in a process, when the variation around the target is only 3.4 defective outputs out of one million under the assumption that the process average may change over the long run by as much as 1.5 standard deviations. 6Sigma is a quality improvement program with a goal to decrease the number

of defects to as low as 3.4 parts per million and it depends on the use of normal distribution to forecast defective rates. 6Sigma qualities are the benchmark of excellence for product and process quality, popularized by Motorola based on zero defect concept introduced by Philip B. Crosby.

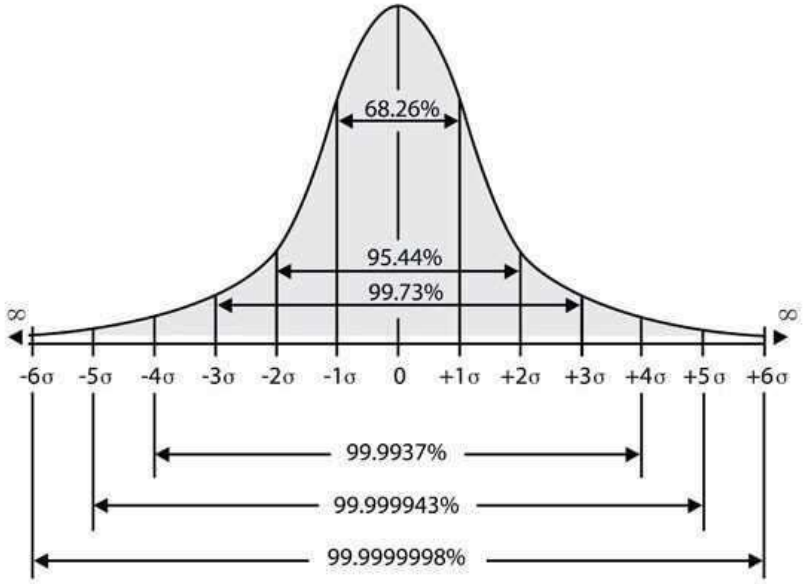

Figure 1: Representation of six sigma process

3.AIM OF SIX SIGMA

The main aim of 6sigma is to improve quality (i.e., reducing waste) by supporting organizations to produce better products and services in less amount of time and costs. There is a direct relationship between quality levels and ‘‘sigma levels’’ of performance. For example, the company operates at 6sigma produce 3.4 defects per million and the company operates at 4sigma produce around 6,210 defects per million.6Sigma simply focuses on customer necessities, prevention of defects, a decrease in cycle time, and lowering costs and the benefits from 6Sigma go directly to the bottom line. Unlike cost-cutting programs which reduces value and quality, 6Sigma identifies and eliminates costs which give no value to customers. these costs are very high for Companies, who are not implementing 6sigma. Companies implementing 3 or 4sigma are

spending between 25% and 40% of their revenues to fix problems. This is called the cost of poor quality. Companies implementing 6Sigma spending less than 5% of revenues to fix problems. Cost of Poor-Quality values shown in the figure2 below is at the lower end of the range of results reported from different studies. The cost of this gap will be huge. General Electric calculated that gap between 3,4 and 6 Sigma was costing them around $8 billion to $12 billion per year. The reason why costs are related to sigma levels is simple: sigma levels are a measure of error rates and correction needs money. Figure3 shows the relationship between errors and sigma levels. when the error rate decreases exponentially as the sigma level increases.

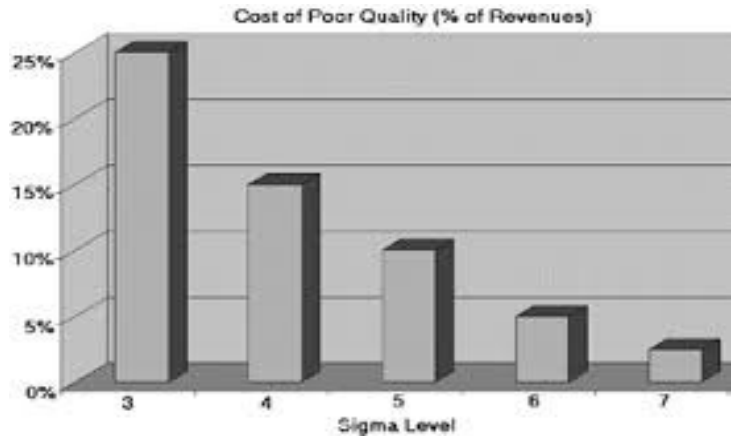

Figure 2: cost of poor quality vs sigma level

4.SCOPE OF SIX SIGMA

Six sigma is used in many sectors and industries, which includes Telecom, Aviation, Automobile, Online retail, Hospitality, Restaurants, IT, BPO, FMCG, Fashion, Petroleum, Entertainment, Health care, Education, Government

