“LEAN SIX SIGMA: GREEN BELT” CERTIFICATION COURSE

Course Material

Leadership thru' Business Excellence

Asian Institute of Quality Management (AIQM)

(A Division of Vijigeeshu QMS Pvt. Ltd.)

Head Office: 95 - 96 – 97, 5th Floor, K. K. Market, G – Wing, Bibewadi, Pune – 411043
Mumbai Office: B-1/204 Lok Gaurav, LBS Marg, Vikhroli West, Mumbai - 400083

*Phones: 91-20-40084939, 91-22-25790460
*Cell: 00 – 91 - 9320003503

*E-mail: director@aiqmindia.com, directoraiqm@gmail.com

ASCB(E) Accrediting Certifying Bodies UK

Leadership thru' Business Excellence

Asian Institute of Quality Management

(Division of Vijigeeshu QMS Pvt. Ltd)

www.aiqmindia.com

AIQM – Organization Profile

Vision: AIQM, a leading institute in Asia, is dedicated to empowering working professionals & students to achieve excellence in organizational processes.

Training Programs Offered

- **Business Analytics Workshop**
- **IATF 16949:2016 Transition Training for Automotive Professionals including Core Tools: APQP – FMEA – MSA – SPC – PPAP**
- **Seven QC Tools for Quality Improvement**
- **Global-8D Problem Solving Methodology**
- **Implementing 5S & Kaizen-Lean Management**
- **Lean Six Sigma Champion Workshop For Senior Management**
- **Lean Six Sigma Yellow Belt, Green Belt, Black Belt, Master Black Belt Certification Courses**
- **DMAIC Methodology for Implementing Lean Six Sigma Improvements**
- **Statistical Process Control (SPC) Techniques with Minitab Training**

Part-list of AIQM Clients

Service Organizations:

- Abu Dhabi Police – UAE
- Amazon -India
- Detasad – Saudi
- Eaton Technologies - India
- Global Hospital – India
- Infosys – India
- NCB Bank - Saudi
- Prince Sultan Military Hospital – Saudi
- Prudential Life Insurance - India
- Tech Mahindra - India

Manufacturing Organizations:

- Abdul Latif Jamil (Toyota) – Saudi
- Albaik Foods – Saudi
- Abbott Diagnostics – Saudi, Oman
- Almarai Dairy – Saudi
- Crompton Greaves –India
- Haeir - India
- Johnson Controls – Saudi, UAE
- L & T (Heavy Engineering Division)
- Middle East Battery Co. - Saudi
- Roche Diagnostics – Saudi, UAE
- Titan Jewellery Divn. (Tanishq) - India
- Thermax - India
- Zamil Industries – Saudi

Organizational Information

Year Started: 1995

Location: India, Middle East Countries, Malaysia

AIQM Resources:

- 11 Consultants for Black Belt Projects
- 08 Consultants for Green Belt Projects

AIQM Management:

- Established since 1995 by Mr. G.K.K. Singh, an alumnus IIT Bombay and IIM Calcutta
- Successfully run by experts with I.I.T. / I.I.M. background having rich experience in Training, Consultancy, and Business Excellence Practices
- AIQM is committed to operate as per defined procedures, undergoing continual review by ASCB (E) - UK

Our Other Businesses:

- JK Waste Recycling Pvt. Ltd.
- Galaxy Electronics (India) Inc.
- Galaxy Inspection & Testing Services

AIQM Achievements:

- 90,000 Professionals trained
- 27,000 Lean Six Sigma Belts Certified Worldwide
- 300,000 Man-days of Consulting Practice
- 2800 Satisfied Corporate Clients
- 9000 Business Transformation & Process Improvement projects executed.

Consultancy Services for Organizations:

- Mentoring of Lean Six Sigma, Lean Management & Business Analytics Projects.
- Support for achieving various ISO Certifications & CE Markina..

Accreditation:

- Accredited by ASCB (E) – UK since Sept 2003 for Training, E-Learning, Examination and Issue of Accredited Certificates in specified Quality Assurance and Business Process Improvement areas.

