REDUCTION OF REJECTION RATE IN AUTO COMPONENT MANUFACTURING INDUSTRY USING SIX SIGMA METHODOLOGY

A PROJECT REPORT

Submitted By

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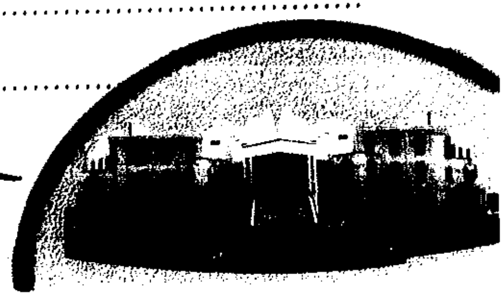

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ABSTRACT

A manufacturing company spends approximately 20% of its revenue for reworking substandard products. Therefore, it not only affects the bottom line but also affects the pricing of the product making it less competitive in the market. Six Sigma has been considered as a powerful business strategy that employs a well structured continuous improvement methodology. To reduce process variability and drive out wastages within the business processes needs an effective application of six sigma tools and expert system.

This work involves proper application of Six Sigma methodology to obtain certain benefits (Reduction of rejection rate).Expert system developed in the present work analyses the common defects in steering knuckle manufacturing line. The expert system is designed using .Net. The knowledge base is open to further addition and modifications. The system can offer intelligence advice or take an intelligent decision about a processing function for avoidance of the rejection. Some of the ways to minimize the defects have been formulated through this project.

ஆய்வு சுருக்கம்

தன்னியக்க பாகங்கள் தயாரிக்கும் நிறுவனத்தில் தயாரிக்கப்படும் தரமற்ற பொருட்களை சரி செய்ய அந்நிறுவனத்தின் வருவாயிலிருந்து ஏறக்குறைய 20% செலவாகிறது. இதனால் பொருளின் தரம் மட்டும்மல்லாது, அதனுடைய உற்பத்தி செலவும் அதிக்கரிக்கின்றது. மேலும் சந்தையில் அப்பொருளின் விற்பனையும் பாதிக்கப்படுகிறது. சிக்ஸ் சிக்மா (Six Sigma) என்பது வலிமையான வியாபார யுக்தியாக கருதப்படுகிறது, ஏனெனில் இது தொடர்ச்சியான வியாபார முன்னேற்றதிற்கு உரிய வழிமுறையாகும். சிக்ஸ் சிக்மா மற்றும் நிபுணர் அமைப்பயை கொண்டு, செயல் பாகத்தின் வேறுபாட்டினையும், கழிவுகளை குறைக்கலாம்.

இந்த ஆய்வில் சிக்ஸ் சிக்மா முறையைக் கொண்டு தரமற்ற பொருட்களின் உற்பத்தி சத்வீதத்தை குறைக்கப்பட்டுள்ளது. ஸ்டியரிங் நக்ல் (Steering Knuckle) உற்பத்தி வரிசையில் உற்பத்தியாகும் குறைபாடுள்ள பொருட்களை கண்டறிய நிபுணர் அமைப்பு உருவாக்கப்பட்டுள்ளது. இந்த நிபுணர் அமைப்பானது டாட் நெட் என்னும் மென்பொருளை பயன்படுத்தி உருவாக்கப்பட்டது, மேலும் இதை நம் வசதிக்கு ஏற்றவாறு மாற்றியமைத்துக் கொள்ளலாம்.

இந்த அமைப்பில் உள்ள நுண்ணறிவு ஆலோசனைகளையும் அல்லது நுண்ணறிவு முடிவுகளையும் செயலாக்கத்திற்கு பயன்படுத்தும்போது அதில் ஏற்படும் நிராகரிப்புகளை குறைக்க பயன்படுகிறது. மேற்கண்ட இந்த ஆய்விலிருந்து மேலே குறிப்பிட்ட சில குறைபாடுகளை குறைக்க சில வழிமுறைகள் கண்டறியப்பட்டுள்ளது.

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LIST OF SYMBOLS

Symbols	**Definition**
μ	Population mean
σ	Population standard deviation
σ^2	Population variance
$\bar{y}$	Sample mean
V	Sample variance
Ri	Range for each subgroup
Φ	Standard cumulative normal distribution
Zi	Short-term and long-term sigma level
S	Sample standard deviation
C_p	Potential process capability index
C_{pk}	Process capability index

LIST OF ABBREVIATIONS

Abbreviation	**Definition**
SK	Steering Knuckle
CL	Center Line
COPQ	Cost of Poor Quality
C_p,C_{pk}	Process Capability Index
CPL	Lower Capability Index
CTQ	Critical-to-quality
TQM	Total Quality Management
DMAIC	Define-Measure-Analyze-Improve-Control
DOE	Design of Experiments
DPMO	Defects Per Million Opportunities
DPO	Defects Per Opportunity
DPU	Defects Per Unit
FMEA	Failure Modes and Effects Analysis
TQC	Total Quality Control
KPIV	Key Process Input Variable
LCL	Lower Control Limit
LSL	Lower Specification Limit
PPM	Parts per million
QC	Quality Control
QFD	Quality Function Deployment
SPC	Statistical Process Control
SQC	Statistical Quality Control
UCL	Upper Control Limit
USL	Upper Specification Limit

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

1.1 QUALITY: THE STORY SO FAR

Right trough the industrial revolution, manufacturers have pursed one goal "how to improve profits?" with a single minded passion. Towards this end, they automated their operations, introduced newer products and tried out cut each other through aggressive pricing. But one factor they could not grapple with was dealing with goods of variable quality. Way back in 1990's they realized that if were to make goods that were consistent in quality a had reasonable durability, then they had better chance of increasing their profits. In mid 1920's a team of researchers headed by Walter shewhart at western electric company began using the statistics route to control product quality by analyzing the manufacturing processes.Shewhart published his findings in 1931. Thus was born modern quality management movement, which has today conclusively engulfed just about every organization, manufacturing or otherwise.

Yet the journey from a company that is conscious of need for quality to a company that actually imbibes quality in every step it takes is a long one. Indeed there still are so many who consider quality as the prime differentiator. For them quality products means better price. Nothing illustrates this more than the collective case o India inc,nearly 50 years of protected regime; planned economy and state run enterprises have ensured that quality never really appeared on company's strategy Rader, and hoe can it? Companies were guaranteed of selling their capacity. Since there was no competition worth naming particularly from abroad, product innovation and service quality were not really essential. Customer will buy anyway.

The opening up of the Indian economy I the early 1990's world class products have forced their way into the Indian markets and Indian business have no options but to 'DO or DIE'. Today the average India consumer has more their backs to the well, Indian companies are desperately gunning to get back what they lost due to complacence. And many have chosen the quality route to achieve this.

1.2 INEFFICIENCIES OF INDIAN MANUFACTURING

In a way it makes sense that they adopt quality route. One of the leading country's leading quality evangelists says companies can improve their profits by almost as much as 255 by simply paying attention to quality and reduction of wastage. According to conservative estimates, Indian companies are still losing more than the five percent of their industrial production by way of poor quality. In an Industrial production of rs.160, 000 crores, that amounts to a staggering Rs.8, 000 crores. The following figure illustrates how the poor quality erodes the value of the product.

Source: MM Journal, July 2000.

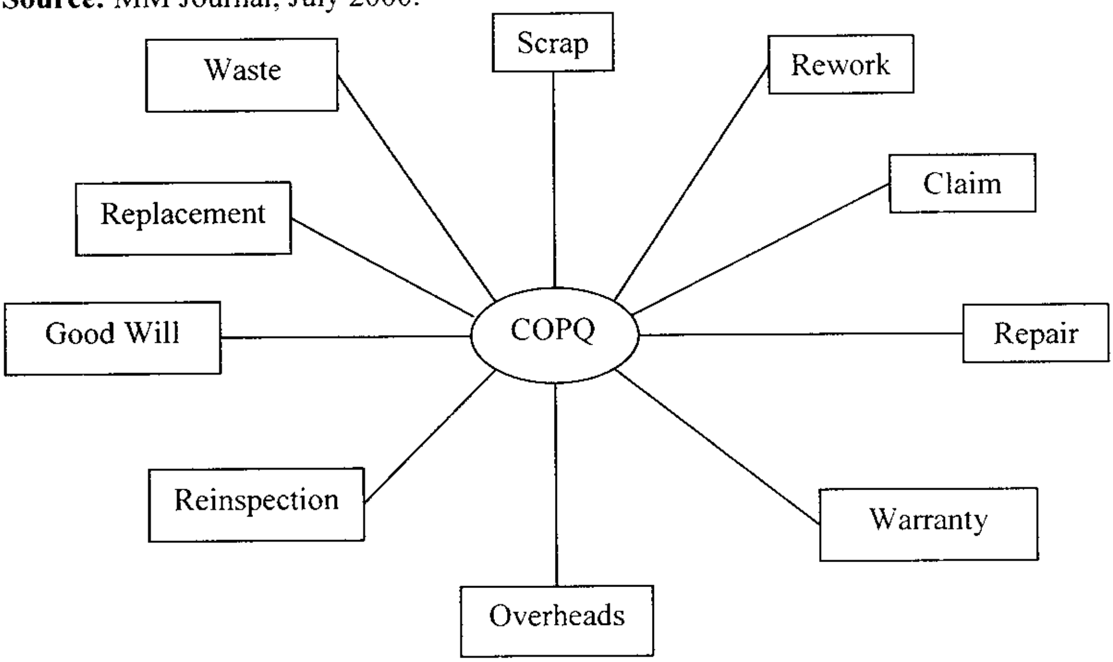


Fig 1.1 How poor quality reduce value

According to the quality guru Phillip Crosby, "a manufacturing company wastes approximately 20% of its revenue by reworking substandard products, which in the service sector goes to 35% of operating expenses. Therefore, it not only affects the bottom line but also affects the pricing of the product making it prevention is barely 4.3% However many companies that do not employ quality standards suffer; they pay a price for it. The cost of poor quality (COPQ), according to one of the estimates in Indian automobile industry, is as high as 40% of sales.

1.3 HOW INDIAN COMPANIES ARE DOING SIX SIGMA?

In the very first year adopting the six sigma way, allied signal saved US$ 175 million and Motorola got a return on investment (ROI) of US $250 million in its world wide operation by employing it. General Electric(GE) has saved $7 billion impressed was GE's jack Welch with six sigma results ,he upped its implementation from 200 projects in 1995 to 6000 project by 1997.Interestingly ,GE is running at a sigma level between four and five currently.

Closer home, Motorola and GE Indian business units have also taken up the implementation with the various degrees of success. Among other Indian pioneers, TELCO, BHEL, Pedilite and Hero Honda have jumped onto the six sigma bandwagon. And due to incessant coverage six sigma remains a hot property in India

Prof .Bhushan dewan of Narsee Monjee of Institute Of Management studies says by and large "Indian companies fall between two to three sigma".

Some of the best Indian companies according to Char les J Loew, managing consultant at Motorola university are operating at just three to four sigma quality levels which is why most of their MNC companies have a minimum 10% cost advantage over Indian companies. Azim premji, chairman of Wipro made a clear on why and how six sigma will propel Wipro into the global elite of world class companies.

Six sigma demands a cultural renaissance; this implies lot of hard work for Indian industries, where quality really suffers as a way of life. Anil Sharma, regional training manager (India), GE international operation was quoted as saying, 'the organization has to create the culture of openness. You can't implement six sigma in an organization where there is a culture of fear or where on the work force. A quality oriented through process should be installed in the organizations. When the quality becomes a way of life for the people who work on the business process, they really produce results rather than when monitored by another entity.

Quality is not a novel concept .For several, it's a way of life. Today the Indian business man on the run, without a choice. It has become a question of survival. Today we see quality movements flowing movements in and out of our business. We have seen our manufacturers adopting ISO standards and Japanese methods like JIT, TPM, and TQM and so on. To day six sigma is the in running.

Chapter 2

Literature Review

CHAPTER 2

LITERATURE REVIEW

Following are the overview of the relevant work done earlier related to the problem identified and the methodology to be adopted to solve the chosen problem for this work. It gives the description of literature reviewed from various research papers published in international and national journals, proceedings of various conferences and books.

Jiemin Wang et al. (1998) is describes the development of a pattern, recognition system designed to detect and analyze various patterns that can occur on statistical quality control charts. The system looks not only for simple patens, such as trend, shift and stratification, but also for superimposed patterns, such as trend + shift. The effect of noise associated with individual patterns is also amassed. The benefits of the approach compared with the alternatives are discussed. Control charts are important statistical process control tools for determining whether a process is run in its intended mode or in the presence of unnatural patterns.

Nandini Das (2000) present how SPC technique was used to solve a quality problem through planned data collection and the use of statistical tool. He was conducted in an integrated aluminum industry in India who was facing poor customer acceptance of one of their high valued product web stock, which was used to produce toothpaste tubes. Pareto analysis used here for showing dragging problem, which resulted in a short length of the toothpaste tube, was the most frequent problem. High and inconsistent coefficient of friction (cof) was identified as the root cause of this dragging problem through planned data collection. A detailed and in depth study was initiated to achieve low and consistent cof. Optimum conditions of the process parameters were obtained using design of experiments viz Taguchi's orthogonal array. The recommendations were validated by confirmatory trials. The desired range of output cof was achieved. The of implementation the occurrences of the dragging problem was substantially reduced.

Selvan Rungasmay et al. (2002) explained SPC and important about it. Statistical process control (SPC) is a powerful technique for monitoring, managing, analyzing and improving the process performance through the use of statistical methods. In this paper, the implementation of SPC is examined and analyzed, based on a survey of 33 manufacturing small and medium enterprises (SMEs). The results presented here are focused on 12 critical success factors (CSFs) identified from the literature. The results of the analysis have shown that the critical success factors, in order of importance, are: management commitment, process prioritization, control charting, teamwork, measurement system evaluation and so on.

Ricardo Banuelas et al. (2003) presented report about design for Six Sigma. Design/redesign approach known as design for six sigma (DFSS). The former follows the phases: define measure, analyze, improve and control. This approach is known as DMAIC methodology and is employed in existing processes/products. On the other hand, design for six sigma employs the IDOV (identify, design, optimize and verify) methodology, during the design/redesign of processes or products. Six sigma has been considered as a philosophy that employs a well-structured continuous improvement methodology to reduce process variability and drive out waste within the business processes using statistical tools and techniques.

Tolga taner et al. (2003) one of the fundamental problems related to SPC implementation is that the only thing taught to engineering community in the academic world in relation to SPC is control charting and types of control charts. Very little has been taught on the management and implementation aspects of SPC. such as where to get started how to get started etc. This problem can be tackled by providing a structured approach (or roadmap) for implementing SPC in organizations. The roadmap assists engineers recognize the amount of effort and initial cost required to undertake SPC implementation. The road map looking is Gain appreciation of SPC from top management and company's senior executives through a one day training program.

Juju Antony (2004) highlights common problems and gaps in the state-of-the-art in DoE and also presents method for optimizing the product life using DoE methodology. He is also used cause and effect diagram for find the earlier failure mode. Experimental design is a very potent tool that assists industrial engineers in tackling quality control problems effectively and economically. The initial attempt on the application of experimental design by the engineering team failed due to lack of awareness of the technique and statistical knowledge required in using the technique.

Kai Yang (2004) provided a report about Multivariate statistical methods. Multivariate statistical methods are seldom applied in Six-Sigma practice as well as quality assurance practice in general. With the advancement of information and computer technology, the barriers in applying multivariate statistical methods are disappearing.

Ricardo Banuelas et al. (2004) provide. A cause study about reducing waste in coating process using six sigma methodologies. It describes in detail how the project was selected and how the six sigma methodologies were applied. IT also shows how various tools and techniques within the six sigma methodology have been employed to achieve substantial financial benefits. Six Sigma has been considered a powerful business strategy that employs a well structured continuous improvement methodology to reduce process variability and drive out waste within the business processes using effective application of statistical tools and techniques.

Rodney McAdam et al. (2004) presented a principles and practice used in the implementation and operation of Six-Sigma. It critically evaluates the application of Six-Sigma in two sites and at four levels within a case organization. Critical contextual factors identified were Management, Communication, Project Management, Six-Sigma training and Rewards and Recognition, which if implemented, could accelerate the integration of Six-Sigma into an organization's

Ron Basu (2004) provided a review of the concept of quality and quality management. The new waves of Six-Sigma, Lean Processes and FIT SIGMA are embedded in the holistic programs of Operational Excellence .We have concluded that success factors are derived from the resultant vector of the mutually contradicting driving forces and straining forces. The critical success factors are: top management commitment, availability of resources, well designed education and training programs for appropriate tools and techniques, and a rigorous project management approach.