SIPOC framework is used in applying six sigma

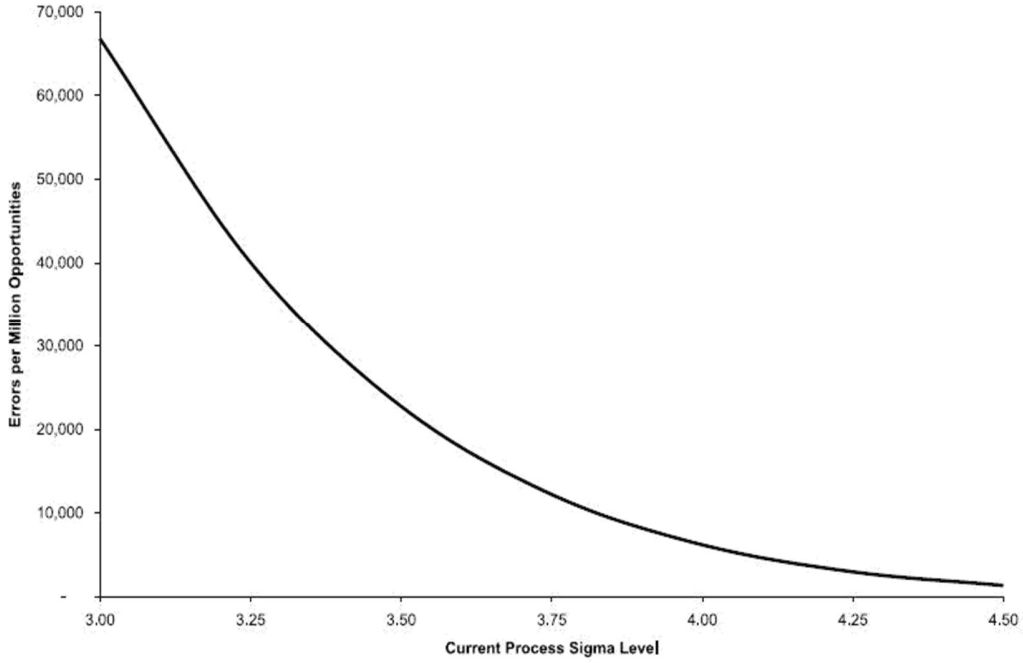

Figure 3: Error rate vs sigma level

SUPPLIER	INPUT	PROCESS	OUTPUT	CUSTOMER
the provider of inputs to our process.	Materials, resources, Data required to execute the process	predefined set of activities that transform an input to a specified output.	product or services that result from the input.	recipient of the process output.

Table 1: SIPOC FRAMEWORK

5.SIX SIGMA ORGANIZATIONAL STRUCTURE

Six sigma organizational structure is belt kind. It consists of Champion, Master Black Belts, Black Belts, Green Belts and Yellow Belts.

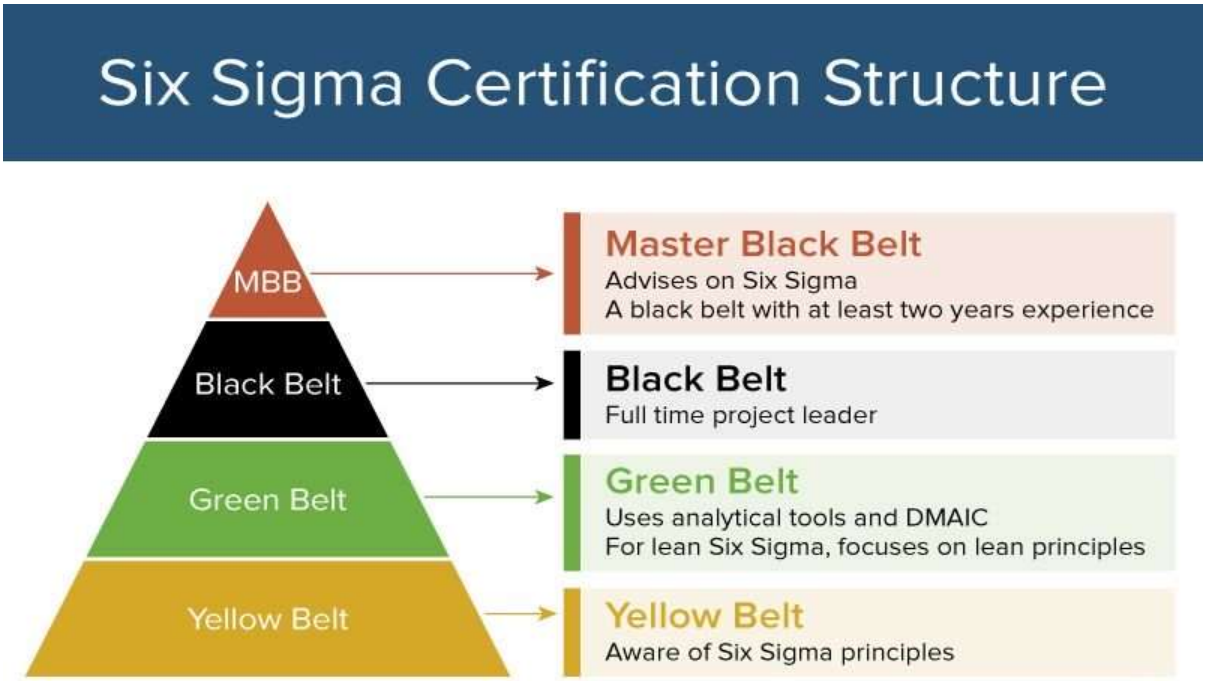

Figure 4: six sigma organizational structure

5.1Yellow belt

- Basic understanding of analytical tools used in the manufacturing process
- Helps in data collection, validation, monitoring and effectiveness of operations
- He is a part-time team member from the supervision department of manufacturing team.
- Provides supporting roles as he is a part time member from the organization.

5.2Green belt

- Drives fewer complex projects although much more than yellow.
- Understand basic working knowledge for Lean 6Sigma project and its corresponding operations.
- Part time team member, but has a much inclusive role when compared to yellow.

- Works under the guidance of black belt, trained to analyze & solve quality problems.

5.3Black belt

- Communicate with the champion regarding the operational program for production.
- Generally full-time person for lean 6Sigma projects and drives complex projects.
- Train and educate green/yellow belts, understanding team dynamics and assigning responsibilities to the team members.

5.4Master black belt

- Supports black belts and is placed above black belt in the hierarchy concerning production.
- Monitors and remove bottlenecks which occurs because of error in manufacturing line.
- Spread expertise about lean six sigma in the organization and its benefits arising from it.
- Assistant and advisor to champions but below him in the hierarchy of the organization.

5.5Champion

- Sponsor of the projects and lean six sigma production and its corresponding operations.
- Takes decision on bottlenecks that have been identified by the above people in the organization.
- Promotes and support projects with resources and allocates them efficiently.
- Leader of the organization.

6.METHODOLOGIES OF SIX SIGMA

6.1DMAIC PROCESS

DMAIC cycle is the core tool for 6Sigma projects and is a closed- loop process that deletes unproductive stages, often concentrates on new measurements/metrics and uses technology for continuous improvement. The DMAIC methodology should be used when a product or process is in existence in the company but is not meeting customer requirements or is not performing adequately.