TABLE OF CONTENTS

CHAPTER	DESCRIPTION	PAGE
	Module -1: Fundamentals & Principles	
1	Introduction to Six Sigma	5
	Definition of Quality – Kano model, VOC, CTQs	
2	Evolution of the Quality function - Journey from Quality Measurement to Six Sigma	14
	Appraisal and Prevention in processes using RCO & ICD	
	Root Cause Analysis - Correction, Corrective action, Preventive action	
	Goals of Six Sigma	
	Team formation for implementing Lean Six Sigma Projects	
3	Cross-functional Cooperation / Boundary-less collaboration in Six Sigma organization	23
	Delivering value to customer through Q.C.D.	
4	The Process Approach	27
	Identifying CTPs	
	Improving CTPs to achieve CTQs	
5	DPU & DPMO – Calculating Sigma Level	30
6	Cost of Quality – Impact on sigma level of a process	34

7	Motorola's journey from 3.4 to 6.0 sigma	39
8	Six Sigma – Basic Principles (self-reading)	43
	Cultural Changes required while implementing Six Sigma (self-reading)	
	Module-2: Six Sigma tools & methodologies	
9	Understanding Variation in processes	48
	Assignable / Special cause Variation	
	Non-assignable / Inherent cause Variation	
10	Seven Tools of Quality	53
11	Use of SPC in Six Sigma	66
12	DMAIC methodology (Define-Measure-Analyze-Improve-Control)	78
13	Failure Mode & Effect Analysis (FMEA)	94
	Module-3: Lean Management	
14	Lean Management (The 08 wastes)	100
15	Value Stream Process Mapping (VSM)	106
----	**WORKBOOK SECTION**	111

Chapter 1

INTRODUCTION TO LEAN SIX SIGMA

> ***Mind is like a parachute: works best when it is open***
> ***- Charlie Chan***

1.1 LEAN SIX SIGMA MANAGEMENT SYSTEM

a. What is Six Sigma?

- Developed in 1986 by Motorola – USA, Six Sigma is all about business results, with a focus on customers.
- Six Sigma projects must produce a return on investment in a short time (e.g. 6 months)

Six Sigma relies on:

- ✓ **Collection of data** to understand "How the process is running currently?"
- ✓ Finding **root causes for variation and waste,** through analysis of the collected data
- ✓ **Group-wisdom** of Cross Functional Teams (CFTs)
- ✓ Involvement and support of **Senior Management**
- ✓ Developing **innovative solutions** that lead to:
  - * Reduction of **defects / rejections and re-work** in processes
  - * Increasing **customer satisfaction**.

b. What is Lean Management?

Developed in Japan (**Toyota Production System – TPS**), Lean Management is about delivering value to the customer.

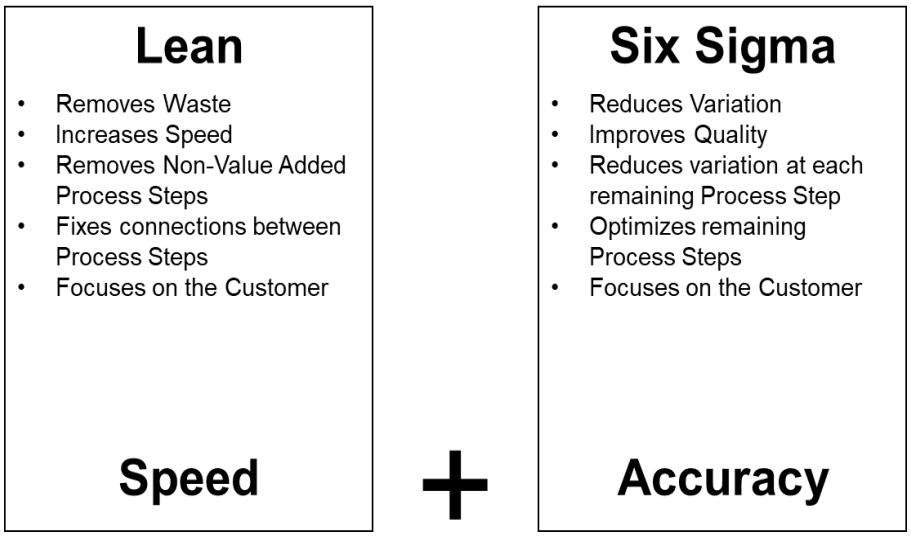
Value is anything for which a customer is willing to pay

Any activity, while producing a product or service that **does not add value** for customer is a waste. It must be eliminated from the organization's practices.