Goh et al. (2004) are proposed methods for Improving on the six sigma paradigm and them taken realistic view of the six sigma framework, with an examination of the basis of six sigma and its long-term potential. It is argued that in the dynamic business environment of the twenty-first century, a forward looking organization should aim beyond the six sigma benchmark; thus additional requirements are recommended to fortify the common six sigma approach, leading to an "eight-S" paradigm for sustained excellence in performance.

Kevin Linderman et al. (2005) is presents the goal of improvement team. The tenets of goal theory have been well established as a motivation mechanism in the management literature. However, some quality-management advocates often criticize the use of goals. This research investigates the tension between goals and quality management in the Six Sigma context. They find empirical support that goals can be effective in Six Sigma improvement teams when teams adhere to the Six Sigma tools and method. However, challenging goals are counterproductive when Six Sigma teams do not use the tools and methods rigorously and the differences between quality management and goal theory by showing that the Six Sigma tools and method interact with goals.

Ricardo Banuelas et al. (2005) Examines the differences and similarities of six sigma improvement methodology Compared with the DFSS approach. He represent the analytical hierarchy process(AHP), a multiple criteria decision making technique .for the evolution of six sigma projects in order to determine the when six sigma approach becomes a priority over DFSS.

Chapter 3

Six Sigma Over-View

CHAPTER 3

SIX SIGMA OVER-VIEW

3.1 WHAT IS SIX SIGMA?

Sigma (σ) is a letter in the Greek alphabet that has become the statistical symbol and metric of process variation. The sigma scale of measure 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, when the variation around the target is such that only 3.4 outputs out of one million are defects under the assumption that the process average may drift over the long term by as much as 1.5 standard deviations.

3.1.1 Definition of Six Sigma

Six Sigma may be defined in several ways.

1. Tomkins (1997) defines Six Sigma to be "a program aimed at the near-elimination of defects from every product, process and transaction"

2. Harry (1998) defines 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. It was the result of a series of changes in the quality area starting in the late 1970s, with ambitious ten-fold improvement drives. The top-level management along with CEO Robert Galvin developed a concept called Six Sigma. 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 (Bhote, 1989). The results in terms of reduction in process variation were on-track and cost savings totaled US$13 billion and improvement in labor productivity achieved 204% increase over the

In the wake of successes at Motorola, some leading electronic companies such as IBM, DEC, and Texas Instruments launched Six Sigma initiatives in early 1990s. However, it was to until 1995 when GE and Allied Signal launched Six Sigma as strategic initiatives that a rapid dissemination took place in non-electronic industries all over the world (Hendricks and Kelbaugh, 1998). In early 1997, the Samsung and LG Groups in Korea began to introduce Six Sigma within their companies. The results were amazingly good in those companies. For instance, Samsung SDI, which is a company under the Samsung Group, reported that the cost savings by Six Sigma projects totaled US$150 million (Samsung SDI, 2000a). At the present time, the number of large companies applying Six Sigma in Korea is growing exponentially, with a strong vertical deployment into many small- and medium-size enterprises as well.

As a result of consulting experiences with Six Sigma in Korea, the author (Park et. al., 1999) believes that Six Sigma is a "new strategic paradigm of management innovation for company survival in this 21st century, which implies three things: statistical measurement, management strategy and quality culture". It tells us how good our products, services and processes really are through statistical measurement of quality level. It is a new management strategy under leadership of top-level management to create quality innovation and total customer satisfaction. It is also a quality culture. It provides a means of doing things right the first time and to work smarter by using data information. It also provides an atmosphere for solving many CTQ (critical-to-quality) problems through team efforts. CTQ could be a critical process/product result characteristic to quality, or a critical reason to quality characteristic.

3.2 WHY IS SIX SIGMA FASCINATING?

Six Sigma has become very popular throughout the whole world. There are several reasons for this popularity. First. it is regarded as a fresh quality management strategy which can replace TQC, TQM and others. In a sense, we can view the development process of Six Sigma as shown in Figure 3.1.Many companies which were not quite successful in implementing previous

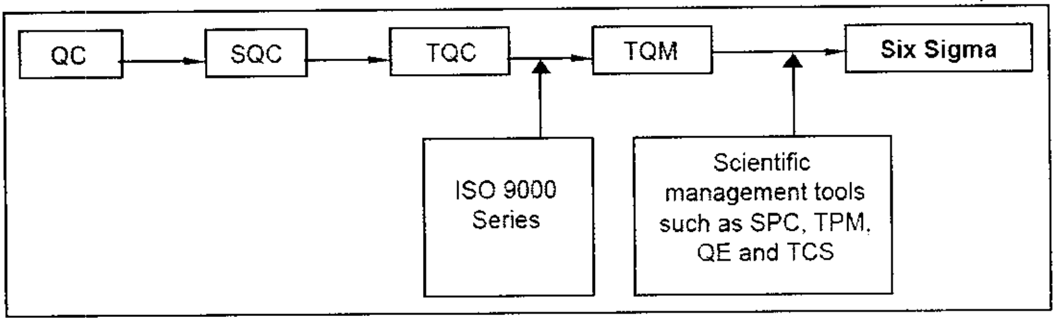


Figure 3.1 Development Process of Six Sigma in Quality management

Six Sigma is viewed as a systematic, scientific, statistical and smarter (4S) approach for management innovation which is quite suitable for use in a knowledge-based information society. The essence of Six Sigma is the integration of four elements (customer, process, manpower and strategy) to provide management innovation as shown in Figure 3.2

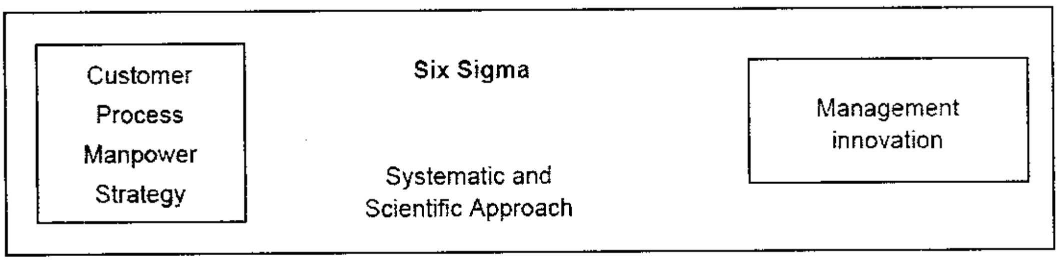


Fig 3.2 Essence of Six Sigma

Six Sigma provides a scientific and statistical basis for quality assessment for all processes through measurement of quality levels. The Six Sigma method allows us to draw comparisons among all processes, and tells how good a process is. Through this information, top-level management learns what path to follow to achieve process innovation and customer satisfaction.

Second, Six Sigma provides efficient manpower cultivation and utilization. It employs a "belt system" in which the levels of mastery are classified as green belt, black belt, master black belt and champion. As a person in a company obtains certain training, he acquires a belt. Usually, a black belt is the leader of a project team and several green belts work together for the project team. Third.

The pace of change during the last decade has been unprecedented, and the speed of change in this new millennium is perhaps faster than ever before. Most notably, the owner has shifted from producer to customer. The producer-oriented industrial society is over, and the customer-oriented information society has arrived. The customer has all the rights to order, select and buy goods and services. Especially, in e-business, the customer has all-mighty power. Competition in quality and productivity has been ever-increasing. Second-rate quality goods cannot survive anymore in the market. Six Sigma with its 4S (systematic, scientific, statistical and smarter) approaches provides flexibility in managing a business unit.

3.3 KEY CONCEPTS OF MANAGEMENT

The core objective of Six Sigma is to improve the performance of processes. By improving processes, it attempts to achieve three things: the first is to reduce costs, the second is to improve customer satisfaction, and the third is to increase revenue, thereby, increasing profits.

3.3.1 Process

A general definition of a process is an activity or series of activities transforming inputs to outputs in a repetitive flow as shown in Figure 3.3. For companies, the output is predominantly a product taking the form of hardware goods with their associated services. However, an R&D activity or a no manufacturing service activity which does not have any form of hardware goods could also is a process.

Literally, the inputs can be anything from labor, materials, machines, decisions, information and measurements to temperature, humidity and weight. Inputs are either control factors which can be physically controlled, or noise factors which are considered to be uncontrollable, too costly to control, or not desirable to control. The model of Six Sigma in terms of processes and improvement is that y is a function of x and v:

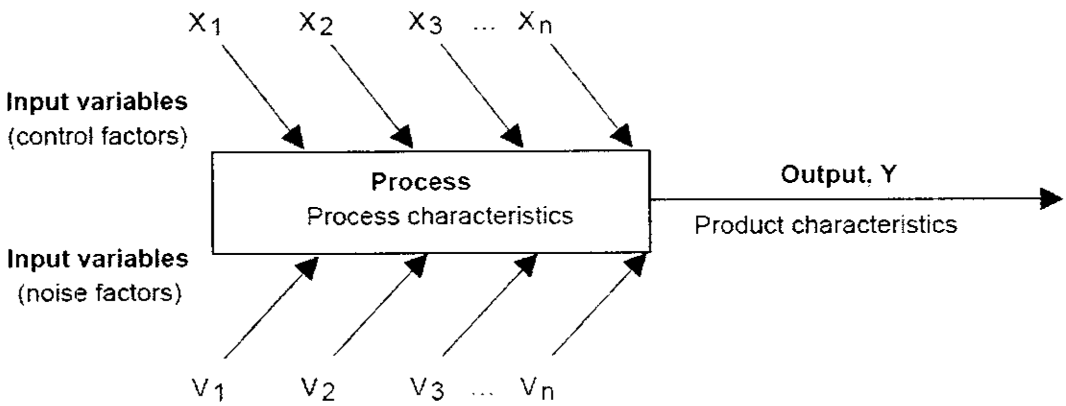


Fig 3.3 the process with inputs and outputs

$y = f(x1, x2... xk; v1, v2... vm)$

Here, *y* represents the result variable (characteristics of the process or product), *x* represents one or more control factors, and *v* represents one or more noise factors. The message in the process is to find the optimal levels of *x* variables which give desired values of *y* as well as being robust to the noise factors *v*. The word "robust" means that the *y* values are not changed much as the levels of noise factors are changed. Specified against which data can be collected. These characteristics are used for measuring process performance.

To measure the process performance, we need data for the relevant characteristics. There are two types of characteristics: continuous and discrete. Continuous characteristics may take any measured value on a continuous scale, providing continuous data, whereas discrete characteristics are based on counts, providing attribute data. Examples of continuous data are thickness, time, speed and temperature. Typical attribute data are counts of pass/fail, acceptable/unacceptable, good/bad or imperfections.

3.3.2 Variation

The data values for any process or product characteristic always vary. No two products or characteristics are exactly alike because any process contains many sources of variability. The differences among products may be large, or they may be immeasurably small, but they are always present. The variation, if the data distribution that best fits the observations. This distribution can be characterized by:

- Location (average value)
- Spread (span of values from smallest to largest)
- Shape (the pattern of variation – whether it is symmetrical, skewed, etc.)

Variation is indeed the number one enemy of quality control. It constitutes a major cause of defectives as well as excess costs in every company. Six Sigma, through its tracking of process performance and formalized improvement methodology, focuses on pragmatic solutions for reducing variation.

Variation, which is the most important, relates to "how close are the measured values to the target value," cycle time to "how fast" and yields to "how much." Cycle time and yield are the two major elements of productivity.

It is common to classify them into two types: common causes and special causes. Common causes refer to the sources of variation within a process that have a stable and repeatable distribution over time. This is called "in a state of statistical control." The random variation, which is inherent in the process, is not easily removable unless we change the very design of the process or product, and is a common cause found everywhere. Common causes behave like a stable system of chance causes. If only common causes of variation are present and do not change, the output of a process is predictable.

3.3.3 Cycle Time, Yield and Productivity

Every process has a cycle time and yield. The cycle time of a process is the average time required for a single unit to complete the transformation of all input factors into an output. The yield of a process is the amount of output related to input time and pieces. A more efficient transformation of input factors into products will inevitably give a better yield. Productivity is used in many different aspects. National productivity can be expressed as GDP/population where GDP input." Productivity for industrial activity has been defined in many ways, but the following definition proposed by the European Productivity Agency (EPA) in 1958 is perhaps the best.

- Productivity is the degree of effective utilization of each element of production.
- Productivity is, above all, an attitude of mind. It is based on the conviction that one can do things better today than yesterday, and better tomorrow than today.

It requires never-ending efforts to adapt economic activities to changing conditions, and the application of new theories and methods. It is a firm belief in the progress of human beings.

3.3.4 Customer Satisfaction

Customer satisfaction is one of the watchwords for company survival in this new 21st century. Customer satisfaction can be achieved when all the customer requirements are met. Six Sigma emphasizes that the customer requirements must be fulfilled by measuring and improving processes and products, and CTQ (critical-to-quality) characteristics are measured on a consistent basis to produce few defects in the eyes of the customer. Having identified the CTQ requirements, the customer is usually asked to specify what the desired value for the characteristic is, i.e., target value, and what a defect for the characteristic is, i.e., specification limits. This vital information is utilized in Six Sigma as a basis for measuring the performance of processes.

3.4 MEASUREMENT OF PROCESS PERFORMANCE

Among the dimensions of the process performance triangle variation is the preferred measurement for process performance in Six Sigma. Cycle time and yield could have been used, but they can be covered through variation. For example, if a cycle time has been specified for a process, the variation of the cycle time around its target value will indicate the performance of the process in terms

The distribution of a characteristic in Six Sigma is usually assumed to be Normal (or Gaussian) for continuous variables and Poisoning for discrete variables. The two parameters that determine a Normal distribution are population mean, μ, and population standard deviation, σ. The mean indicates the location of the distribution on a continuous scale, whereas the standard deviation indicates the dispersion.

3.4.1 Standard Deviation and Normal Distribution

The population parameters, μ(population mean), σ (population standard deviation) and σ^2 (population variance), are usually unknown, and they are estimated by the sample statistics as follows.

$\bar{y}$ = sample mean = estimate of μ

s = sample standard deviation = estimate of σ

V = sample variance = estimate of σ^2

If we have a sample of size n and the characteristics are $y1, y2 ... yn$, then,μ,σ and $\sigma^2$are estimated by, respectively

$$\bar{y} = \frac{y_1 + y_2 + \ldots + y_n}{n} \quad \text{------------------------------- Eq 3.1}$$

$$s = \sqrt{V} \quad \text{------------------------------- Eq 3.2}$$

$$V = \frac{\sum_{i=1}^{n} (y_i - \bar{y})^2}{n - 1} \quad \text{------------------------------- Eq 3.3}$$

However, if we use an $\bar{x} - R$ control chart, in which there are k subgroups of size n, σ can be estimated b

$$s = \frac{\bar{R}}{d_2} \quad \text{--------------------------------- Eq 3.4}$$

Where

$\bar{R} = Rib / n$, and Ri is the range for each subgroup and

d_2 is a constant value that depends on the sample size n. The values of d_2

Many continuous random variables, such as the dimension of a part and the time to fill the order for a customer, follow a normal distribution. Figure 3.4 illustrates the characteristic bell shape of a normal distribution where X is the normal random variable; u is the population mean and σ is the population standard deviation. The probability density function (PDF), $f(x)$, of a normal distribution is

$$f(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{1}{2}\left[\frac{x-\mu}{\sigma}\right]^2} \quad \text{------------------------- Esq. 3.5}$$

Where we usually denote $X \sim N, (\mu\ \sigma^2)$

When $X \sim N(\mu , \sigma^2)$, it can be converted into standard normal variable $Z \sim N(0, 1)$ using the relationship of variable transformation

$$Z = \frac{X - \mu}{\sigma} \quad \text{------------------------------- Esq. 3.6}$$

Whose probability density function is?

$$f(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}z^2} \quad \text{------------------------------ Esq. 3.7}$$

3.4.2 Defect Rate, ppm and dpmo

The defect rate, denoted by p, is the ratio of the number of defective items which are out of specification to the total number of items processed (or inspected). Defect rate or fraction of defective items has been used in industry for a long time. The number of defective items out of one million inspected items is called the ppm (parts-per-million) defect rate. Sometimes a ppm defect rate cannot be properly used, in particular, in the cases of service work. In this case, a DPMO (defects per million opportunities) is often used. DPMO is the number of defective opportunities which do not meet the required specification out of one million possible opportunities.