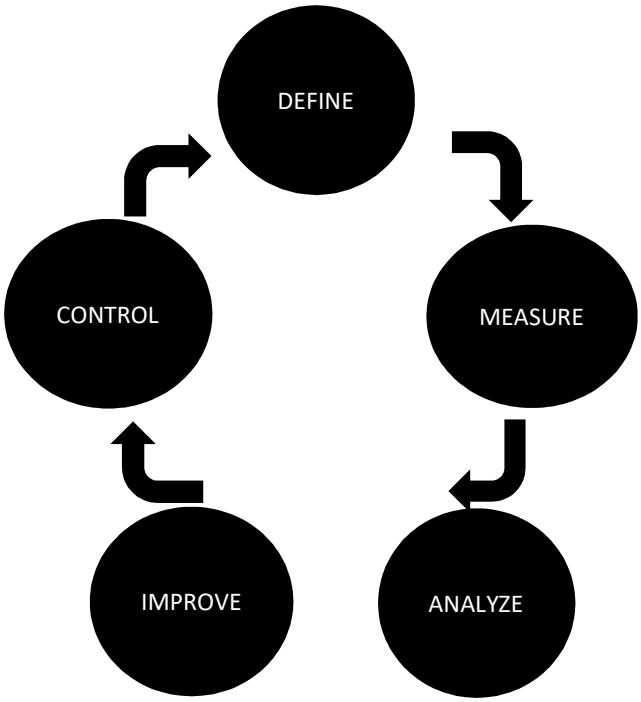

Figure 5: DMAIC Cycle

Define – define the project goal and customer requirements.

Measure- measure the process to determine the present performance.

Analyze- analyze the collected data and find the root cause of defects or variations.

Improve – improve the process by eliminating the main cause of variations

Control – control the process future performance.

steps	Key process
Define	• Define the requirements and expectations of the customer. • Define the project boundaries. • Define the process by mapping the business flow.
Measure	• Develop a data collection plan. • Measure the process to satisfy customer's needs. • Collect and compare data to determine issues and shortfalls.
Analyze	• Determine the variation in the process. • Prioritize opportunities for future improvement • Analyze the cause of defects and source of variation
Improve	• Improve the process to eliminate variations • Develop creative alternatives and implement enhanced plans.
Control	• Develop a strategy to monitor and control the improved process. • Implement the improvements of the systems and structures.

Table 2: phases of DMAIC Process

6.1.1 Define: This phase is to identify the problem, requirements & objectives of the project. The aim of the project should focus on strategic issues which are aligned with the organization's business strategy and the customer's requirements. This phase includes define customer's requirements as they relate to the project. Explicit Customer needs are called as Critical-To-Quality characteristics; develop defect definitions in a precise manner; perform a base line study that gives the general level of the performance measure before the project implementation; build a team character and champion; calculate the financial impact of the problem on the organization and get the approval of the project from the senior management.

6.1.2 Measure: This phase is to understand the present performance by identifying the best way to measure present performance and to start measuring it. These measurements should be useful & relevant to identify and measure the source of variation.

- Identify the performance requirements of relevant Critical-To-Quality characteristics
- Map relevant process with identified input and output so that at each process steps, the relevant outputs and all the potential inputs that might impact each output are connected to each other. create list of potential measurements.
- Analyze capability of the measurement system and establish the base line of process capability.
- Identify where errors can occur in measurements.
- Start measuring the inputs, processes & outputs and collecting data.
- Make sure that the problem exists based on the measurements.
- Refine the problem or aim from the analysis phase (2)

6.1.3 Analyze: This phase is to generate the hypothesis and for validation. Data collected from measure phase is analyzed in this phase so that hypothesis about the main causes of variations in the data can be generated and then validated. In this phase practical business. problems are changed into statistical problems & analyzed as statistical problems. This includes:

- create hypothesis about root causes of variation & critical inputs
- find the root causes and critical inputs that have the significant impact and validate the hypothesis of using multivariate analysis (3)

6.1.4 Improve: This phase concentrates to develop ideas to eliminate the main causes of variation, testing, and solution standardization. This phase includes:

- Find possible ways to eliminate causes of variation and check critical inputs.
- Determine the relationship between variables.

- Define the upper and lower specification limits (based on engineering or customer requirements) of a process to judge the acceptability of a specific characteristic, and if followed strictly results in defect-free products/services and modify the relevant process or optimize the critical inputs. (4)

6.1.5 Control: This phase is to establish standard measures to maintain performance and to solve problems, including problems with the measurement systems. This phase includes:

- Measurement systems validation.
- Check process long term capability.
- Deploy process control with control plan to ensure that problems occurred are not reoccurring again by monitoring the process continuously that creates the products/services. (5)

6.2 DFSS process

DFSS means Design for 6Sigma. The phases of DFSS are not globally recognized like DMAIC. DFSS is an approach than a defined methodology. Because every company or training organizations will define DFSS differently. Many times, a company will implement DFSS to match their business, industry & culture; sometimes they will implement the version of DFSS used by the consulting company supporting in the deployment.

DFSS is used to design or re-design a product/service from the beginning. The anticipated Sigma level for a DFSS product or service in a process is at least 4.5 (1 defect for 1000 opportunities) But can be 6 Sigma or higher depending on the product/service. Producing such a low defect level from product/service launch means that customer requirements (CTQs) must be completely understood before the completion of the design and implementation. (6)

DFSS methodology is called DMADV, and holds the same number of letters, number of phases as the DMAIC methodology.