LEAN TOOLS AND TECHNIQUES:

- Identify the **08 types of Waste** that are hidden in an organization's activities,
- **Eliminate** such activities,
- Improve **efficiency** of the organization's processes.

c. What is Lean Six Sigma:



In recent years, adoption of Lean Six Sigma Methodologies has increased phenomenally.

Today 82 % of the Fortune-100 companies are using Lean Six Sigma to sustain their performance as top-performers in the world.

1B. DEFINITION OF QUALITY - KANO MODEL, VOC, CTQ

1.2 DEFINITION OF QUALITY:

A short definition that is widely accepted, today is:

Quality is Customer Satisfaction, aimed at meeting the:

- Stated Needs,
- Unstated Needs / Understood Needs,
- Expectations …… of the customer.

In terms of **KANO Model** (See Figure-1 on next page):

Basic Attributes (Unstated / Understood Needs) are:

Attributes which must be present in order for the product / service to be useful.

(However, the customer will remain neutral towards the product / service even if quality of these aspects is increased to a higher level).

Linear Attributes (Stated Needs):

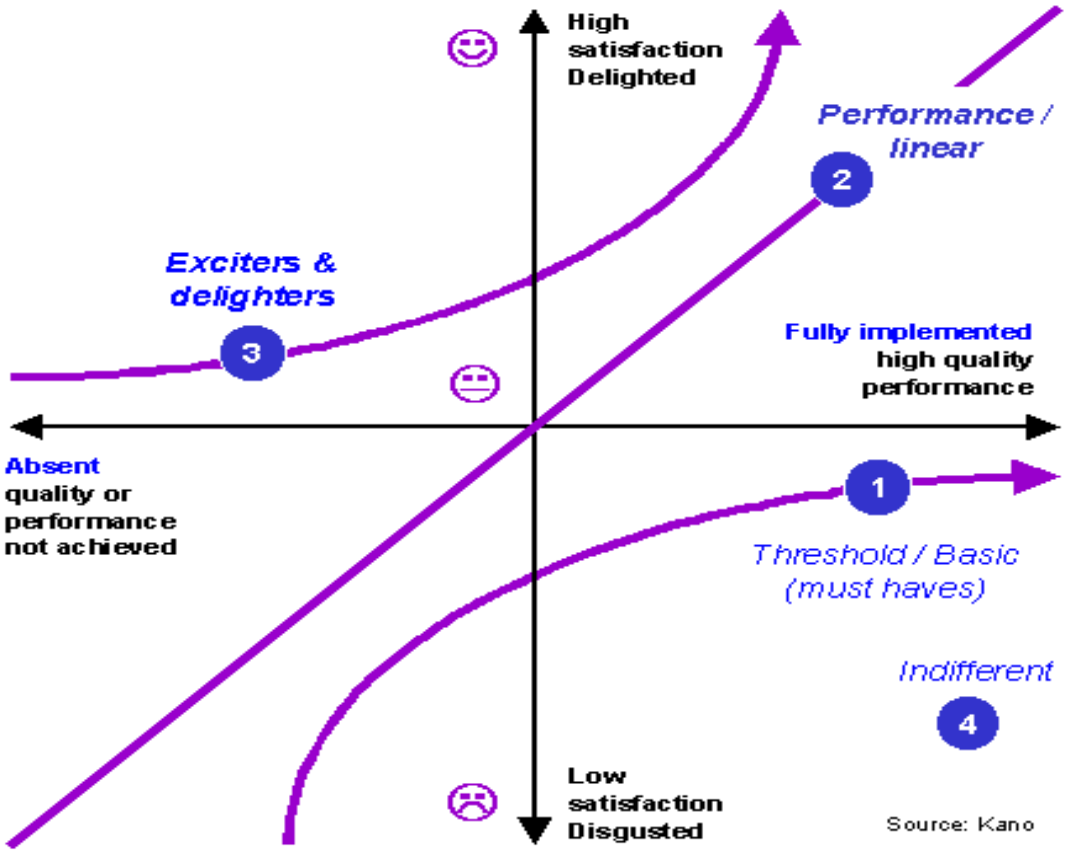
These characteristics have a linear co-relation to the customer satisfaction.