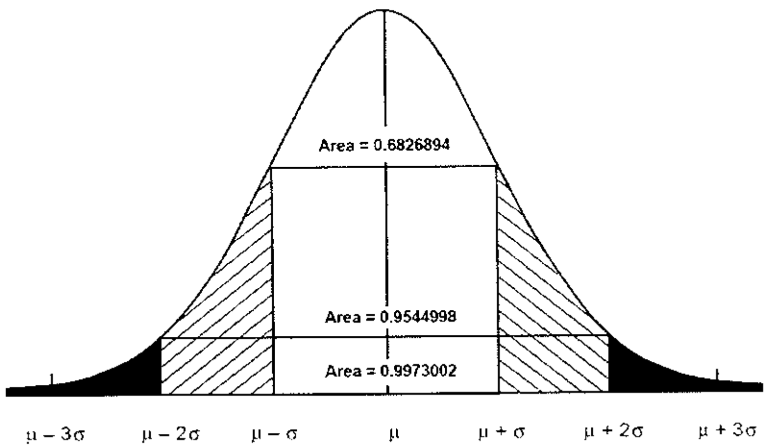


Fig 3.4 Normal Distribution

3.4.3 Sigma Quality Level

Specification limits are the tolerances or performance ranges that customer's demand of the products or processes they are purchasing. Figure 3.5 illustrates specification limits as the two major vertical lines in the figure. In the figure, LSL means the lower specification limit, USL means the upper specification limit and T means the target value. The sigma quality level (in short, sigma level) is the distance from the process mean (μ) to the closer specification limit.

In practice, we desire that the process mean to be kept at the target value. However, the process mean during one time period is usually different from that of another time period for various reasons. This means that the process mean constantly shifts around the target value. To address typical maximum shifts of the process mean, Motorola added the shift value $\pm 1.5\sigma$ to the process mean. This shift of the mean is used when computing a process sigma level as shown in Figure 3.5. From this figure, we note that a 6σ quality level corresponds to a 3.4ppm rate. Table 3.1 illustrates how sigma quality levels would equate to other defect rates and organizational performances. Table 3.1 shows the details of this relationship when the process mean is $\pm 1.5\sigma$ shifted.

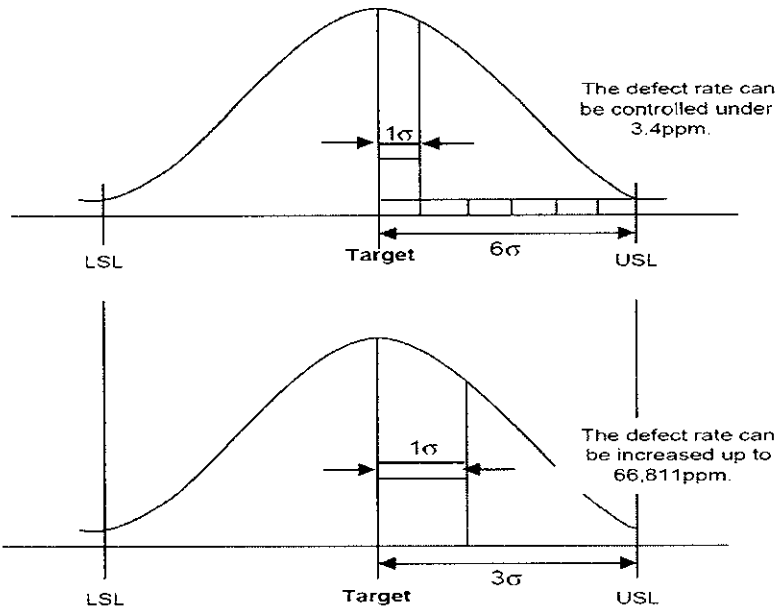


Fig 3.5 Sigma quality levels of 6σ and 3σ

3.4.4 Process Capability Index

There are two metrics that are used to measure the process capability. One is potential process capability index (C_p), and another is process capability index (C_{pk})

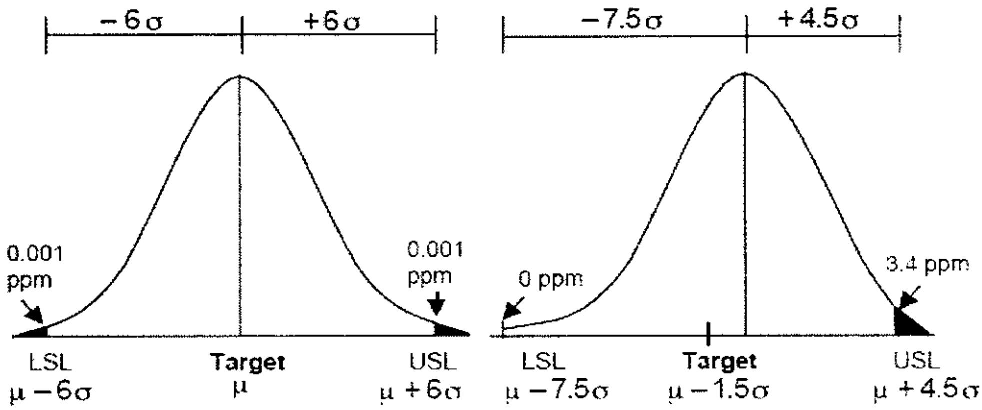


Fig 3.6 Effects of a 1.5 σ shift of process mean when 6 σ quality levels is achieved

3.4.5 Potential Process Capability Index (C_p)

C_p index is defined as the ratio of specification width over the process spread as follows.

Table 3.1 PPM changes when Sigma quality level change

Sigma quality level	Process mean, fixed		Process mean, with 1.5σ shift	
	Non-defect rate (%)	Defect rate (ppm)	Non-defect rate (%)	Defect rate (ppm)
σ	68.26894	317,311	30.2328	697,672
2σ	95.44998	45,500	69.1230	308,770
3σ	99.73002	2,700	93.3189	66,811
4σ	99.99366	63.4	99.3790	6,210
5σ	99.999943	0.57	99.97674	233
6σ	99.9999998	0.002	99.99966	3.4

$$Cp = \frac{\text{specification width}}{\text{process spread}} = \frac{USL - LSL}{6\sigma}$$ -------------------- Esq. 3.8

The specification width is predefined and fixed. The process spread is the sole influence on the C_p index. The population standard deviation, σ, is usually estimated by the equations (3.1) or (3.2). When the spread is wide (more variation), the C_p value is small, indicating a low process capability. When the spread is narrow (less variation), the C_p value becomes larger, indicating better process capability. The C_p index does not account for any process shift. It assumes the ideal state when the process is at the desirable target, centered exactly between the two specification limits.

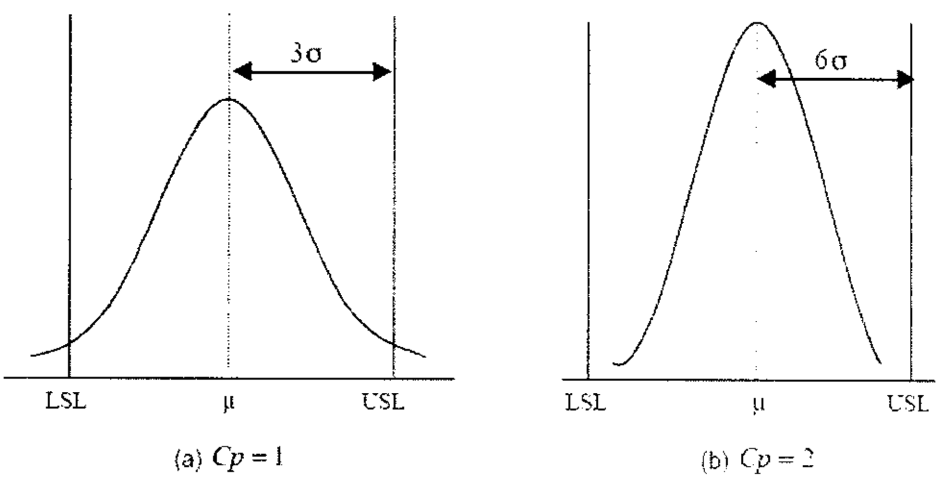


Fig 3.7 Process Capability Index

3.4.6 Process Capability Index (C_{pk})

In real life, very few processes are at their desirable target. An off-target process should be "penalized" for shifting from where it should be. C_{pk} is the index for measuring this real capability when the off-target penalty is taken into consideration. The penalty or degree of bias, k is defined as:

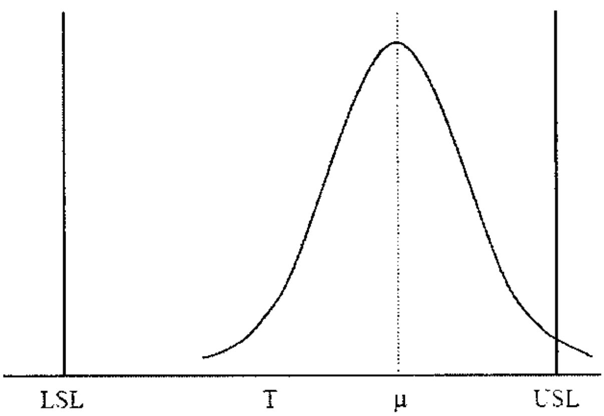
$$k = \frac{|\text{target}(T) - \text{process mean}(\mu)|}{\frac{1}{2}(USL - LSL)} \qquad \text{------------------------ Esq. 3.9}$$

And the process capability index is defined as:

$$Cpk = Cp(1-k) \qquad \text{--------------------- Esq. 3.10}$$

When the process is perfectly on target, k = 0 and C_{pk} = C_p.Note that C_{pk} index increases as both of the following conditions are satisfied.

- The process is as close to the target as possible (k is small).
- The process spread is as small as possible (process variation is small)



$$Cpk = (1-k)\frac{USL - LSL}{6\sigma},$$

$$k = \frac{|T-\mu|}{\frac{USL - LSL}{2}}$$

= degree of bias

Fig 3.8 Process Capability Index C_{pk}

We have dealt with the case when there are two specification limits. USL and LSL. However, when there is a one-sided specification limit. or when the

$$Cpk = \frac{|\text{process mean}(\mu) - \text{closer specification limit from } \mu|}{3\sigma}$$ ------ Esq. 3.11

We often use upper capability index (*CPU*) and lower capability index (*CPL*). *CPU* is the upper tolerance spread divided by the actual upper process spread. *CPL* is defined as the lower tolerance spread divided by the actual lower process spread

$$CPU = \frac{USL - \mu}{3\sigma}, \qquad CPL = \frac{\mu - LSL}{3\sigma}$$ --------------- Esq. 3.12

C_{pk} *in* (3.15) may be defined as the minimum of *CPU* or *CPL*. It relates the scaled distance between the process mean and the closest specification limit to half the total process spread.

C_{pk}=min (CPU, CPL) -------------------- Esq. 3.13

3.5 RELATIONSHIP BETWEEN CP, CPK AND SIGMA LEVEL

If the process mean is centered, that is $\mu = T$, and $USL - LSL = 6\sigma$, then from (3.9), it is easy to know that $C_p = 1$, and the distance from μ to the specification limit is 3σ. In this case, the sigma (quality) level becomes 3σ, and the relationship between C_p and the sigma level is

Sigma Level=3 x C_p

However, in the long run the process mean could shift at most by 1.5σ to the right or left hand side, and the process mean cannot be centered, that is, it can be biased. In the long-term, if the process mean is 1.5σ biased and $C_{pk} = 1$ then the sigma level becomes $3\sigma + 1.5\sigma = 4.5\sigma$. Figure 3.2 shows a 6σ process with typical 1.5σ shift. In this case, $C_{pk} = 1.5$ and the sigma level is 6σ. In general, the relationship between C_{pk} and the sigma level is

Sigma Level= 3 x C_{pk}+1.5, 3 x (Cpk+1.5)

Hence, in the long-term the relationship between C_p and C_{pk}

Table 3.2 Relationship between *Cp*, *Cpk* and Sigma level

Cp	*Cpk* (5.1σ shift is allowed)	Quality level
0.50	0.00	1.5 σ
0.67	0.17	2.0 σ
0.83	0.33	2.5 σ
1.00	0.50	3.0 σ
1.17	0.67	3.5 σ
1.33	0.83	4.0 σ
1.50	1.00	4.5 σ
1.67	1.17	5.0 σ
1.83	1.33	5.5 σ
2.00	1.50	6.0 σ

3.5.1 Sigma Level for Discrete Data

When a given set of data is continuous, we can easily obtain the mean and standard deviation. Also from the given specification limits, we can compute the sigma level. However, if the given set of data is discrete, such as number of defects, we should convert the data to yield and obtain the sigma level using the standard normal distribution in Appendix table A-1. Suppose the non-defect rate for a given set of discrete data is y. Then the sigma level Z can be obtained from the relationship Φ (z) = y, where Φ is the standard cumulative normal distribution

$$\Phi(z) = \int_{-\infty}^{z} \frac{1}{\sqrt{2\pi}} e^{-\frac{w^2}{2}} dw$$

$$= y$$ ----------------- Esq. 3.14

For example, if $y = 0.0228$, then $z = 2.0$ from Appendix A-1. If this y value is obtained in the long-term, then a short-term sigma level should be considering the 1.5σ mean shift. Here, *Zs* and *Zl mean* a short-term and long-term sigma level, respectively. The methods of computing sigma levels are explained below for each particular case.

$$Z_s = Z_l + 1.5$$ ------------------------------ Esq. 3.15

3.5.2 Case of DPU

Suppose that the pinhole defects in a coating process have been found in five units out of 500 units inspected from a long-term investigation. Since the number of defects follows a Poisson distribution, and DPU = 5/500 = 0.01, the probability of zero defect is from (1.9) and the corresponding Z value is Z = 2.33. Since the set of data has been obtained for a long-term, the short-term sigma level is Zs = 2.33 + 1.5 = 3.83

$$y = e^{-DPU} = e^{-0.01} = 0.99005$$

3.5.3 Case of Defect Rate

If r products, whose measured quality characteristics are outside the specifications, have been classified to be defective out of n products investigated, the defect rate is $p = r/n$, and the yield is $y = 1 - p$. Then we can find the sigma level Z from the relationship. For example, suppose two products out of 100 products have a quality characteristic which is outside of specification limits. Then the defect rate is 2 percent, and the yield is 98 percent. Then the sigma level is approximately z = 2.05.

If this result is based on a long-term investigation, then the short-term sigma level is $Zs = 2.05 + 1.5 = 3.55$.

Fig 3.3 Relationship between sigma level, defect rate, yield

Sigma level (considering 1.5σ shift)	Z value from standard normal distribution	Defect rate (ppm)	Yield (%)
2σ	0.5	308,770	69.1230
3σ	1.5	66,811	93.3189
4σ	2.5	6,210	99.3790
5σ	3.5	233	99.9767
6σ	4.5	3.4	99.99966

Chapter 4

Methodology

CHAPTER 4

METHODOLOGY

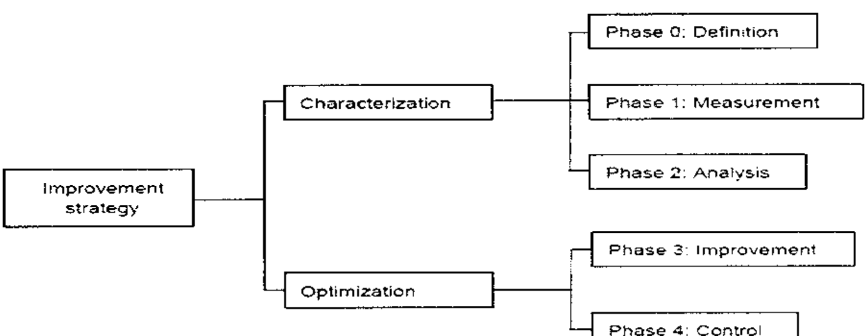
4.1 INTRODUCTION

In this work, DMAIC process, six sigma tools and quality control tools, expert system (Software developed for this work) are used to reduce a rejection rate in auto component manufacturing industry. Some Six sigma tools are Pareto diagram, Cause and Effect diagram, control charts, Graphs (Line graph, bar graph and Pie chart).