It consists of 5 phases (Define, Measure, Analyze, Design and Verify):

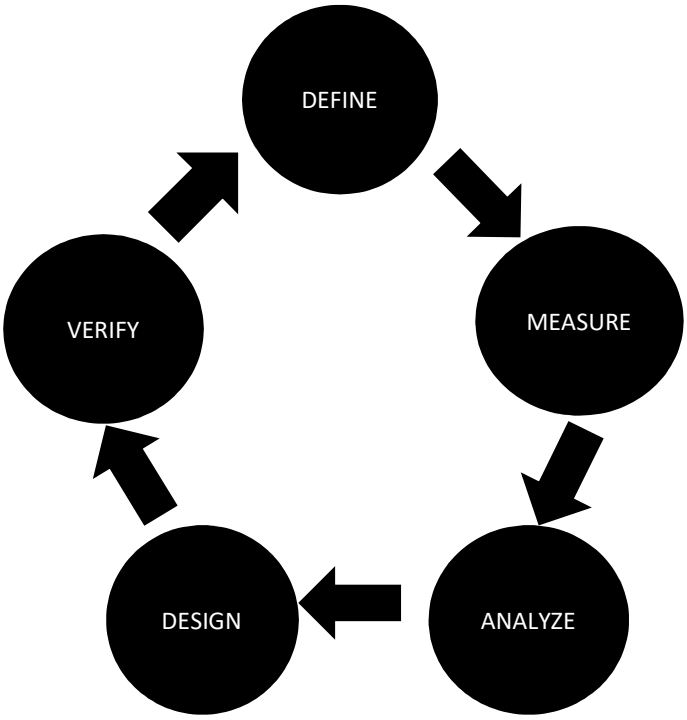

Figure 6: DMADV cycle

Define: define the project goals and customer requirements.

Measure: Measure and determine customer requirements and specifications; benchmark with competitors and industry.

Analyze: analyze the process options to meet the customer requirements.

Design: design the process to meet the customer requirements.

Verify: Verify the design performance and the capability to meet customer needs.

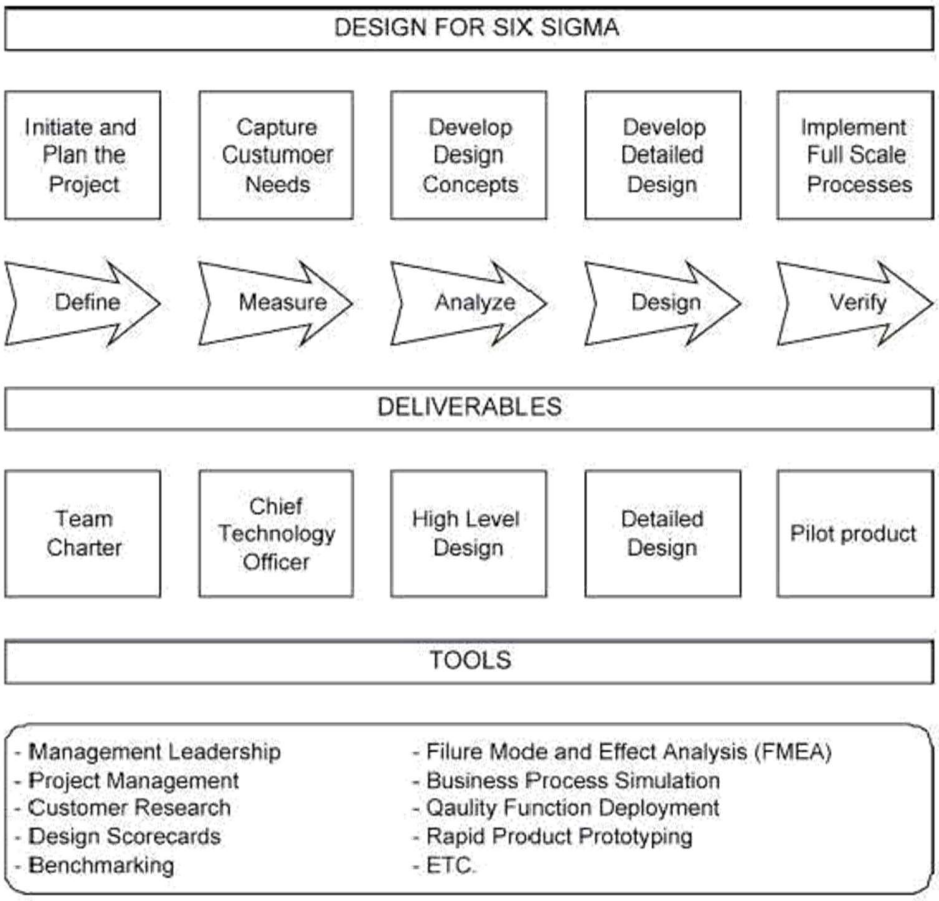

Figure 7: DFSS PROCESS

There are different methodologies to use in DFSS as follows

- **IDOV** (Identify, design, optimize, validate)
- **ICOV** (identify, characterize, optimize, validate)
- **DCOV** (define, characterize, optimize, verify)
- **DMADO** (define, measure, analyze, design, optimize)
- **DMADV** (define, measure, analyze, design, optimize, verify)
- **DCCDI** (define, customer concept, design, implement)

- **DMEDI** (define, measure, explore, develop, implement)

6.3 DIFFERENCE BETWEEN DMAIC AND DFSS

- Ferryanto explains that "DFSS is a methodology that considers the issues highlighted by the end customers at the design stage while DMAIC solves operational issues" (2005).
- The benefits of DFSS cannot be evaluated easily and will be obtained in long time, on the other side benefits of 6Sigma are quantified in financial terms and obtained more quickly.
- El-Haik and Roy clarify the differences that "The D MAIC methodology tends to provide incremental improvements in comparison to DFSS where there can be radical improvements" (2005).
- The projects improved through DMAIC methodology ar e constrained by the assumptions made during the development and design stages, whereas DFSS builds quality into the design by implementing preventive thinking and tools in the products development's process" (Smith,2001).

The DFSS approach can exploit any of the many possible methodologies. The fact is that all these DFSS methodologies use the same advanced design tools which are partly different from DMAIC tools and DMAIC cannot (theory of creative problem solving, axiomatic design, Quality Function Deployment, Failure Modes, and Effects Analysis, benchmarking, Design of Experiments, simulation, statistical optimization, error proofing, Robust Design, etc.).