Increased quality of execution will result in increased customer satisfaction. If quality on these aspects is reduced, the customer satisfaction will reduce.

Expectations (Exciters / Delighters):

Customers may get great satisfaction from an added feature - and are willing to pay a price premium. However, satisfaction will not decrease (below neutral) if the product lacks the feature.

Figure 1: The Kano model



Dr. Juran – Another Quality Expert has defined Quality as **"Fitness for Use":**

a) The product / service should be fit to meet requirements defined by customer.

b) Yet the manufacturer / service-provider should give "only so much to customer as he values – Not More. (Giving more is a waste).

Q: Can you co-relate Juran's "Fitness for Use" with Kano model?

:TYPES OF CUSTOMERS:	
External Customer	***Internal Customer***
An end-user (or channel partner) who pays for the product or service delivered by a company, thus generating revenue for the company.	***The recipient (person, process, or department) of another person's or department's output (product, service, data, material or information) within an organization.***

Exercise:

- Consider any process whose output goes to an external customer.

  List the Quality Characteristics required by this customer

(Before you start this exercise, do you have any question)

Let us categorize these quality characteristics below as:

STATED NEEDS	UNDERSTOOD / UNSTATED NEEDS	DELIGHTERS / EXCITERS

B. Out of the above list, please TICK MARK 2 or 3 quality characteristics that you would consider most important as a customer.

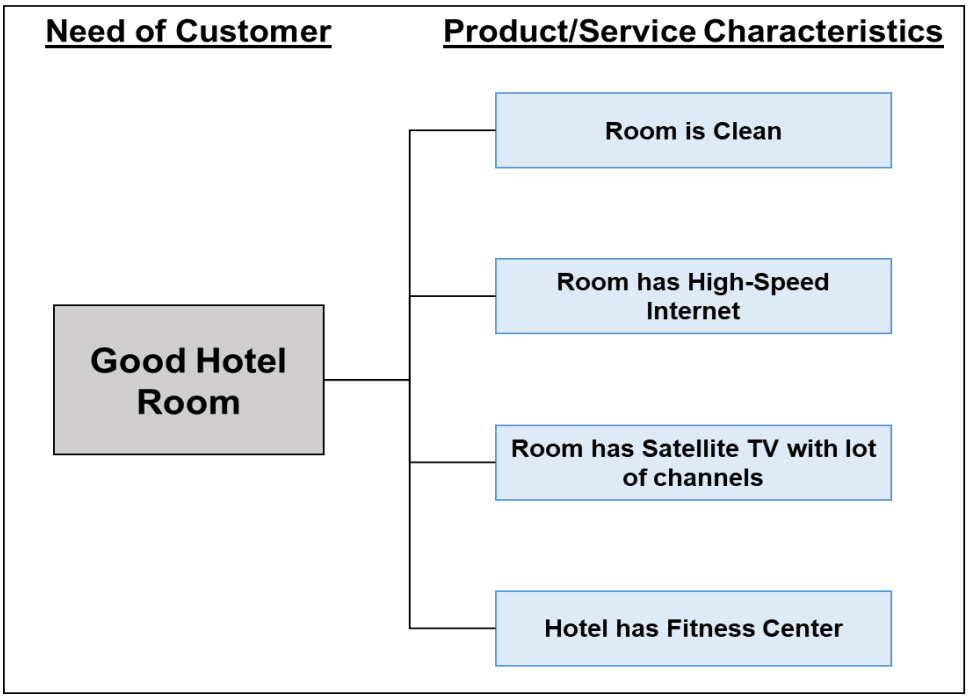
VOICE OF CUSTOMER (VOC) AND CTQS FOR A PROCESS:

- Quality Characteristics are generally derived on the basis of feedback from external / internal customer. This is referred to as the Voice of Customer (VOC).
- The **vital-few quality characteristics** of a product / service which have major impact on satisfaction of the customer are called as Critical to Quality (CTQ) characteristics.

Critical to Quality (CTQ)

The Vital Few Quality Characteristics of a product /service which have major impact on satisfaction of customer are called as Critical to Quality (CTQ) characteristics.

E.g:



In short,

Process → **Output** → **Who is the Customer?** → **VOC** → **Quality Characteristics** → **CTQ's**

(CUST. SEGMENT)

And if we meet the customer's CTQs, we would have fulfilled his requirements / needs, at least to 80% extent.

Based on this definition of Quality, Motorola found a way to "measure quality" which they expressed in terms of "defects" and a "SIGMA" level. (E.g. Customer CTQ not achieved can be considered as a DEFECT).

The Quality Goal for any process was fixed by Motorola as: ***Less than 3.4 defects per million opportunities for error i.e. 0.00034%, i.e. an accuracy of 99.99966% (or 99.9997%).***

:SIGMA LEVELS & DPMO DEFINED BY MOTOROLA:

Process Capability (Sigma Level)	Defect Count in %	Defects Per Million
1.0	69	6,90,000
2.0	30.8	3,08,000
3.0	6.68	66,800
4.0	0.62	6,210
5.0	0.023	230
6.0	0.00034	3.4

According to Dr. Deming:

When you measure, you can understand,

When you understand, you can improve,

When you improve, you can control,

When you improve & control you achieve your goal.

SUMMARY

In six sigma management system, if we want to improve any process, we follow the under-mentioned steps:

1. **Who is the customer for the process (internal customer or external customer)?**
2. **Find the Quality Characteristics required by him (Based on VOC)?**
3. **What are the CTQs?**
4. **What are the actions required to achieve the CTQs?**

Chapter 2

EVOLUTION OF THE QUALITY FUNCTION ..... A JOURNEY FROM

QUALITY MEASUREMENT TO SIX SIGMA

Why spend time finding, fixing and fighting when you can prevent the problem in first place.

Dave Crosby

2.1 QUALITY ASSURANCE

Quality function started as inspection of a product at the end of a production line to ensure that the product was manufactured as per the design. It was initially handled by an inspector who was probably an experienced operator who continued to report to the production supervisor. **The function was mainly testing or inspection and the system of achieving quality was appraisal**. The inspector only measured quality and reported the results.

The wisdom of entrusting the supervision of inspection to the supervisor responsible for production was soon questioned. This led to the inspection being handled by a supervisor independent of production reporting directly to the on the Works Manager. The supervisor of inspection had the authority to take action based on the results of inspection. By approving what met the requirements and rejecting what failed to do so, he controlled the quality of products. Thus the function was inspection and control. **This phase can be called 'Quality Control'**. **The system was still appraisal only.**

With the spread of the use of Statistical Quality Control (SQC) tools, developed mostly by **Dr. W. Shewart,** inspection became more scientific. It was also realized that controlling a process while it is being performed, is more effective than testing at end of the line. Thus the action moved **end of the line to on-line.** This phase is known as **"Quality Assurance".**

Table on next page: Process of Evolution of the Quality Function

Phase	Quality Measurement	Quality Control	Quality Assurance	TQM / Six Sigma
Scope	Products	Materials, Products	Materials, Products, Production (Operational) Processes	Materials, Products, All Processes
Area of action	End of line	End of line	On-line	Before the beginning
System	Appraisal	Appraisal	Appraisal Prevention	Prevention Appraisal
Function	Inspection	Inspection Control	Inspection Analysis	Plan, Do, Audit (Check), Act *(Deming's PDCA)*
Status	Operator	Supervisor	Manager	General Manager / Vice President
Reporting to	Production Supervisor	Works Manager	General Manager	Managing Director / President

Exercise: Counting the G's

- **Refer Work Book.**

Assuming that the letter "G" is a defect, count all the "Gs" within 3 minutes.