The major activities of DMAIC process are as follows,

- To study and analysis the existing system
- To identify the problem(s) and factors for higher rejection rate
- Then analysis will carryout for the factors affecting parts rejection
- Check whether the factors are all capable
- Particular time period, continuous reading for rejection parts will take. then chart will prepare
- If the factors are not capable, then cause and effect diagram will do
- Then root causes and causes for the rejection parts is identified
- Then necessary action will carryout to reduce the rejection parts

4.2 PHASES OF DMAIC PROCESS



4.3 FLOWCHART OF DMAIC PROCESS

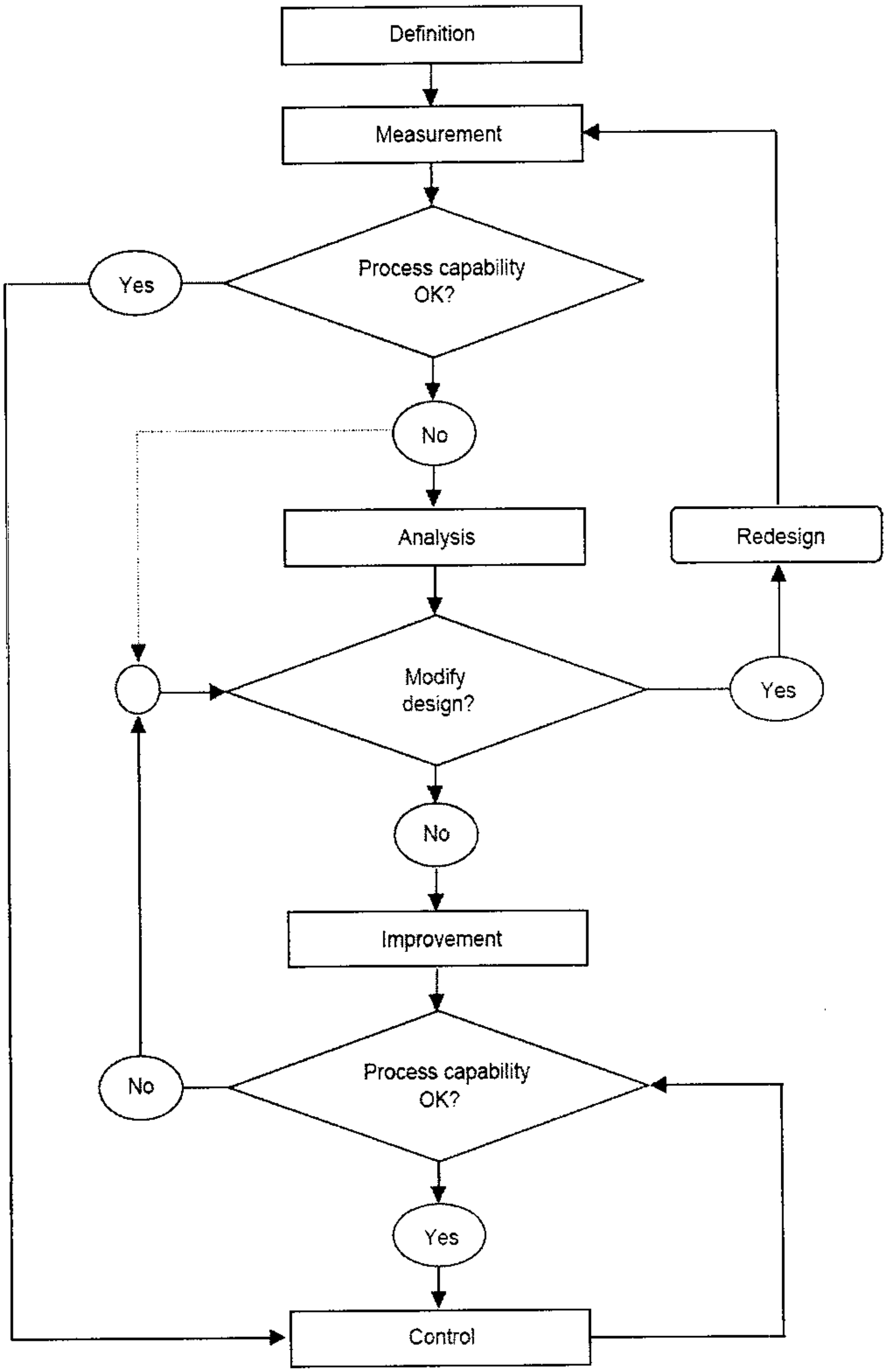


Figure 4.2 Flowchart of DMAIC process

4.4 BASIC QC AND SIX SIGMA TOOLS

4.4.1 Cause-and-Effect Diagram

An effective tool as part of a problem-solving process is the cause-and-effect diagram, also known as the Ishikawa diagram (after its originator) or fishbone diagram. This technique is useful to trigger ideas and promote a balanced approach in group brainstorming sessions where individuals list the perceived sources (causes) with respect to outcomes (effect).

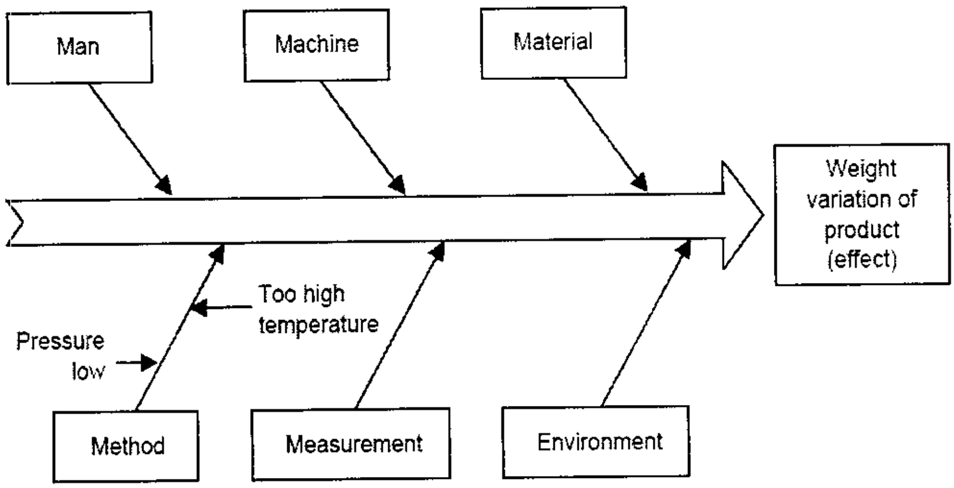


Figure 4.3 Cause-and-Effect diagrams

As shown in Figure 2.3, the effect is written in a rectangle on the right-hand side, and the causes are listed on the left-hand side. They are connected with arrows to show the cause-and-effect relationship. When constructing a cause-and-effect diagram, it is often appropriate to consider six main causes that can contribute to an outcome response (effect): so-called 5M1E (man, machine, material, method, measurement, and environment).

4.4.2 Control Chart

The control chart is a very important tool in the "analyze, improve and control" phases of the Six Sigma improvement methodology. In the "analyze" phase, control charts are applied to judge if the process is predictable; in the "improve" phase, to identify evidence of special causes of variation so that they process is under control. There are various types of control charts, depending on the nature and quantity of the characteristics we want to supervise.

4.4.3 Histogram:

It is meaningful to present data in a form that visually illustrates the frequency of occurrence of values. In the analysis phase of the Six Sigma improvement methodology, histograms are commonly applied to learn about the distribution of the data within the results Ys and the causes Xs collected in the measure phase and they are also used to obtain an understanding of the potential for improvements.

4.4.4 Pareto Chart

In the Six Sigma improvement methodology, the Pareto chart has two primary applications. One is for selecting appropriate improvement projects in the define phase. Here it offers a very objective basis for selection, based on, for example, frequency of occurrence, cost saving and improvement potential in process performance.

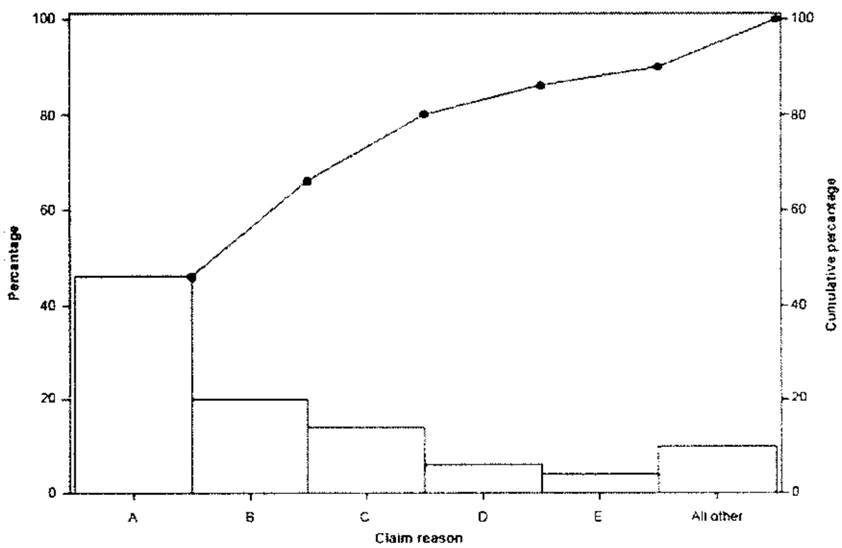


Figure 4.4 Pareto chart

The other primary application is in the analyze phase for identifying the

4.5 EXPERT SYSTEM

4.5.1 Artificial Intelligence

Artificial intelligence is a part of a computer field concerned with developing intelligent computer programs and also artificial intelligence is the study of how to make computers to do things ,which at the moment ,people do better .It is the art of doing things without human intelligence.

4.5.2 Artificial Intelligence Applications

Applied artificial intelligence research concentrates on several different areas, most notably natural language processing, expert system, and game playing.

4.6 INTRODUCTION OF EXPERT SYSTEM

Expert systems are sophisticated computer programs that manipulate knowledge to solve problems to solve problems efficiently and effectively in a narrow problem area

The process of building an expert system is often called knowledge engineering .It typically involves a special form of interaction between the expert system builder, called the knowledge engineer, and one or more human experts in some problem area. The knowledge engineer "extracts' from the human their procedures, strategies and rules of thumb for problem solving and builds this knowledge into the expert system.

An expert system is a person who because of training and experience is able to do things, the rest of us cannot. Experts are not only proficient but also smooth and efficient in the actions they take. Experts know many things, tricks and caveats for applying what they know to problems and tasks. They are also good at recognizing problems they face as instances of types with which they are familiar. The behavior of experts I the body of operative knowledge have termed expertise.

4.6.1 Organization of Expert System

The knowledge in an expert system is organized in a way that separates the knowledge about how to solve problems or knowledge about how to in tract with the user. This collection of knowledge is called knowledge base, while the general problem solving knowledge is called the inference engine. The program with knowledge organized this way is called a knowledge based system.

4.6.2 Features of an Expert System

The feature of an expert system is following,

- Explicit and accessible
- High level expertise
- Predictive modeling
- Institutional memory
- Training facility

4.7 STRUCTURE OF AN EXPERT SYSTEM

4.7.1 Knowledge Base

The knowledge base in an expert system is shown in figure 2.1 contains facts (data) and rules (other representations) that use those facts as the basis for decision making. Having the domain knowledge separate makes it easier for the knowledge developer to design procedures for manipulating this knowledge.

4.7.2 Inference Engine

The inference engine contains an interpreter that decides how to apply the rules to infer new knowledge and a scheduler that decides that decides the order In which the rules should be applied. An expert system must have both the appropriate knowledge and the means to use the knowledge effectively to be considered skilled task. An inference engine contains knowledge about how to make effective use of the domain knowledge.

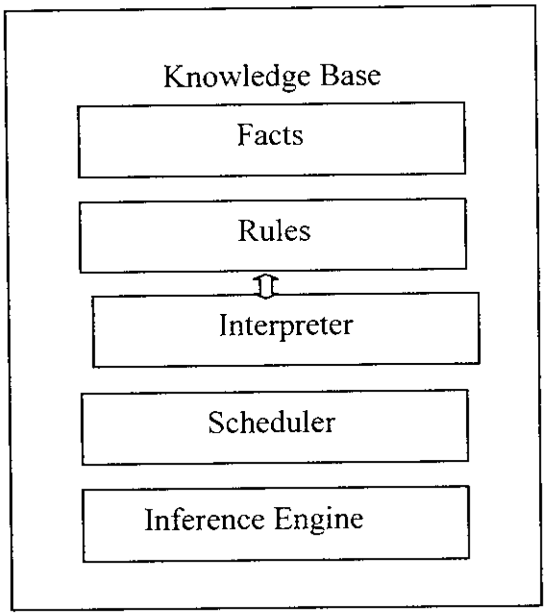


Fig 4.5 Structure of an Expert System

4.8 STAGES OF EXPERT SYSTEM DEVELOPMENT

The process of expert system development can be divided into five stages they are explained briefly.

4.8.1 Identification

The knowledge engineer attempts to extract fundamental concepts from the cases presented in order to develop a "first pass" problem description. The domain expert then suggests changes to the description and provides knowledge engineer with additional knowledge.

4.8.2 Conceptualization

This stage involves analyzing the problem further to ensure that it specifics as well as generalities are understood. The knowledge engineer frequently creates a diagram of the problem to depict graphically the relationships between the objects and processes in the problem domain.

4.8.3 Formalization

In this stage the problem is connected to its proposed solution. an expert system by analyzing the relationships in the conceptualization stage.

4.8.4 Implementation

During this stage, the formalized concepts are programmed into the computer that has been chosen for the system development.

4.8.5 Testing

Testing provides an opportunity to identify the weaknesses in the structure and implementation of the system and to make appropriate corrections.

4.9 ACTIVITIES OF EXPERT SYSTEM

The following Table 4.1 shows the activities of expert system.

Table 4.1 Activities of expert system

CATEGORY	PROBLEM ADDRESSED
Interpretation	Inferring situation descriptions from sensor data
Prediction	Inferring likely consequences of given situation
Diagnosis	Inferring system malfunctions from observable
Design	Configuring objects under constraints
Planning	Designing actions
Monitoring	Comparing observations to expected outcomes
Debugging	Prescribing remedies for malfunctions
Repair	Executing plans to administer prescribed remedies
Instruction	Diagnosing, debugging and repairing behavior
Control	Governing overall system behavior

4.10 REPRESENTATION OF KNOWLEDGE

How the knowledge is structured in a program is known as knowledge representation. Some of knowledge representation techniques are,

4.10.1 Rule-Based Methods

Rule based knowledge representation centers on the use of IF condition the IF part of a rule, the action specified by the THEN part of the rule is performed. This action may affect the problem area, may direct program control or may instruct the system to reach a conclusion. Rules provide a natural way for describing processes driven by a complex and rapidly changing environment. A set of rules can specify how the program should react to the changing data without requiring detailed advance knowledge about the flow of control.

4.10.2 Frame Based Methods

Both frame and semantic nets are frame based representation methods frame based knowledge representation uses a network of nodes connected by relations and organized into a hierarchy. Each node represents a concept that may be described by attributes and values associated with the node. Nodes low in the hierarchy automatically inherits properties of higher level nodes. These methods provide a natural efficient way to categorize and structure taxonomy

4.11 EXPERT SYSTEM TOOLS

Expert system tools used is as follows

- Frame based languages
- FRL
- DPL
- Logic-based languages
- ALICE
- Object-oriented language
- KBS
- ROSS
- Procedure oriented languages
- PSL
- Rule-based languages
- ARS
- ART

4.12 APPLICATION OF EXPERT SYSTEMS

Some of the applications of expert systems are as follows

- Engineering
- Manufacturing
- Medicine
- Military

4.12.1 Manufacturing

IMACS assists managers in a compute systems manufacturing environment with paperwork management, capacity planning, inventory management and other tasks related to managing the manufacturing processes.

ISIS constructs factory job shop schedules. The system selects a sequence of operations needed to complete an order, determines start and end times and assigns source to the operations.

4.12.2 Engineering

NPPC helps nuclear power plant determine the cause of some abnormal event by applying rules in conjunction with a model of point operation. The system diagnoses the causes of accident and then suggests procedures for correcting the problem. Reactor assists reactor operators in the diagnosis and treatment of nuclear reactor accidents by monitoring instrument readings, such as water flow and contaminant radiation level looking for deviations from normal operating conditions.

Chapter 5

Case Study

CHAPTER 5

CASE STUDY IN AUTOCOMPONENT MANUFACTURING INDUSTRY

This chapter outlines the study of various issues of six sigma while attempting to implement it in a project of analyzing and rectifying the various defects of steering knuckle production line, in a live industrial ground

5.1 COMPANY PROFILE

Sakthi Auto Component limited is one among the multifaceted sakthi group situated at Mukasi Pallagoundenpalayam, Erode district, Tamilnadu state, India, established in the year 1983.The head office of SACL is located in Germany.

Sakthi auto has a capacity to produce 24000 tones/annum of S.G.IRON castings on a 100 acre land. ACL is major supplier of critical components to passenger car manufacturers. The components are Steering knuckles, Brake drums, Brake discs, Hubs, Brake calipers, Carriers, Differential cases Manifolds and Slack adjuster etc. Other products of sakthi auto component limited are Iron castings including Steering knuckles, Brake drums, Brake disc.

Presently the suppliers of these components are made to Maruthi udyog ltd., Hyundai, Ind auto ltd., Ford, Honda siel cars and Tractors and farm Equipments Ltd. Etc. Sakthi Auto Components limited has been awarded the INDUSTRIAL SAFETY AWARDS for three consecutive years.

It has also been recognized by Maruthi Udyog Limited as a first class critical component vendor.