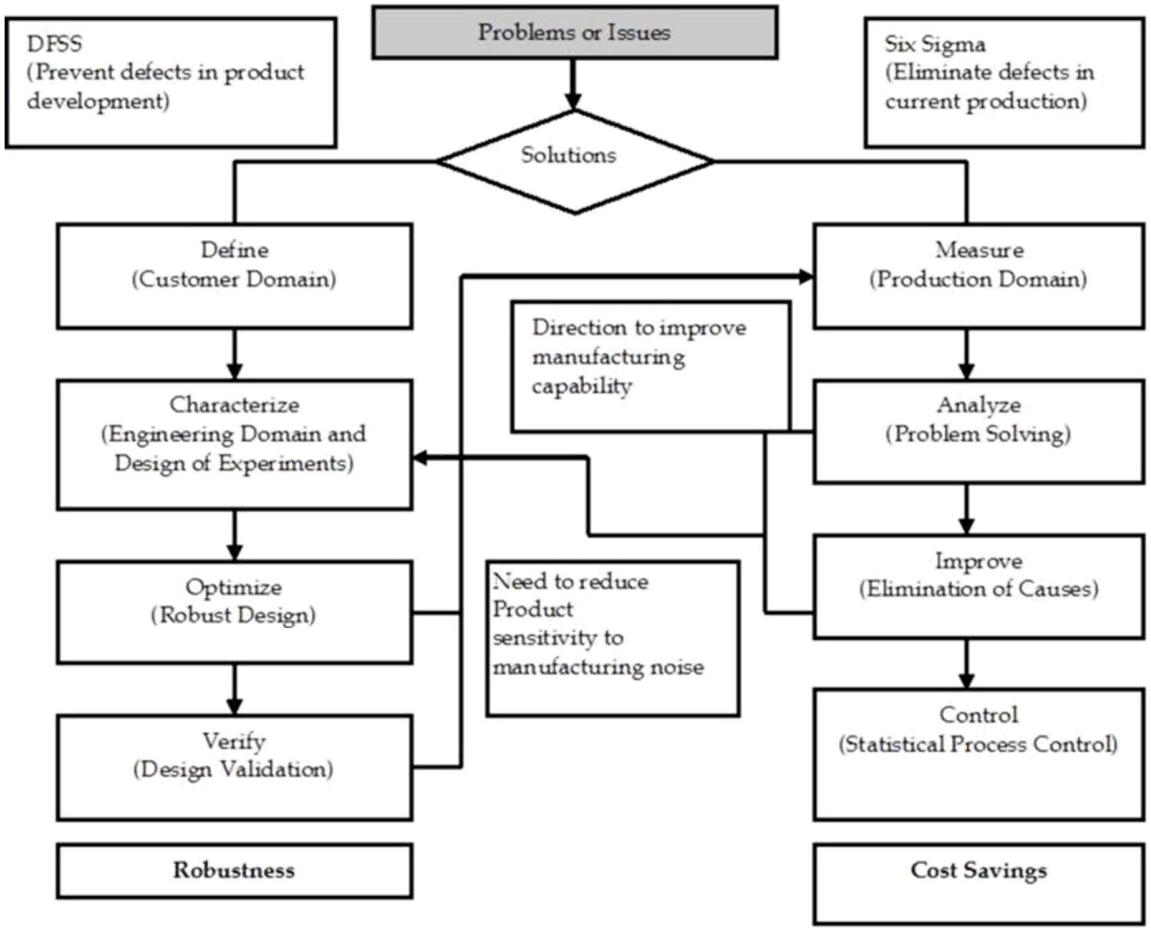

Figure 8: DFSS VS DMAIC

7. ROLE OF SIX SIGMA IN MANUFACTURING SECTOR

Due to great economic fall after world war 2 in both developed and underdeveloped countries all over the world. Each and every organization in the world started to improve their capabilities during the industrial revolution to improve their business. Now a days due to exploitation to global market it is necessary to have business and organizational excellence, which can be done by producing quality in their products at lower costs so they can gain profit.Six Sigma is a breakthrough strategy which can improve the business.

For manufacturing sector it is very important to adopt six sigma methodologies for defect free production and to be globally competitive. Application of six sigma does not matter to the size of the business, six sigma methodologies apply to no matter the size of the business, you can succeed in six sigma as long as you follow the process effectively. It can also be applied to other sectors like services, research and development, transactions and banking etc. six sigma methodologies works in both billion dollars corporation and also in million dollars private companies. By experience it has proven that in small scale industries the development is more visible. On every industrial sector we can see the focus of six sigma.

8. METHODOLOGIES AND TOOLS USED IN MANUFACTURING SECTOR

DMAIC is the commonly used methodology in 6Sigma. It comprises of several tools and techniques at different phases. The success of 6Sigma depends upon the different tools and techniques selection at each phase. From the literature review, observed that in Define phase, process map and project charter tools; in Measure phase the process capability and histogram; in Analyze phase cause and effect analysis, Pareto chart; in Improve phase prioritization matrix, brainstorming and process capability and in Control phase control plan, mistake proofing & control chart was widely used.

8.1 Tools used in six sigma methodologies

The tools used in different phases of DMAIC methodologies

PHASES	OBJECTIVE	TOOLS
DEFINE	Define the opportunity	Cost of poor quality, voice of stakeholder, project charter
MEASURE	Measure current performance	Failure modes and effect analysis, critical to quality requirements

ANALYZE	Analyze root cause of the problems	Histograms, hypothesis tests, regression analysis
IMPROVE	Develop the process to eliminate main causes	Solution selection matrix, to be process maps.
CONTROL	Control the process to sustain the gains	Control charts

Table 3: tools used in different phases of six sigma methodology

9.SIX SIGMA IMPLEMENTATION IN AUTOMOBILE INDUSTRY

In this section we are going to talk about 5 automobile companies and on how they implement six sigma in operational sense and how it affects them about on their strategic sense and sales and customer satisfaction.

9.1 TATA MOTORS

Introduction

Tata motors is the India's largest automobile company. Tata motors has its operations spread in other countries like UK, Thailand, south Africa, Spain and Indonesia. The British iconic brands jaguar and land Rover are acquired by tata motors in 2008.

Tata was founded by JAMSHEDJI TATA in 1945. Tata motors is part of the tata group. Tata motors was founded by RATAN TATA. It started commercial vehicle segment in 1954 and started small vehicle segment in 1992. The headquarter of tata group is located in Mumbai.