Q 1. What are the Lessons Learnt from this exercise?
Q 2. Could you think of a better way of doing this process so that the mistakes can be reduced?

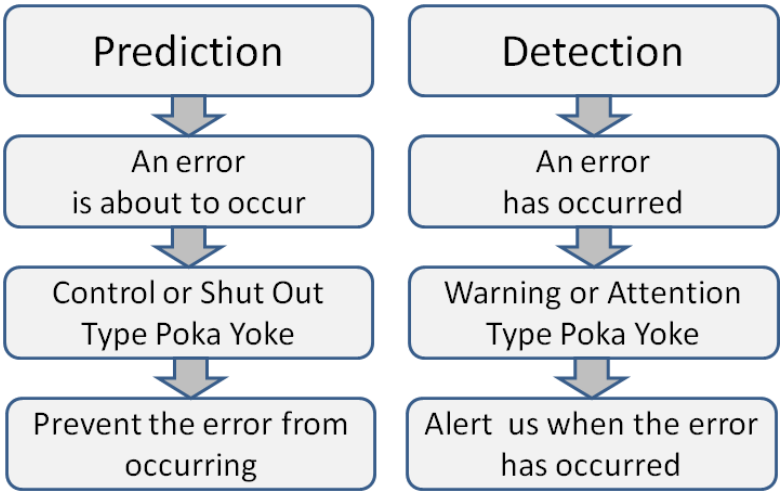
2.2 TYPICAL ROUTES FOR ACHIEVING PREVENTION (MISTAKE PROOFING / POKA YOKE):

RCO PREVENTION (Reduce Chance of Occurrence)	ICD PREVENTION (Increase Chance of Detection)
Preventing mistakes by designing the process / equipment such that an operation just cannot be performed incorrectly.	**Any attempt to perform a process / operation incorrectly, (or just performed) is met with a warning signal or alarm.**
EXAMPLES	**EXAMPLES**
• **Pen-drive will enter the USB port in one direction only** • **Microwave will shut down the moment we open its door.** • **Airport Trolley** • **Compulsory fields in online form**	• **Alarm for over-temperature** • **Alarm / Indication for "seat belt" or "handbrake on" in a car** • **Spell Check indicates entry of a wrong spelling.**

EXAMPLES OF RCO + ICD

1. Overload situation in elevator

2. Railway Signal



2.3 CORRECTION, CORRECTIVE ACTION, PREVENTIVE ACTION:

Correction	Corrective Action	Preventive Action
➢ Rectifying the mistake that has occurred. (damage control).	➢ First Find the Root Cause (Ask Why 5 times) OR (Fish Bone) ➢ Build Poka Yoke in the process to prevent re-occurrence of the root cause. (Japanese call this as "Kill the root cause").	➢ Extend the learning to other departments of the organization ➢ Build Poka Yoke in the process to prevent occurrence of the root cause in the first place. ➢ Globalize the solution ➢ Or Think pro-actively and build prevention in processes before things go wrong.

Lean Six Sigma is all about building prevention in processes.

If the process does not allow mistakes / defects to be generated, then there would be no need to "inspect" for defects or mistakes.

2.4 GOALS OF LEAN SIX SIGMA MANAGEMENT SYSTEM:

Lean Six Sigma is a management system that helps any organization to improve their profitability.

It involves systematic data collection & statistical analysis to achieve one of the following **THREE Goals:**

- ❑ Reduce defects in any process to reach a level of less than 3.4 per million opportunities for error.
- ❑ Eliminate Wasteful Practices.
- ❑ Delight internal and external customers by fulfilling their present & future needs.