5.1.1 Leading Customers

Following Company's are most leading customers of Sakthi Auto Component limited.

- Maruthi udyog Ltd
- Hyundai
- Ind Auto Ltd
- Ford
- Honda siel cars and tractors
- Farm Equipments Ltd
- General Motors
- Delphi

5.2 PROBLEM IDENTIFICATION

In this competitive world today, where nothing but change is constant, it is very much necessary to gain and maintain a competitive advantage. Sakthi Auto Component limited is one among the multifaceted sakthi group situated at mukasi pallagoundenpalayam, erode district, tamilnadu state, India, established in the year 1983.

Sakthi auto has a capacity to produce 24000 tones/annum of S.G.IRON castings on a 100 acre land. SACL is major supplier of critical components to passenger car manufacturers. The components are Steering knuckles, Brake drums, Brake discs, Hubs, Brake calipers, Carriers, Differential cases ,Manifolds and Slack adjuster etc.Steering knuckles manufactured here experiences a large rejection rate. These knuckles are manufactured in three production lines via FMS, SPM &TAL line. The quality control team of SACL found a place in the committee constituted for quality improvement of the above component production line. For further analysis.

Data has been collected for last three months production and rejection statistics for the steering knuckle production line from the company`s record. Maximum number of rejection occurs in tall line trough collection of rejection rate data`s on previous 3 months (September, October, and November). Hence Tall line is considered for this project. Six sigma methodologies are proposed here to reduce rejection rate. Various quality control tools are employed to solve this problem.

Fig 5.1 Steering Knuckle

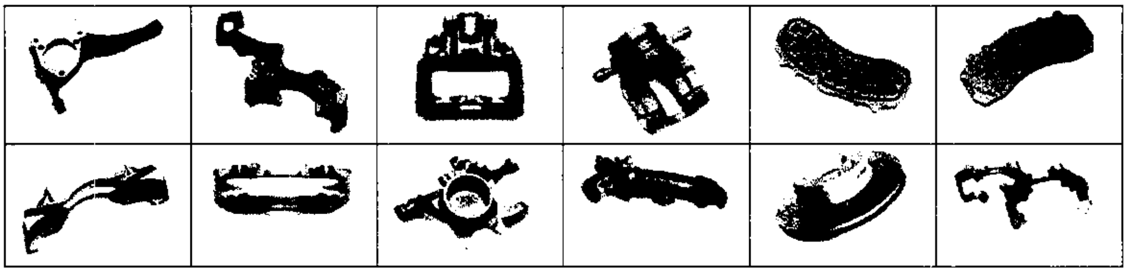


Fig 5.2 Products of Sakthi Auto components Limited

5.3 PRODUCT PROFILE

5.3.1 Chemical Composition of Steering Knuckle

This is the average value of casting line of steering knuckle chemical standards. This standard is varied to other type of steering knuckle. The following steering knuckle chemical standards only for maruthi udyog Ltd.

Table 5.1 Chemical Standards of steering knuckle casting line

S. No.	Elements	SG	Grey
1	%C	3.610	3.250
2	%Si	2.610	1.710
3	%Mn	0.273	0.740
4	%P	0.020	0.040

S. No.	Elements	SG	Grey
6	%Cr	0.270	0.196
7	%Ni	0.020	0.014
8	%Cu	0.003	0.003
9	%Sn	0.130	0.251
10	%Mo	0.004	0.024
11	%Mg	0.002	0.002
12	%Pb	0.050	0.000
13	%Zn	0.004	0.004
14	%Zr	0.001	0.003
15	%V	0.002	0.001
16	%W	0.002	0.002
17	%As	0.004	0.015
18	%Co	0.004	0.003
19	%B	0.000	0.001
20	%Sb	0.003	0.000

5.3.2 SK Specification

Check Method : Bore dial

Clamping Pr. : 10Kgf/Cm^2

Cutting Speed : 200 ~ 300

Feed : 0.1

Material : FCD – 450

Parameters : Inner Diameter

Part name : KS Mode B "LH/RH"

Part No : 45151 M76 G00

Sample Size/Freq : 5p/hr

Specification : 62.0(± .20)

5.3.3 Permissible Error

Maximum Permissible error when comparing with primary & type (Internal standards).

Table 5.2 Permissible Error

S. No.	Elements	PE %
1	Carbon	± 0.080
2	Silicon	± 0.080
3	Manganese	± 0.050
4	Phosphorous	± 0.010
5	Sulfur	± 0.080
6	Magnesium	± 0.010
7	Nickel	± 0.010
8	Aluminum	± 0.010
9	Chromium	± 0.050
10	Copper	± 0.005
11	Tin	± 0.005
12	Molybdenum	± 0.005
13	Lead	± 0.002
14	Zinc	± 0.002
15	Titanium	± 0.005

5.4 DATA COLLECTION WITH CHART REPRSENTATION

Every hour 5 pieces are tested manually in Tal line production .The pieces are inspected through Bore dial method. Various check methods are used for manual inspection. Some of check methods are Bore dial, Micro meter, SNAP gauge, Vernier caliper .The following tabular column shows a data of inner diameter data of SK

Table 5.3 Hourly data collection of Steering Knuckle Production Line

1	61.96	61.95	61.95	61.96	61.96	61.95	61.96	61.96	61.96	61.95	61.96
2	61.96	61.96	61.96	61.96	61.96	61.95	61.95	61.96	61.96	61.95	61.96
3	61.96	61.96	61.96	61.96	61.96	61.95	61.95	61.95	61.95	61.96	61.96
4	61.96	61.95	61.96	61.96	61.96	61.95	61.96	61.95	61.95	61.96	61.96
5	61.96	61.95	61.96	61.95	61.95	61.96	61.96	61.96	61.96	61.95	61.96
XB	**61.96**	**61.95**	**61.96**	**61.96**	**61.96**	**61.96**	**61.95**	**61.95**	**61.96**	**61.95**	**61.96**
R	**0.002**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.004**	**0.002**	**0.003**	**0.004**	**0.002**

Table 5.3 Hourly data collection of Steering Knuckle Production Line

12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
61.96	61.95	61.96	61.96	61.95	61.96	61.96	61.95	61.96	61.95	61.95	61.96
61.96	61.95	61.96	61.96	61.96	61.96	61.96	61.95	61.96	61.95	61.95	61.95
61.96	61.96	61.95	61.95	61.96	61.96	61.95	61.95	61.96	61.96	61.95	61.96
61.95	61.95	61.95	61.95	61.96	61.96	61.95	61.95	61.96	61.96	61.96	61.96
61.96	61.96	61.96	61.95	61.95	61.95	61.95	61.96	61.96	61.96	61.95	61.96
61.96	**61.95**	**61.96**	**61.95**	**61.96**	**61.96**	**61.95**	**61.95**	**61.96**	**61.95**	**61.95**	61.96
0.002	**0.002**	**0.004**	**0.004**	**0.003**	**0.003**	**0.004**	**0.004**	**0.002**	**0.004**	**0.002**	**0.004**

From the data collection,

Formula for SPC chart

5.4.1 $\bar{X}$-Chart:

$\bar{X}$ =61.959

R=0.0029

1. UCL= $\bar{X}$ +A_2R.
   UCL=61.960
2. LCL= $\bar{X}$ -A_2R
   LCL=61.956

The process condition and capability are founded through $\bar{X}$ chart and R-Chart.This charts are shown in below diagrams.

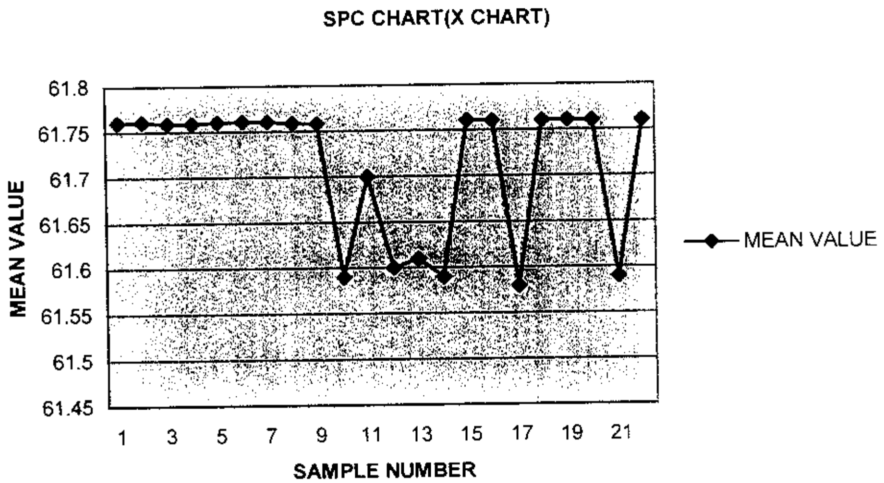


Fig 5.3 SPC Chart (X) for Steering knuckles

5.4.2 R-Chart:

1.UCL=D_4R
UCL=0.00618

2. LCL=D_3R
LCL=0

(Note: The D_3, D4 Value Taken from appendix table 2)

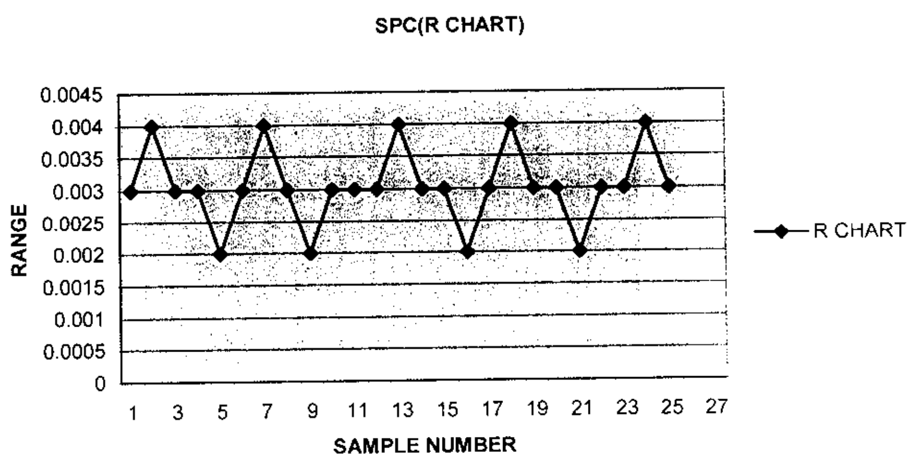


Fig 5.4 SPC Chart(R) for Steering knuckles

5.5 PROBLEM /DATA ANALYSIS

As a next step, here studied the distribution of effects in the components by observing the presence of defects in last three months records of rejection rate sheet at the customer end and also final inspection of steering knuckle production line .The percentage of defects are plotted by Pareto diagram.

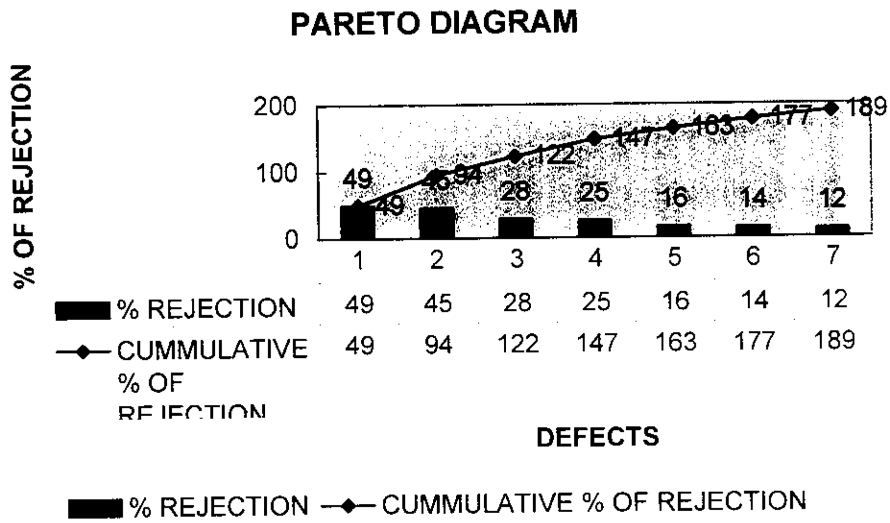


Fig 5.5 Pareto Diagram for Tal line (M/C) rejection

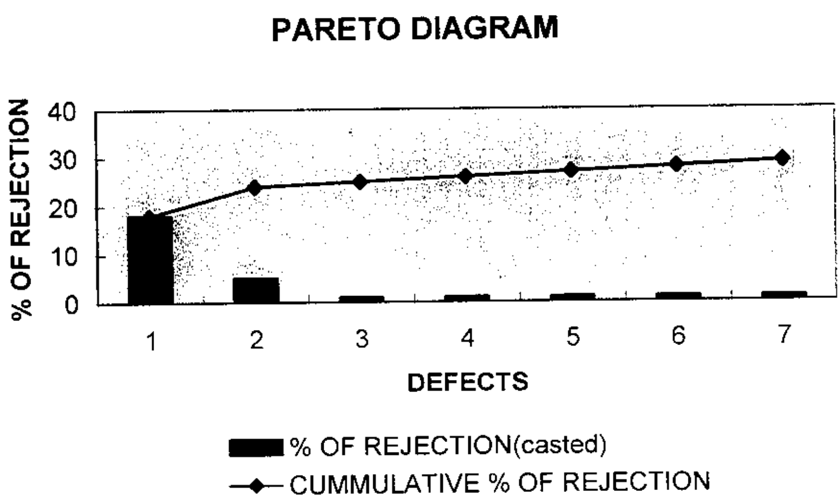


Fig 5.6 Pareto Diagram for Tal line (casting) rejection

From this Pareto diagram ,founded major defects of the steering knuckle, that are King pin arm wall thickness undersize ,Front bore sand inclusion , Inner diameter blow hole, Outer diameter blow hole ,Front bore blow hole ,Front bore over size, Under diameter blow hole, 26 uneven, Outer diameter sand drop, Inner diameter sand drop, Caliber arm blow hole.

5.6 PROCESS CAPABILITY

σ = R/D2
σ =0.OO12

CP= (USL-LSL)/6σ

CP=5.5

CPK=min of ((USL-X)/3σ, (X-LSL)/3σ)

CPK=5.2

Table 5.4 Process Capability

STABILITY		CAPABILITY	
OK	**NOT OK**	**OK**	**NOT OK**
✓		✓	

From this calculation and control charts,

CP value of the process is 5.2 >1.67, so the process is capable.

5.7 MAJOR DEFECTS

- Front bore sand inclusion
- King pin arm wall thickness undersize
- Front bore blow hole
- Under diameter blow hole
- Outer diameter sand drop
- Inner diameter sand drop

Inner diameter blow hole
Outer diameter blow hole
Front bore over size
26 uneven
Caliber arm blow hole

5.8 LEVEL OF SIGMA ON PROCESS

As stated earlier in the chapter2, the sigma can be used as quality scale in which for each sigma value the quality rate is calibrated as follows

Defects per unit (DPU) is may be calculated as

- Defects Per unit(DPU)=

  $\frac{\text{Total number of defectives observed}}{\text{Total units inspected /produced}}$

  DPU=0.0484138

Table 5.5 Six sigma level

Sigma level with 1.5 σ shift	Defect rate(ppm)	Yield(%)
2σ	308,770	69.12300
3σ	66,811	93.31890
4σ	6,210	99.37900
5σ	233	99.97670
6σ	3.4	99.99966

Then defects per opportunities may be calculated as

- Defects per opportunities (DPO)=DPU/opportunities(m)
- DPMO=DPO*1000,000

  = 0.0484138*1000,000

  = 48413.8

From the standard sigma to DPMO conversion in appendix 1, the corresponding sigma value can be obtained as,

For DPMO = 48413.8 the sigma value is = 3.15

5.9 CAUSE AND EFFECT DIAGRAM

A cause and effect diagram is a picture composed of line and symbols designed to represent a meaningful relationship between an effect and its causes. It is sometimes referred to as an Ishikawa or fish bone diagram of its shape.

Cause and effect diagrams are used to investigate either a bad effect or take action to correct the causes that are responsible. For every effect, there are likely to be numerous causes. The cause and effect diagram with the effect on the right and causes on the left. The effect is the quality characteristics that needs improvement causes are some time broke down into the major causes of work methods, materials, measurement, people, equipment and the environment. Other major causes could be used for service type problems depending on the effect. Each major cause is further subdivided into numerous minor causes.