COMPETITORS AND CHALLENGES

Tata motors success mostly depends on the number of sales in India, so the success of the vehicles in India is crucial for the company success. The competitors to tata motors in India are Mahindra, Maruti, Chevrolet, Ashok Leyland, Honda, Toyota and Hyundai.

TATA ENGINEERING

In General the qualities defined as a degree or grade of excellence or worth, for the companies To be competitive the most important thing is maintaining the quality, Nowadays days the important for quality has increased a lot. Tata engineering understood the importance of quality better than the most. By the end of March 2001 the company has loss of rupees 500 crores, They initiated comprehensive quality improvement programme in September 2000 and recovered from loss of Rs 500 crores to rupees 28 cross profit in the first quarter of 2002-03.

Tata business excellence model (TBEM)

The core value of this model are to improve organizational performance and capabilities, To improve communication and also to share best practices among the companies groups.

Framework of (TBEM)

- leadership
- strategic planning
- customer and market focus
- measurement analysis and knowledge management
- workforce focus
- process management
- business results

SIX SIGMA UNDER TBEM

The quality improvement is done under the umbrella of the Tata business excellence model it is an open ended framework that helps the business excellence in Group Companies.The main component of quality is 6 Sigma as it is widely proven methodology that helps to produce flawless products on services

The company to follow the 6 Sigma Tata engineering had to eliminate many Sigma defects, the factors that made to eliminate the defects are the competition level , increasing the customer expectations every time and also the shifting of market conditions .The main focus of the six sigma programme was to remain the customer.The Company analyzed their products what customer want from them and the characteristics required by the customer in their products for example if you consider a truck , load capacity, speed ,operation smoothness and fuel efficiency. these are the examples of characteristics of a product . Defining the Critical to quality of a product is important to implement the six Sigma model ,These attributes are included in the manufacturing process parameters which are analyzed to meet the required results in the six Sigma process to meet the customer expectations.

To implement this process the main problem the company faced was in changing that mindset of its people, To succeed the company changed it's way of thinking and also the thinking of their people .

The company conducted blanket communication and training exercise throughout the organization, they initially started this process with higher level position of the organization and then implemented to the rest of the employees

HOW DID THEY DO IT

They implemented strong six Sigma organization and the robust audit and monitoring mechanism to ensure they reached their targets and to sustain it, Large number of teams were involved to implement the project. There was one at high level to see the entire process and other members at the manufacturing plants. To identify and isolate the problems they formed filtering procedure. Initially they gave importance to critical to quality features at the Top level Then they came to the components and later to the supplier level critical to quality characteristics. Three process levels was under the six Sigma, they are manufacturing, support services and plant support services.

9.2 TOYOTA

Introduction

Toyota Motor Corporation is a Japanese automotive manufacturer with its headquarters in aichi, Japan. As of 2017, Toyota had 364,445 employees worldwide and, as of September 2018, was declared the sixth largest company in the world. In the year 2017, Toyota was the largest automobile manufacturer in the world.Toyota has had the history of being the early adopters of Lean Manufacturing. Originally called Just-in-time production, it was built on the approach created by the founder of Toyota, Sakichi Toyoda, his son Kiichiro Toyoda, and engineer Taiichi Ohno. Toyota's organizational philosophies are defined by the principles of TPS(Toyota Production System).

TPS (TOYOTA PRODUCTION SYSTEM)

The pillars of Toyota Production system.

Just-In-time manufacturing also known as PULL strategy is a concept where the entire production process gets initiated only when customer place a order for a car. When the order is placed it goes into the initial step of production in the factory and orders are generated to the suppliers to replenish the spare parts. It is a turnaround from the traditional mass production philosophy.

Jidoka means automation in Japanese language. Any defects arising in the production process are identified by these automated systems, which stops the production line until the defects are sorted out thereby preventing any further escalation in the deviations. Therefore, Toyota had an inbuit quality monitoring system which helps in reduction of further additional quality control process. These systems helped to spot and correct the mistakes occurring in the production line spontaneously.

Figure 9: Jidoka equation

REDUCTION OF INEFFICIENCIES

The three possible inefficiencies in TPS are listed as follows

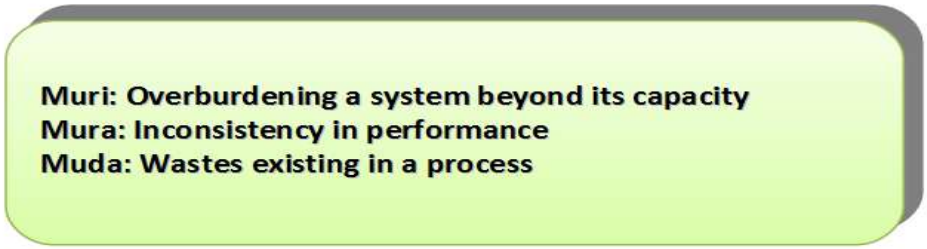

Figure 10: Inefficiency nomination

TPS believes that the above three inefficiencies in the process leads to all kinds of problems like non-adherence to delivery time committed, longer cycle time of production, repeated defects occurring during production and the resulting corrective actions. These problems lead to both increased cost or time and reduce the value of products in the eyes of customers.