The Ultimate Goal in all these efforts is:
To Increase R.O.I. (Profits) for the organization.

Typical Savings Target for a Lean Six Sigma Project:

*** Green Belt: AED / SR 0.25 Million per annum**

*** Black Belt: AED / SR 0.5 Million per annum**

Homework:

Read Article in Workbook:

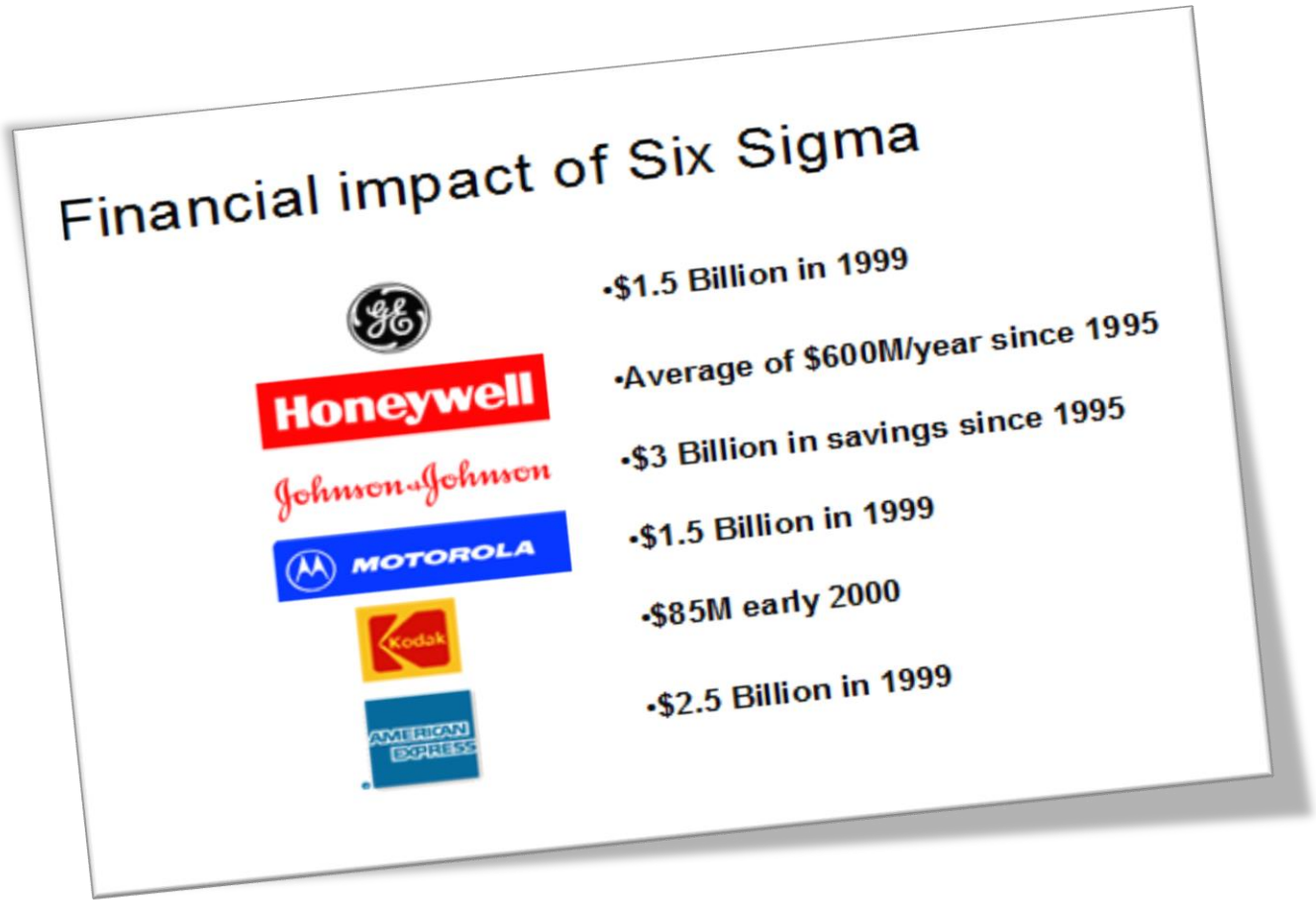
"How Teams are formed for Implementing Six Sigma Projects".