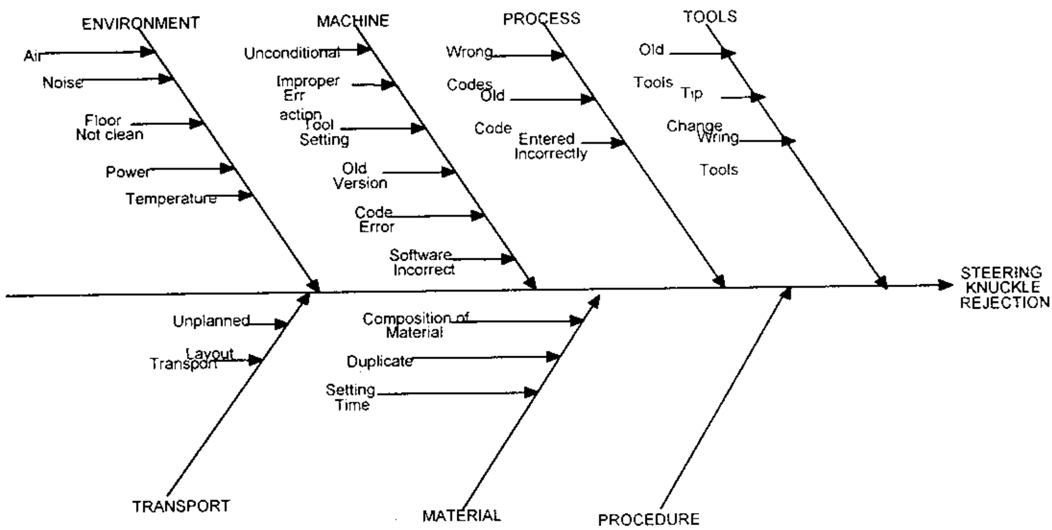


Fig 5.7 Cause and Effect Diagram for Steering Knuckle rejection

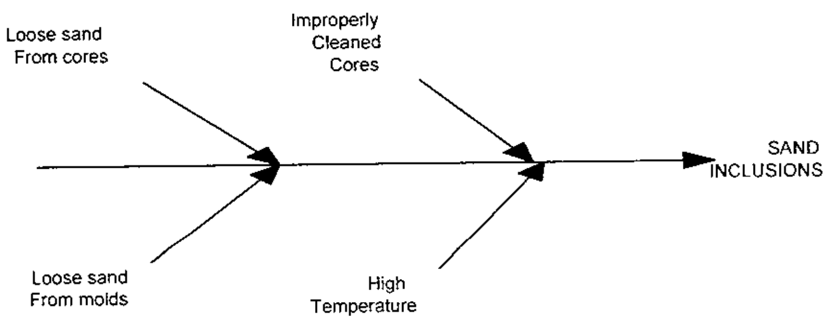


Fig 5.8 Cause and Effect diagram for sand inclusion

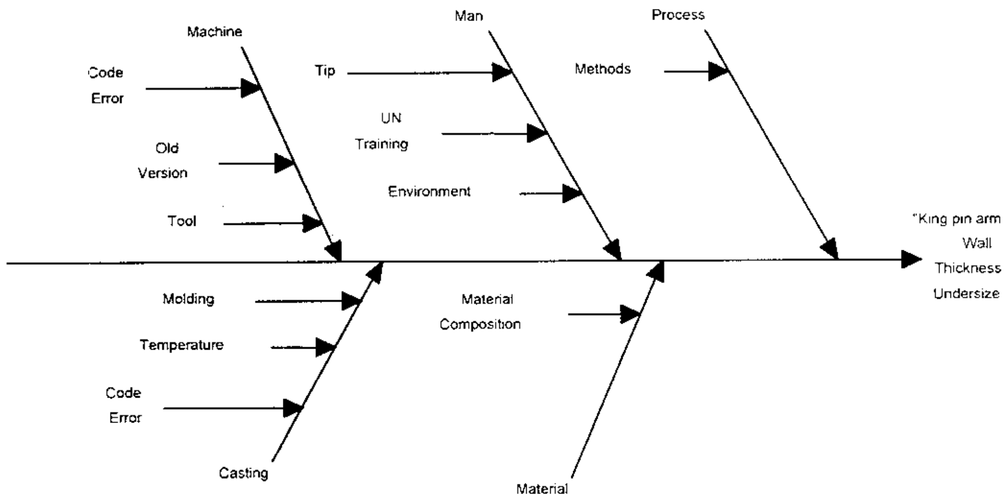


Fig 5.9 Causes for King pin arm wall thickness undersize

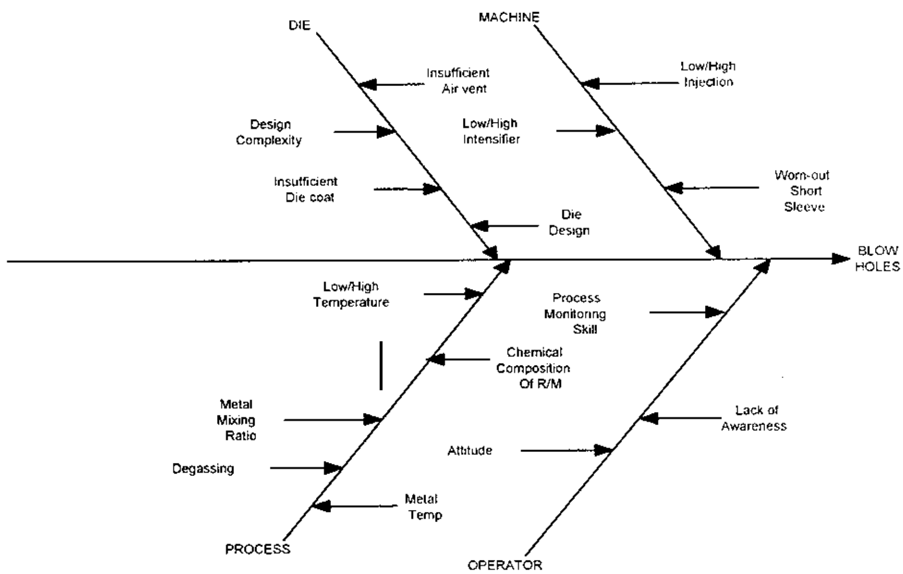
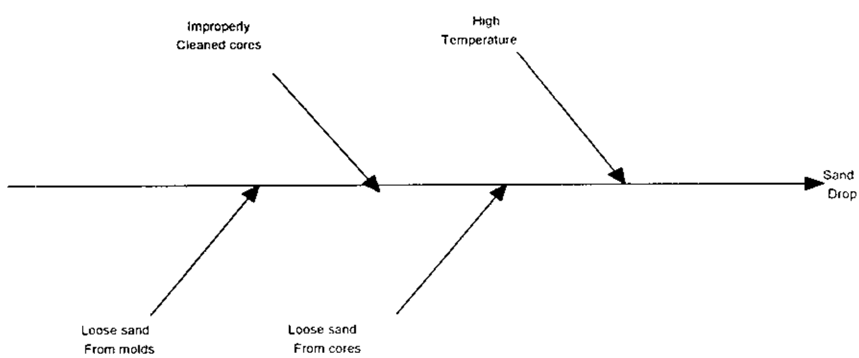


Fig 5.10 Cause and Effect diagram for blow holes



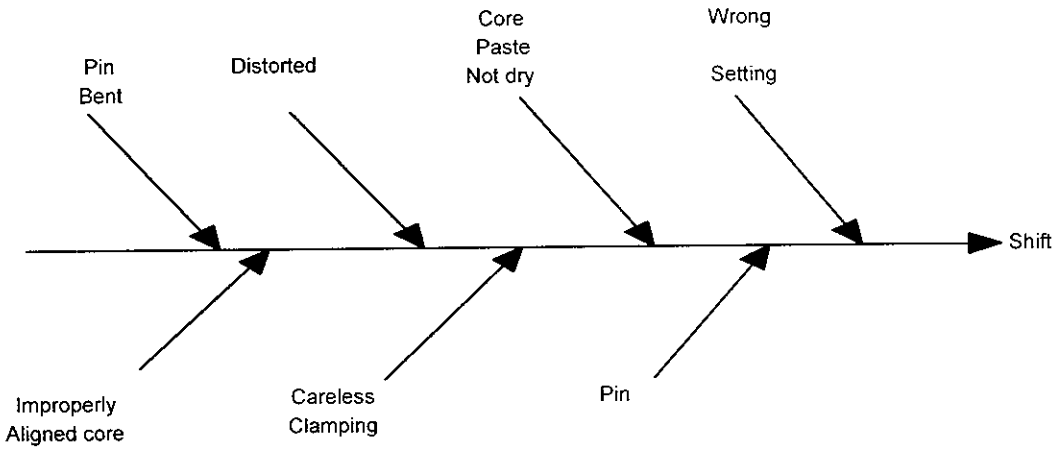


Fig 5.12 Cause and Effect diagram for shift

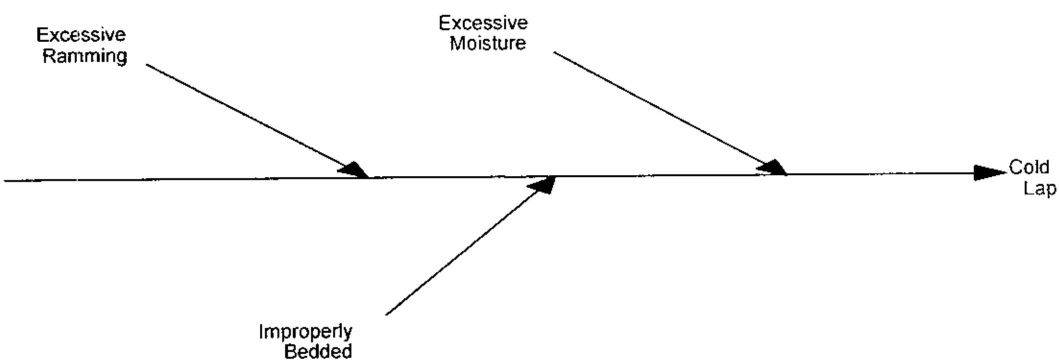


Fig 5.13 Cause and Effect diagram for cold lap

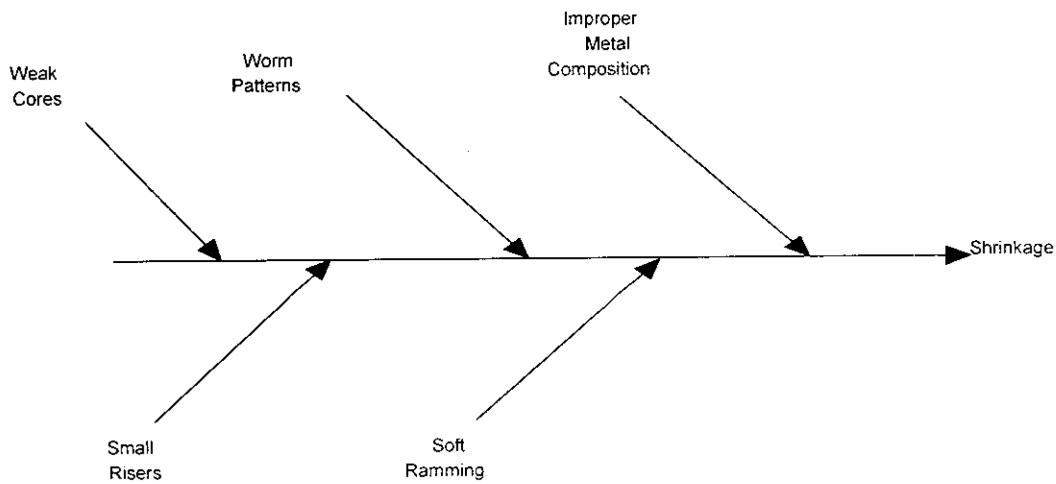


Fig 5.14 Cause and Effect diagram for shrinkage

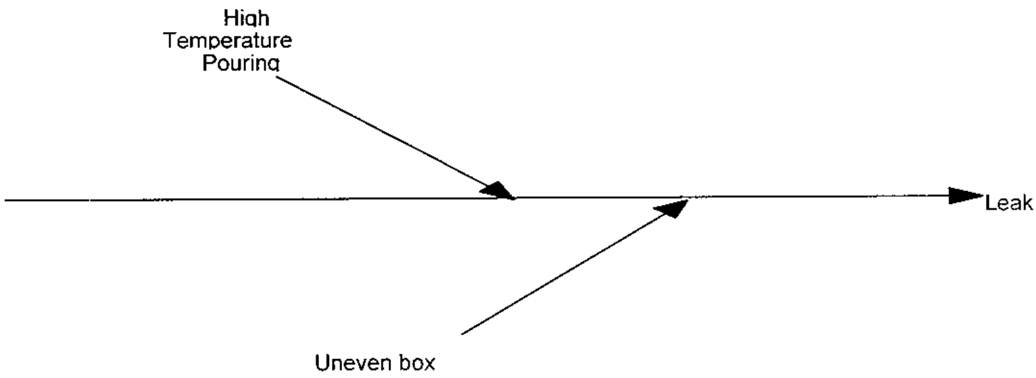


Fig 5.15 Cause and Effect diagram for leak

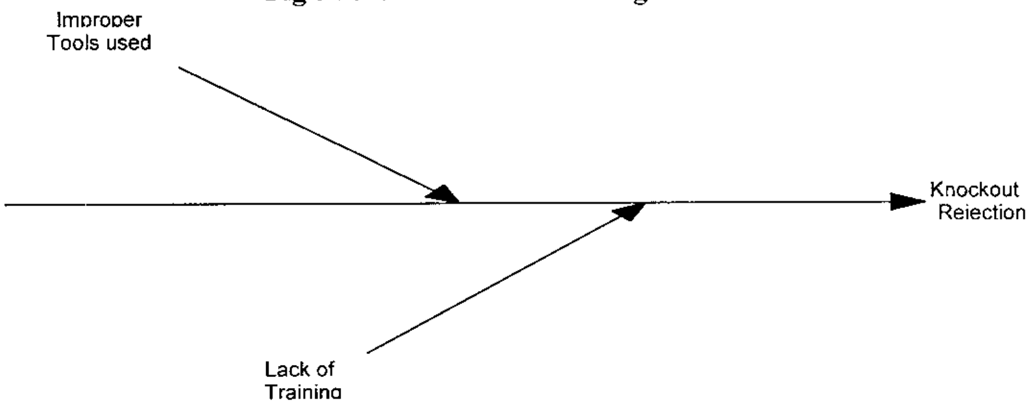


Fig 5.16 Cause and Effect diagram for Knockout rejection

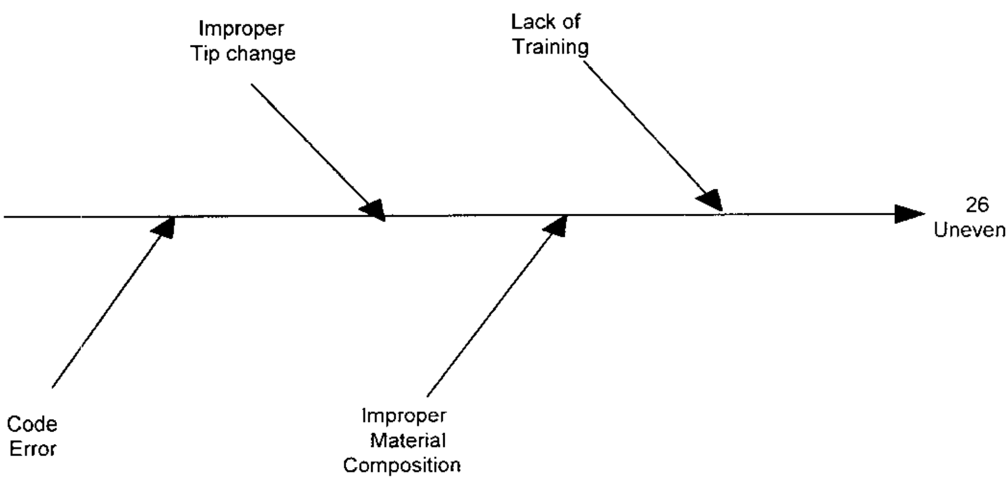


Fig 5.17 Cause and Effect diagram for 26 uneven

5.10 PARAMETERS IDENTIFICATION

A brain storming session was conducted and with the help of ishikawa diagram, all parameters, which were through to contribute to more defects, were

The identified process parameters were listed as follows

- Component design complexity
- Process capability of machine being used
- Machine plunger limit switch position
- II phase turns
- Intensifier pressure
- System pressure
- Die temperature
- Chemical mixing ratio
- Metal degassing frequency
- Die coat agent and frequency of usage
- Metal temperature
- Chemical composition of material being used.

Out of above stated parameters, five process parameters had been selected for further analysis. The rest were distinguished as constant parameters and kept steady thought the experimentation. This selection of parameters of interest and their working range were based on earlier studies by the company experts.