PROCESS PRODUCT MATRX

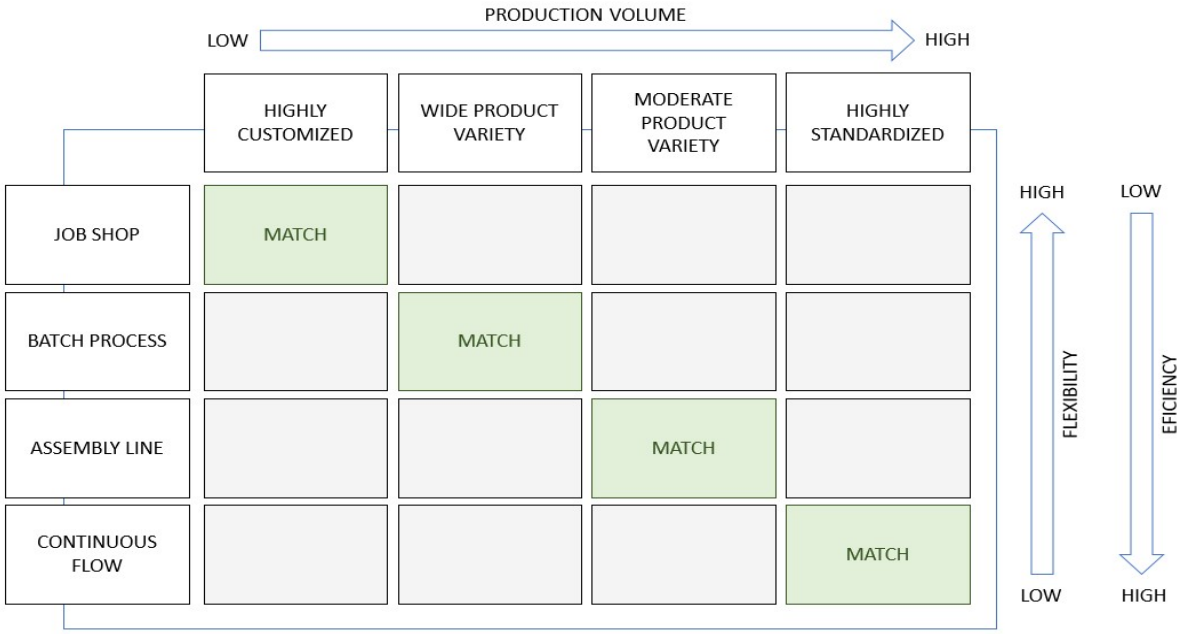

Figure 11: process product matrix

It is a strategy Toyota employs to match the process that is suitable for a particular product. It helps in flexibility in dealing with different markets. On the horizontal axis of the matrix, we have the production volume. They can vary from customized products with high variation between units, to standardized products which are mass produced. On the vertical process, we have the production process for a particular type of product and it also depends on factors like quantity, quality and specifications pertaining to the product. This method is used to find the perfect trade-off between efficiency and flexibility.

SIX SIGMA Strategy of Toyota Production System:

1. Decreased setup times: The higher the setup time, the higher the waste leading to underutilization of labour and machineries thereby reducing the value. By handling procedures, using carts and training employees to carry out their own setups, Toyota has managed to slash setup times from month to hours, and even minutes.

2. Minimum Production: Manufacturing things in bulk sometimes leads to high setup costs, higher capital cost, huge inventories, more lead time and huge defect costs. Toyota has found this ideal method of minimum production to make setup inexpensive and short, now it has become possible for them to manufacture various things in smaller quantities adding to flexibility.

3. Workers Empowerment and Involvement: Toyota had bought about a system to cluster the employees into teams for the purpose of training on specialized tasks. The responsibility of the team was to effectively monitor the internal factory work and to repair specialized equipments. Each team had a head who had to take utmost responsibility for a correct functioning of the team.

4. Dealers Participation: Toyota treats its dealers as effective partners and an integral part of TPS (Toyota production system). Dealers are also well familiar with what Toyota needs and work in accordance with the company in achieving maximum possible customer satisfaction.

9.3 FORD MOTORS

Introduction

Ford is an American company with headquarter in Dearborn, Michigan and is founded by Henry ford. Innovative and dynamic approach in manufacturing is the company's approach. The manufacturing concepts as standardization, assembly lines are implemented by Henry Ford. Ford was a visionary man, he made complex tasks into a simple procedures using specialized tools and the interchangeable parts. The assembly line was great achievement and his work made to grew more radical with continuous improvement. He took the existing process and made them to be more functional efficient and effective. These ideas made to decrease in costs of production and simplifying the labor process and reduce the required workspace.

WHY FORD USED SIX SIGMA PROCESS

The Factors that made ford to initiate six Sigma are

- cost reduction
- improving quality
- poor customer satisfaction rates
- lowering environmental impact by reducing solvent consumption

FORD's APPROACH TO SIX SIGMA

The company started using six sigma in late 90's. They don't want to be just another automobile company they want to be completely a consumer products company. They want to improve the quality standards and improve customer satisfaction rates. They followed consume driven six sigma approach. Ford was first automaker to implement six sigma methodology in large scale. The main problem they had is there are more than 20000 defects possibility in manufacturing their products. Their aim was to reduce to one defect in 14.8 vehicles and they succeeded in achieving it substantially.

PROBLEMS IN SIX SIGMA INITIATIVE FOR FORD

Even though the ford succeeded in achieving six sigma they had to face many obstacles in the implementation, they are

- Employee commitment : The employees both at the top level and senior management did not give their commitment in following the six sigma initially, this problem made them difficult to implement six sigma.
- Time, money and productivity : Lack of commitment lead to poor productivity and key resources like time and money made employee training more difficult.
- Date needs: Six sigma implementation needs a lot of data, as ford was new to six sigma it made them difficult to gather the data in order to implement six sigma successfully initially.

FORD'S SIX SIGMA SUCCESS

Ford approached lean six sigma techniques like date driven problem solving which helps them to solve problems related to waste issues, in the last decade and half they had to eliminate more than 2.19 billion dollars. The company's methodology for quality improvement and waste elimination made huge impact on the company's operations. Their consumer driven six sigma approach made to save them billions of dollars worldwide, helping them to complete 10,000 improvement projects since 2000's. ford's customer satisfaction improved five points. The problems like inadequate productivity, poor use of resources, low customer satisfaction are eliminated by ford by using six sigma.

9.4 GENERAL MOTORS

Introduction

GM(General Motors) is an American automobile company headquartered in Detroit, Michigan, USA that makes and sells cars, SUVs and its related financial services. The company is the largest native automobile manufacturer, and one of the largest in the world. In 2018, it was ranked 10 in the largest American company by revenue by Fortune 500. General Motors has market presence in 37 countries; its core automobile brands are Chevrolet, Buick, GMC, and Cadillac. It's record annual sales was 10 million vehicles in 2016.