5.11 EXPERT SYSTEM SOFTWARES FORMS

Some of the forms developed in expert system software using .Net/SQL 2000 .The are shown in following figures. This system used easily identify a reason of defects and also helpful to find a way of rectifying the defects. A founded ways are loaded in this software. The knowledge base is open to further addition and modifications. The system can offer intelligence advice or take an intelligent decision about a processing function for avoidance of the rejection

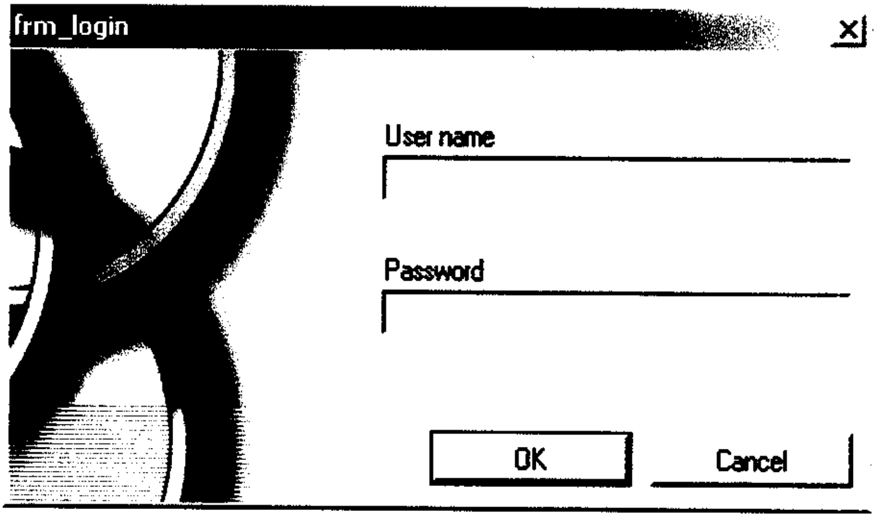


Fig 5.18 Login form

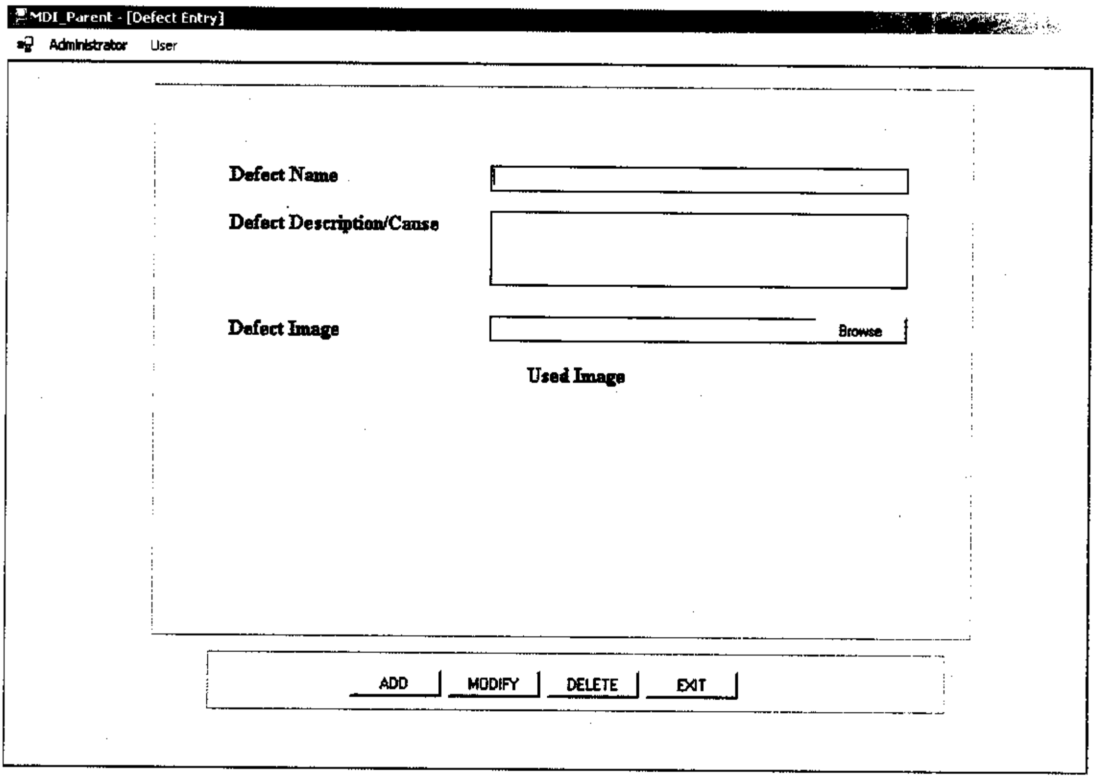


Fig 5.19 Administrator Defects/Causes form

P-2340

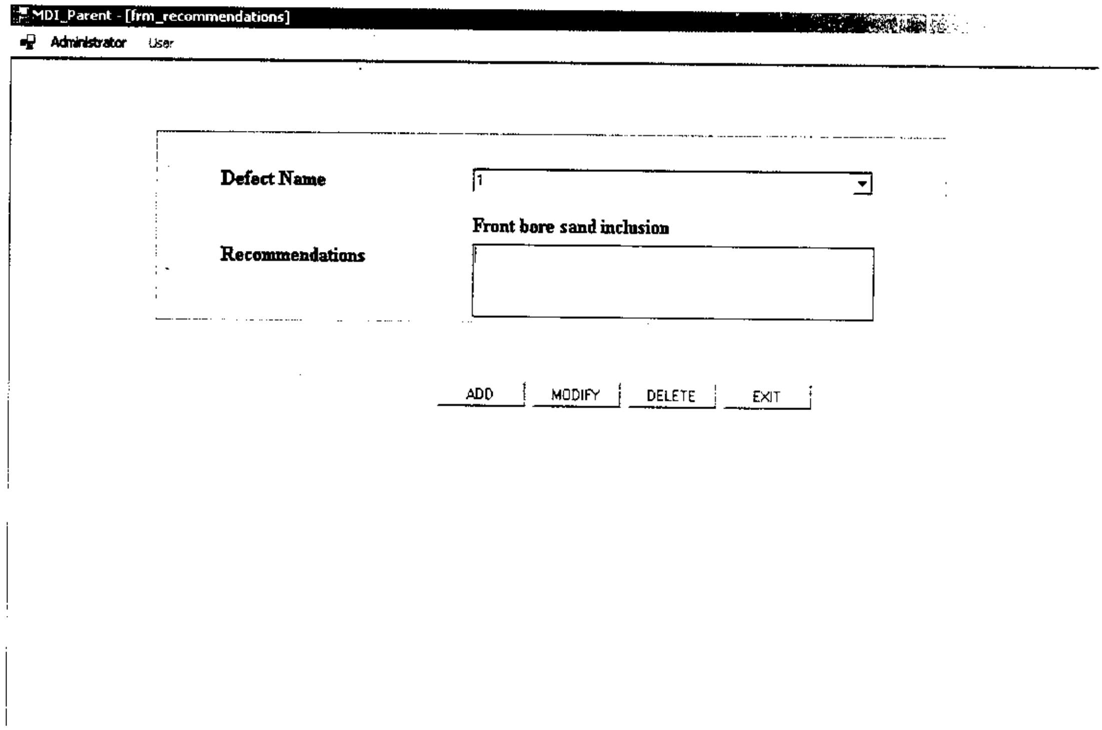


Fig 5.20 Administrator recommendation form

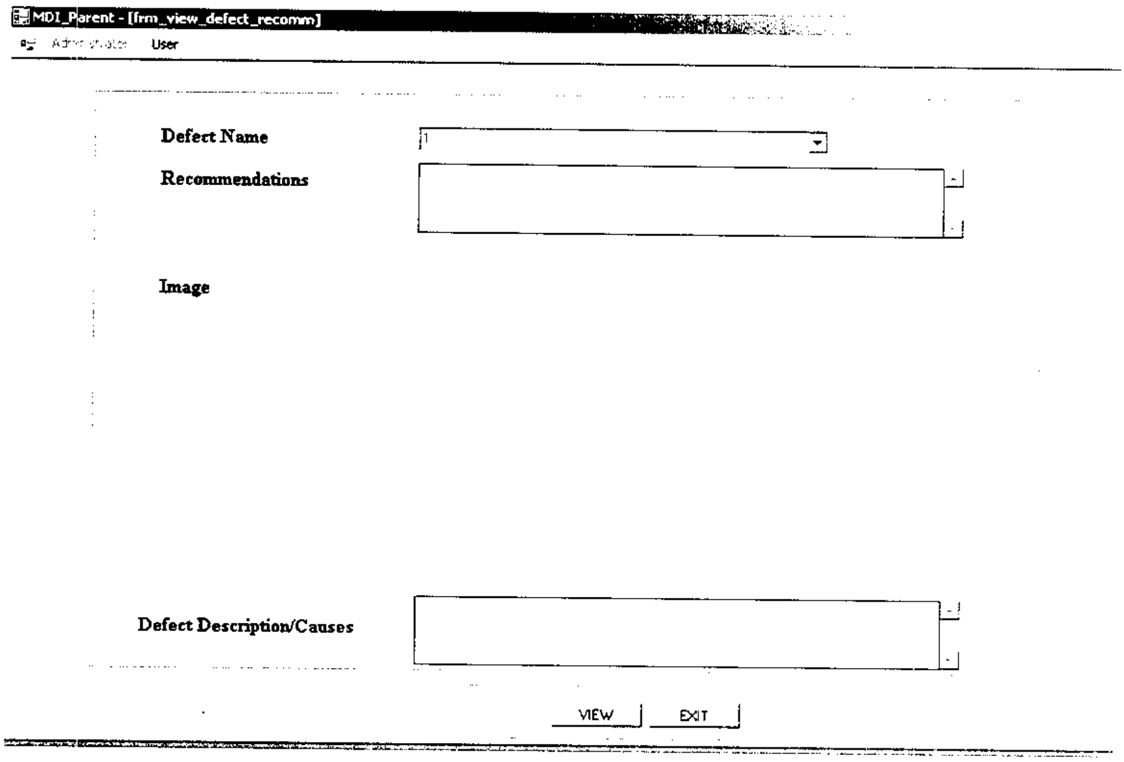


Fig 5.21 Users form (Causes and recommendation identification form)

Chapter 6

Results and Discussion

CHAPTER 6

RESULTS AND DISCUSSION

6.1 RESULTS OF THE PROJECT WORK

At the time of approached the company for initiating the quality improvement activities through six sigma, the steering Knuckle was in the peak of rejections and the company had operated under pressure to supply more number of components than actual schedule to meet their client's commitment and moreover the cost of all rejections including the preliminary preparation processes like CNC machining, heat treatment along with material cost has to bear them only. After initiating the project work and by the proper way analysis, it became possible for the author to bring down the rejection quantity through cause and effect diagram and expert system.

The following recommendations were given for the SK component defects. These recommendations are found through six sigma tools, and data's collected from company.

❖ **Frond bore sand inclusion**

- Air gun should be used to clean the cores
- Use appropriate proportion of oil and sand
- Maintain sand strength
- Maintain appropriate temperature

❖ **King pin arm wall thickness undersize**

- Proper tip change
- Correct training to workers
- Avoid code error
- Material composition

❖ **Blow hole**

- Properly cleaning the recycle sand
- Proper gating system should be provided
- Avoid interrupted pouring

❖ **Sand drop**

- Maintain appropriate temperature
- Air gun should be used to clean the cores
- Use appropriate proportion of oil and sand
- Maintain sand strength

❖ **Shift**

- Use quality paste for joining the cores
- Guide pin an clamping pin should be inspected every week
- Proper clamping of mould box.
- Worn pin should be replaced

❖ **Cold lap**

- Reduce the high moisture content
- Mould box should be placed on the leveled floor
- Ramming machine jolting time should be appropriate

❖ **Shrinkage**

- For every shift tightening the pattern bolts and nuts
- Worm patterns should be replaced
- Ramming time should be appropriate

❖ **Leak**

- Maintain appropriate temperature
- Uneven box should be replaced

❖ **Knockout**

- Use appropriate tools

- **26 uneven**
    - Proper tip change
    - Correct training to workers
    - Avoid code error
    - Material composition

6.2 DISCUSSION

Through this project work,

- This system deals with some of the common defects in steering knuckle production line. Graphic illustrations of some of the common defects in SK line can be included for explanatory purpose

- Comparing the expenditure involved in developing the expert system can carry out a study on the cost effectiveness of the system and that incurred in obtaining expert advice over a period of time. This will enable the justification of use expert system from the economy point of view.

- Cause and Effect diagram, Pareto chart, SPC charts were discussed in the case study.

- Cause and effect diagram and expert system are helping us to identify the possible causes for the particular defect.

- Pareto chart shows the visual impact about the defects occurred in the SK line. It shows which particular defects plays the major role among the several defects occurred in the SK line. Brain storming tool help us to collect the several causes for the particular defect.

Also computerized software may be employed for analyzing the SK defects and then it will be add some improvement in the quality of the component. Through some sources, we noticed one software called "Procast" which is used to analyze the blowholes in the casting line of SK component. Since at the later part of project work only it came to our knowledge and hence don't have enough time

Chapter 7

Conclusions

CHAPTER 7

CONCLUSIONS

Through This work to show the strength and power of latest quality buzz, six sigma a live case study was conducted in a real industrial background and tangible benefits of way of reduction of rejection rate was founded. For analyzing the case study, we had employed many statistical tools like bar chart, control charts, Cause and effect diagram, Run chart, scatter diagram, Pareto chart in places where it could be employed. Also the well known and powerful process experimentation tool, Called expert system was employed to identify the influencing factors for defects in steering knuckle production .Also optimal factor setting were determined at which at which the rejection rate found lesser through expert system and six sigma tools.

Finally the effect of the project work was projected in terms of expert system as a way that even semiskilled operator can identify the defect by its appearances and subsequently fix causes and remedies. The recommendations for defects are founded through six sigma tools and its are used to reduce the rejection rate in steering knuckle production line .The developed software system reduces the SK rejection rate ,rework . It increases the product quality, Reliability and productivity.

Appendices

APPENDIX 1

CONVERSION BETWEEN DPMO AND SIGMA

Sigma Level at Specification Limit	Percent with in specification: centered Distribution	Defective rate- centered distribution	Percent within specification:1.5 sigma sifted Distribution	Defective rate-1.5 sigma shifted distribution
1.0	68.2689480	317310.520	30.232875	697672.15
1.1	72.8667797	271332.203	33.991708	660082.92
1.2	76.9860537	230139.463	37.862162	621378.38
1.3	80.6398901	193601.099	41.818512	581814.88
1.4	83.8486577	161513.428	45.830622	541693.78
1.5	86.6385542	133614.458	49.865003	501349.97
1.6	89.0401421	109598.579	53.886022	461139.78
1.7	91.0869136	89130.864	57.857249	421427.51
1.8	92.8139469	71860.531	61.742787	382572.13
1.9	94.2567014	57432.986	65.508472	344915.28
2.0	95.4499876	45500.124	69.122979	308770.20
2.1	96.4271285	35728.715	72.558779	274412.21
2.2	97.2193202	27806.798	75.792859	242071.41
2.3	97.8551838	21448.162	78.807229	211927.71
2.4	98.3604942	16395.058	81.589179	184108.21
2.5	98.7580640	12419.360	84.131305	158686.95
2.6	99.0677556	9322.444	86.431323	135686.77
2.7	99.3065954	6934.046	88.491691	115083.09
2.8	99.4889619	5110.381	90.319090	96809.10
2.9	99.6268240	3731.760	91.9233787	80762.13
3.0	99.7300066	2699.934	93.318937	66810.63
3.1	99.8064658	1935.342	94.519860	54801.40
3.2	99.8625596	1374.404	95.543327	44566.73
3.3	99.9033035	966.965	96.406894	35931.06
3.4	99.9326038	673.962	97.128303	28716.97

Sigma Level at Specification Limit	Percent with in specification: centered Distribution	Defective rate-centered distribution	Percent within specification:1.5 sigma sifted Distribution	Defective rate-1.5 sigma shifted distribution
3.6	99.9681709	318.291	98.213547	17864.53
3.7	99.9784340	215.660	98.609650	13903.50
3.8	99.9855255	144.745	98.927586	10724.14
3.9	99.9903769	96.231	99.180244	8197.56
4.0	99.9936628	63.372	99.379030	6209.70
4.1	99.9958663	41.337	99.533877	4661.23
4.2	99.9973292	26.708	99.653297	3467.03
4.3	99.9982908	17.092	99.744481	2555.19
4.4	99.9989166	10.834	99.813412	1865.88
4.5	99.9993198	6.802	99.865003	1349.97
4.6	99.9995771	4.229	99.903233	967.67
4.7	99.9997395	2.605	99.931280	687.20
4.8	99.9998411	1.589	99.951652	483.48
4.9	99.9999040	0.960	99.966302	336.98
5.0	99.9999426	0.574	99.976733	232.67
5.1	99.9999660	0.340	99.984085	159.15
5.2	99.9999800	0.200	99.989217	107.83
5.3	99.9999884	0.116	99.992763	72.37
5.4	99.9999933	0.067	99.995188	48.12
5.5	99.9999962	0.038	99.996831	31.69
5.6	99.9999979	0.021	99.997933	20.67
5.7	99.9999988	0.012	99.998665	13.35
5.8	99.9999993	0.007	99.999145	8.55
5.9	99.9999996	0.004	99.999458	5.42
6.0	99.9999998	0.002	99.999660	3.40

APPENDIX 2

CONTROL LIMITS FOR VARIOUS CONTROL CHARTS

Sample Size n	$\bar{x}$		σ					R			
	A	A_2	C_2	B_1	B_2	B_3	B_4	d_2	d_3	D_3	D_4
2	2.121	1.880	0.5642	0.000	1.843	0.000	3.267	1.128	0.853	0.000	3.267
3	1.732	1.023	0.7236	0.000	1.858	0.000	2.568	1.693	0.888	0.000	2.575
4	1.501	0.729	0.7979	0.000	1.808	0.000	2.266	2.059	0.880	0.000	2.282
5	1.342	0.577	0.8407	0.000	1.756	0.000	2.089	2.326	0.864	0.000	2.115
6	1.225	0.483	0.8686	0.026	1.711	0.030	1.970	2.534	0.848	0.000	2.004
7	1.134	0.419	0.8882	0.105	1.672	0.118	1.882	2.704	0.833	0.076	1.924
8	1.061	0.373	0.9027	0.167	1.638	0.185	1.815	2.847	0.820	0.736	1.864
9	1.000	0.337	0.9139	0.219	1.609	0.239	1.761	2.970	0.808	0.184	1.816
10	0.949	0.308	0.9227	0.262	1.584	0.284	1.716	3.078	0.797	0.223	1.777
11	0.905	0.285	0.9300	0.299	1.561	0.321	1.679	3.173	0.787	0.256	1.744
12	0.866	0.266	0.9359	0.331	1.541	0.354	1.646	3.258	0.778	0.284	1.719
13	0.832	0.249	0.9410	0.359	1.523	0.382	1.618	3.336	0.770	0.308	1.692
14	0.802	0.235	0.9453	0.384	1.507	0.406	1.594	3.407	0.762	0.329	1.671
15	0.775	0.223	0.9490	0.406	1.492	0.428	1.572	3.472	0.755	0.348	1.652
16	0.750	0.212	0.9523	0.427	1.478	0.448	1.552	3.532	0.749	0.364	1.636
17	0.728	0.203	0.9551	0.445	1.465	0.466	1.534	3.588	0.743	0.379	1.621
18	0.707	0.194	0.9576	0.461	1.454	0.482	1.518	3.640	0.738	0.392	1.608
19	0.688	0.187	0.9599	0.477	1.443	0.497	1.503	3.689	0.733	0.404	1.596
20	0.671	0.180	0.9619	0.491	1.433	0.510	1.490	3.735	0.729	0.414	1.586

APPENDIX 3

SOFTWARE CODING

```
Imports System.IO
Imports System.Data
Imports System.Data.SqlClient
Imports System.Data.SqlTypes
Public Class frm_defect_entry
    Private mImageFile As Image
    Private mImageFilePath As String
    Dim strConnect As String
    Dim conn As SqlConnection

    Private Sub frm_defect_entry_Disposed(ByVal sender As Object,
ByVal e As System.EventArgs) Handles Me.Disposed
        frm_defect = New frm_defect_entry
    End Sub
    Private Sub frm_defect_entry_Load(ByVal sender As
System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
        Label4.Visible = False
        cmb_defect_id.Visible = False
        strConnect = "Data Source=mezoblanca30;Initial
Catalog=major_defects;User ID=sa"
        conn = New SqlConnection(strConnect)
        refresh_combo()
    End Sub
    Sub refresh_combo()
        Dim da As New SqlDataAdapter
        Dim dt As New DataTable
        da = New SqlDataAdapter("select defect_id from
defect_entry_master where deleted=0", conn)
        dt = New DataTable
        da.Fill(dt)
        cmb_defect_id.DisplayMember = "defect_id"
        cmb_defect_id.DataSource = dt
    End Sub
    Private Sub cmd_browse_Click(ByVal sender As System.Object,
ByVal e As System.EventArgs) Handles cmd_browse.Click
        OpenFileDialog1.Title = "Set Image File"
        OpenFileDialog1.Filter = "Bitmap Files|*.bmp|Gif
Files|*.gif|JPEG Files|*.jpg"
        OpenFileDialog1.DefaultExt = "bmp"
        OpenFileDialog1.FilterIndex = 1
        OpenFileDialog1.FileName = ""
        OpenFileDialog1.ShowDialog()
        'If OpenFileDialog1.ShowDialog =
Windows.Forms.DialogResult.Cancel Then
        '    Exit Sub
        'End If
        Dim sFilePath As String
        sFilePath = OpenFileDialog1.FileName
        'If sFilePath = "" Then Exit Sub
        'If System.IO.File.Exists(sFilePath [illegible]
```

```
            clear()
        Catch ex As Exception
            MsgBox(ex.Message)
        End Try
    End Sub


    Private Sub cmb_defect_id_MouseClick(ByVal sender As Object,
ByVal e As System.Windows.Forms.MouseEventArgs) Handles
cmb_defect_id.MouseClick
        Try
            ' //Get image data from gridview column.
            Dim da As New SqlDataAdapter
            Dim dt As New DataTable
            da = New SqlDataAdapter("select
defect_image,defect_cause,defect_name,height,width from
defect_entry_master where deleted=0 and defect_id='" &
cmb_defect_id.Text & "'", conn)
            dt = New DataTable
            da.Fill(dt)
            Dim imageData As Byte()
            imageData = dt.Rows(0)(0)
            '//Initialize image variable
            Dim image1 As Image
            ' //Read image data into a memory stream
            Dim ms As MemoryStream = New MemoryStream(imageData,
0, imageData.Length)
            ms.Write(imageData, 0, imageData.Length)
            '        //Set image variable value using memory
stream.
            image1 = Image.FromStream(ms, True)
            '  //set picture
            PictureBox1.Height = dt.Rows(0)(3)
            PictureBox1.Width = dt.Rows(0)(4)
            PictureBox1.Image = image1
            txt_defect_descrip.Text = dt.Rows(0)(1)
            txt_defect_name.Text = dt.Rows(0)(2)

        Catch ex As Exception
            MessageBox.Show(ex.ToString())
        End Try
    End Sub
    Sub clear()
        txt_defect_descrip.Clear()
        txt_defect_name.Clear()
        txt_defect_image.Clear()
    End Sub

    Private Sub cmd_exit_Click(ByVal sender As System.Object,
ByVal e As System.EventArgs) Handles cmd_exit.Click
        Me.Dispose(True)
    End Sub

    Private Sub GroupBox1_Enter(ByVal sender As System.Object,
ByVal e As System.EventArgs) Handles GroupBox1.Enter

    End Sub
End Class
```

```
Imports System.Data
Imports System.Data.SqlClient
Imports System.Data.SqlTypes
Imports System.Drawing.Image
Public Class frm_recommendations
    Dim strConnect As String
    Dim conn As SqlConnection

    Private Sub frm_recommendations_Disposed(ByVal sender As
Object, ByVal e As System.EventArgs) Handles Me.Disposed
        frm_recomm = New frm_recommendations
    End Sub
    Private Sub frm_recommendations_Load(ByVal sender As
System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
        strConnect = "Data Source=mezoblanca30;Initial
Catalog=major_defects;User ID=sa"
        conn = New SqlConnection(strConnect)
        conn.Open()
        refresh_combo()
    End Sub
    Sub refresh_combo()
        Dim da As New SqlDataAdapter
        Dim dt As New DataTable
        da = New SqlDataAdapter("select defect_name,defect_id from
defect_entry_master where deleted=0", conn)
        dt = New DataTable
        da.Fill(dt)
        cmb_defect_name.DisplayMember = "defect_id"
        cmb_defect_name.DataSource = dt
    End Sub

    Private Sub cmd_add_Click(ByVal sender As System.Object, ByVal
e As System.EventArgs) Handles cmd_add.Click
        Try
            Dim da As New SqlDataAdapter
            Dim dt As New DataTable
            da = New SqlDataAdapter("select defect_id from
recommendations_master where deleted=0 and defect_id='" &
cmb_defect_name.Text & "'", conn)
            dt = New DataTable
            da.Fill(dt)
            If dt.Rows.Count = 0 Then
                Dim cmd As New SqlCommand("insert into
recommendations_master(defect_id,defect_recommendations) values('"
& cmb_defect_name.Text & "','" & txt_recommendations.Text & "')",
conn)
                cmd.ExecuteNonQuery()
                refresh_combo()
                clear()
                MsgBox("Details added successfully")
            Else
                Dim cmd As New SqlCommand("update
recommendations_master set defect_recommendations='" &
txt_recommendations.Text & "' where defect_id='" &
cmb_defect_name.Text & "' and deleted=0", conn)
                cmd.ExecuteNonQuery()
                refresh_combo()
                clear()
                MsgBox("Details added successfully")
```

```
            Private Sub cmd_exit_Click(ByVal sender As Object,
ByVal e As System.EventArgs) Handles cmd_exit.Click
        Me.Dispose(True)
    End Sub

    Private Sub cmb_defect_name_SelectedIndexChanged(ByVal sender
As Object, ByVal e As System.EventArgs) Handles
cmb_defect_name.SelectedIndexChanged
        Dim da As New SqlDataAdapter
        Dim dt As New DataTable
        da = New SqlDataAdapter("select defect_name from
defect_entry_master where deleted=0 and defect_id='" &
cmb_defect_name.Text & "'", conn)
        dt = New DataTable
        da.Fill(dt)
        Try
            Label3.Text = dt.Rows(0)(0)
            txt_recommendations.Clear()
            da = New SqlDataAdapter("select defect_recommendations
from recommendations_master where deleted=0 and defect_id='" &
cmb_defect_name.Text & "'", conn)
            dt = New DataTable
            da.Fill(dt)
            Try
                txt_recommendations.Text = dt.Rows(0)(0)
            Catch ex As Exception

            End Try
        Catch ex As Exception

        End Try
    End Sub

    Private Sub cmd_delete_Click(ByVal sender As Object, ByVal e
As System.EventArgs) Handles cmd_delete.Click
        cmd_update1.BringToFront()
        cmd_cancel.BringToFront()
        cmd_add.Enabled = False
    End Sub
End Class


Imports System.IO
Imports System.Data
Imports System.Data.SqlClient
Imports System.Data.SqlTypes
Imports System.Drawing.Image
Public Class frm_view_defect_recomm
    Dim strConnect As String
    Dim conn As SqlConnection
    Private Sub cmd_view_Click(ByVal sender As System.Object,
ByVal e As System.EventArgs) Handles cmd_view.Click
        Try

            Dim da As New SqlDataAdapter
            Dim dt As New DataTable
            da = New SqlDataAdapter("select
d.defect_id,d.defect_image,d.defect_cause,d.defect_name,d.height,d
.width,r.defect_recommendations from defect_entry_master
```

```
r.defect_id=d.defect_id and r.defect_id='" & cmb_defect_name.Text
& "'", conn)
            dt = New DataTable
            da.Fill(dt)
            Dim imageData As Byte()
            imageData = dt.Rows(0)(1)
            Dim image1 As Image
            Dim ms As MemoryStream = New MemoryStream(imageData,
0, imageData.Length)
            ms.Write(imageData, 0, imageData.Length)
            image1 = Image.FromStream(ms, True)
            pbx_defcet_image.Height = dt.Rows(0)(4)
            pbx_defcet_image.Width = dt.Rows(0)(5)
            Label5.Text = dt.Rows(0)(3)
            pbx_defcet_image.Image = image1
            txt_defcet_cause.Text = dt.Rows(0)(2)
            txt_recommendations.Text = dt.Rows(0)(6)
        Catch ex As Exception
            MessageBox.Show(ex.ToString())
        End Try
    End Sub
    Sub refresh_combo()
        Dim da As New SqlDataAdapter
        Dim dt As New DataTable
        da = New SqlDataAdapter("select d.defect_id from
defect_entry_master d,recommendations_master r where r.deleted=0
and d.deleted=0 and r.defect_id=d.defect_id", conn)
        dt = New DataTable
        da.Fill(dt)
        cmb_defect_name.DisplayMember = "defect_id"
        cmb_defect_name.DataSource = dt
    End Sub

    Private Sub frm_view_defect_recomm_Disposed(ByVal sender As
Object, ByVal e As System.EventArgs) Handles Me.Disposed
        frm_view_recomm = New frm_view_defect_recomm
    End Sub
    Private Sub frm_view_defect_recomm_Load(ByVal sender As
System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
        strConnect = "Data Source=mezoblanca30;Initial
Catalog=major_defects;User ID=sa"
        conn = New SqlConnection(strConnect)
        conn.Open()
        refresh_combo()
    End Sub

    Private Sub cmd_exit_Click(ByVal sender As Object, ByVal e As
System.EventArgs) Handles cmd_exit.Click
        Me.Dispose(True)
    End Sub

    Private Sub GroupBox1_Enter(ByVal sender As System.Object,
ByVal e As System.EventArgs) Handles GroupBox1.Enter

    End Sub
End Class
```

References

REFERENCES

1. Goh T. N. and M. Xierealistic (2004), *"Improving on the six sigma paradigm"*, International journal of TQM Magazine Vol. 16, pp. 235-240.

2. Jay Arthur (2003), *"The six sigma instructor Guide (Green Belt raining)"*, Macmillan India limited.

3. Jiemin Wang, A. K. Kochhar and R. G. Hannam (1998), *"Pattern recognition for SPC"*, the international journal of advanced manufacturing technology, pp.99-109.

4. Juju Antony (2004), *"Some pros and cons of six six sigma: an academic perspective"*, the international journal of TQM Magazine, Vol. 16, pp. 303-306.

5. Kai Yang(2004), *"Multivariate statistical methods and Six-Sigma"*, International Journal of Six Sigma and Competitive Advantage, Vol. 1, No. 1, pp.76-97.

6. Kevin Linderman, Roger G, Schroeder, Adrian S. Choo (2005), *"Six Sigma: The role of goals in improvement teams"*, Journal of Operations Management, Vol. xxx, pp.2-17.

7. MDonald.A.Waterman (1986), *"A guide to expert system"*, Macmillan India limited.

8. Nandini Das (2000), *"Reducing manufacturing defect through statistical investigation in a integrated aluminiunm industry"*, The international journal of Advanced manufacturing technology, pp.56-72.

9. Pande P (2001), *"What is Six Sigma?"* , TMH.

10. Ricardo Banuelas and Juju Antony (2003 a), *"Going from six sigma from design for six sigma: an exploratory study using AHP"*, the international journal of TQM magazine, Vol. 15, pp.334-344.

11. Ricardo banuels, Jiju Antoney (2005 b), *"An application of six sigma to reduce waste"*, The International journal of quality and reliability engineering, pp.51-70.

12. Ricardo banuels, Jiju Antoney and Martin Brace (2005 b), *"An application of six sigma to reduce waste"*, The International journal of quality and reliability engineering, pp.51-70.

13. Rodney McAdam and Alison Evans (2004), *"The organizational contextual factors affecting the implementation of Six-Sigma in a high technology mass-manufacturing environment"*, International Journal of

14. Ron Basu(2004) , *"Six-Sigma to operational excellence: role of tools and techniques"*, International Journal of Six Sigma and Competitive Advantage, Vol. 1, No. 1, pp.44-64.

15. Selvan Rungasamy, Juju Antony and Sid Gosh (2002), *"Critical success factors for SPC implementation in UK small and medium enterprises: some key findings from a survey"*, International journal of TQM Magazine Volume 14, pp. 217-224.

16. Shoran S.N (1993), *"Fundamentals of Expert System"*, First edition

17. Sung H. Park (2003), *"Six Sigma for Quality and Productivity Promotion"*, APO 2003.

18. Tolga taner and Juju Antony (2003), *"A conceptual framework for the effective implementation of statistical process control"*, International Journal of Business Process Management, Vol. 9 No. 4, pp. 473-489.

19. www.isixsigma.com

20. www.sixsigmaforum.com

21. www.sixsigmagroup.co

22. www.sixsigma.com

23. www.ssql.com