LEAN MANUFACTURING

GM post the bankruptcy has given considerable importance to Lean manufacturing and the results have been positive which can be told by increased margins. The initiatives in improving quality, manufacturing operations, IT and logistics have helped GM save billions of dollars. These achievements have been spread globally made possible by working closely with the respective suppliers. Therefor Six Sigma had helped GM to attain possible operational excellence helping them saving costs and increased margins.

THE CADILLAC ESCALADE CASE

In 2015, GM faced a problem with a SUV (Cadillac Escalade) with one if its components notably the 22-inch chrome alloy rims. The problem was traced to the production inability of the supplier to meet GM's target volume. So, it had to adopt a problem solving strategy at various departments inside the company.

After analyzing the problem, it was found that the supplier had committed fewer resources to manufacture the particular component as he had to use to part of the plant to produce rims for the other models in the GM portfolio, resulting in under-utilization of the plant, creating waste and escalating the cost of production thereby reducing the margin.

GM took up this problem and they came up with a re-engineering approach to design a new rim for the SUV in such a way that the supplier producing it would fully utilize his plant to produce the rim resulting in increased production volumes so as to meet the GM's target volume. Complete utilization the plant led to reduction in waste, thereby volumes saw an increase and so as margins.

9.5 NAVISTAR

Introduction

Navistar is an American truck manufacturing company with its headquarters in Lisle, Illinois. The main product portfolio includes commercial trucks, school and commercial buses, chassis for motor homes and diesel engine for trucks, pickup SUV etc. It has a market presence in over 90 countries around the globe. The annual revenue(latest) for the company was around 12.5 billion USD.

SIX SIGMA IMPLEMENTATION

Navistar with the help of a software solution company called ATS Inspect had developed a in-house system that collects quality data, traces the location of the defects in the factory with precise X and Y co-ordinates on panels or within subcomponents.ATS Inspect in the Navistar factory visually presents products to in-line assemblers and inspectors at various points on the plant floor. Touch screen or stylus entry allows fast

accurate capture of quality information. The defect is stored with a photo of the defect to aid repairs and analysis.

Navistar uses the event service application, which alerts personnel via text, e-mail or overhead displays in the plant based on data such as the number of defects per unit, defects per thousand or even safety concerns. This provided the operators with real time defect monitoring so that the time taken to address the issue is considerably reduced. Moreover, Information about the current production is now available to anyone on the Navistar intranet via an internet browser. The real time data is collected and the reaction to production and quality problems is immediate.

SIX SIGMA implementation in Navistar has led to considerable improvements in production quality and higher levels of customer satisfaction.

10. CRITICAL ANALYSIS OF 5 COMPANIES

The 5 companies we spoke about, all of them give considerable importance to SIX SIGMA and its implementation. Along the company's cycle on implementation of six sigma there were evolvements in management commitment, cultural change within the company to adapt, linking six sigma to business strategy and leadership policies. The results of implementing six sigma could be reflected in their respective balance sheets, which appeared positive. Out of 5 companies, 4 were into mass production namely TATA, TOYOTA, FORD and GM. They had to adopt Lean manufacturing along with six sigma to reduce wastages and defects along their production lines, as any defect or error can cause a huge impact not only to the product dealt with, but the whole production line which can prove to be a costly affair. So, the software and systems should be very responsive in order to attend to the problem and not affect the production. In case of NAVISTAR which is a truck manufacturing company does not deal with mass production and six sigma is helpful to increase the overall quality and customer satisfaction. Overall, the implementation of six sigma has led to an overall increase in equipment and labour efficiency which was made possible by high response to any defects or errors, minimalistic consumption of raw materials achieved through reduction of wastage.

These have helped companies to reduce their production costs, improve the quality resulting in better margins

10.1 CRITICAL SUCCESS FACTORS FOR SIX SIGMA IMPLEMENTATION IN MANUFACTURING SECTOR

Lack of training and guiding for successful completion of project are key barrier to implement six sigma, but training programs was very costly.

The critical success factors for six sigma implementation are

- Lack of resources
- Less participation of employees
- Lack of training and knowledge
- Poor six sigma project selection
- Commitment from top management etc

These factors are crucial in six sigma implementation

10.2 KEY PERFORMANCE INDICATORS OF SIX SIGMA IN MANUFACTURING SECTOR

A Key Performance Indicator (KPI) is a measurable value that determines how effectively a company is achieving key business objectives and the goal of organization should be aligned with the 6Sigma initiative. Organizations use KPIs to evaluate their success at reaching targets. some of the important key performance indicators of six sigma in manufacturing sector are

- Cost reduction
- Efficiency
- Quality of the product
- Reduce variation
- Operational cost

10.3 BENEFITS OF SIX SIGMA IMPLEMENTATION

Both small and medium scale industries are observing decrease in process variability, improvement in productivity, improve customer loyalty and minimization of cost to perform operations by using six sigma programs. Co-operation from employees can get by linking six sigma programs to employees, developed work culture and boost morale. Supplier participation can be developed by linking six sigma programs with suppliers in design of the products, decreasing product development cycle, which helps in better implementation of six sigma tools and techniques. Employees will develop and be motivated by sharing six sigma problem solving tools with them. Organizations can gain more volunteering to implement six sigma rather than waiting for it to imposed.

11. CONCLUSION:

Since implementation of six sigma in mid 1980's in Motorola six sigma has significantly evolved and expanded to improve the performance of the processes. Six sigma enables industries to use simple statistical methods for getting operational excellence. Six sigma is a disciplined approach involving of steps: define, measure, analyze improve and control that results in decreasing process variability and zero defects. Implementation of six sigma methodologies are very important in both manufacturing and service sector.

Application of six sigma business strategy is not limited to the size of the organization. Large organizations are having the benefits since last 3 decades by using six sigma business strategy. In case of small industries there are very less documented evidence of six sigma due to lack of understanding and other constraints. For successful implementation of six sigma parent industry have to follow correct methodologies and steps to achieve operational and business excellence. There is scope of improvements for all industries by applying and implementing the improvement strategy.

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