2.5 WORLDWIDE USE OF SIX SIGMA:

1986	Motorola
1989	IBM
1991	Kodak, DEC
1993	ABB
1995	GE, Allied Signal
1997	Dow Chemical, Dupont, NEC, Samsung, LG Electronics, Sony,Toshiba, Whirlpool
1999	American Express, J&J, Ericsson, NCR, Nokia, Philips, US Postal Service

2.5 WORLDWIDE USE OF SIX SIGMA:

In recent years, adoption of Six Sigma Management System has increased phenomenally. Today 53 % of Fortune-500 companies are using Six Sigma -- and that figure rises to 82 % when you look at just the Fortune-100.



2.6 COMPARISON BETWEEN SIX SIGMA & TQM:

SIX SIGMA	TOTAL QUALITY MANAGEMENT (TQM)
Developed by Motorola – USA (Many concepts borrowed from TQM)	Developed in Japan with help of Dr. Deming and Dr. Juran
Implemented through cross-functional teams	Implemented through cross-functional teams
More of the team-members are from middle-management (Six Sigma teams)	**More of the team-members from supervisor / team-leader and operator levels (Quality Circles)**
Focus is on pain areas affecting management	**Focus is on pain areas affecting day to day operations**
Methodology involves data collection, data analysis, root cause analysis and **measurement of quality in terms of "sigma levels"**	Methodology involves data collection, data analysis, root cause analysis
Profit / Savings are calculated at end of each improvement.	No such linkage is established.

Chapter 3

CROSS-FUNCTIONAL COOPERATION / BOUNDARYLESS COLLABORATION IN SIX SIGMA ORGANIZATION

Finding good players is easy. Getting them to play as a team is another story.

Casey Stengel

3. 1 TRADITIONAL ORGANIZATION

A traditional organization is normally categorized by vertical functions, such as:

- ✓ Design / Product development
- ✓ Marketing / Sales
- ✓ Purchase / Stores
- ✓ Human Resources
- ✓ Production / Operations
- ✓ Logistics
- ✓ Accounts
- ✓ Administration.

Functional targets (Key Performance Indicators i.e. KPIs) are delegated to achieve the **management goals** related to:

- Profitability
- Market-Share
- Sales Turnover
- Share-Prices.

3.2 CUSTOMERS INTEREST

But achievement of these functional goals and management goals are of no importance to the Customer. The customers are more interested in what the organization offers them in terms of:

<table>
<tr><th colspan="3">Quality - Q:</th><th>Cost – C</th><th>Delivery (Schedule) – D (or S)</th></tr>
<tr><td rowspan="2">Product Quality</td><td colspan="2">Support Quality</td><td rowspan="2">--</td><td rowspan="2">--</td></tr>
<tr><td></td><td></td></tr>
</table>

Shigeru Aoki, Toyota's Sr. M.D. refers to these **"Q-C-D" goals as SUPER-ORDINATE** compared to the functional goals since these are the goals that give value to customer.

These goals call for ***cross – functional efforts*** cutting horizontally across the whole organization.

Cross – functional cooperation (or Boundary-less Collaboration) is, therefore, a major requirement for an organization implementing six sigma so that it can deliver value to customers on an on-going basis.

3.3 FUNCTIONAL GOALS VERSUS CROSS FUNCTIONAL GOALS

The hierarchy of various Functional goals versus Cross- functional goals was clearly described by Shigeru Aoki as **Toyota's corporate philosophy**:

The ultimate aim of a company is to achieve the Management Goals.

Assuming that this is self – evident, the next "super-ordinate" goals of the company should be such cross – functional goals as:

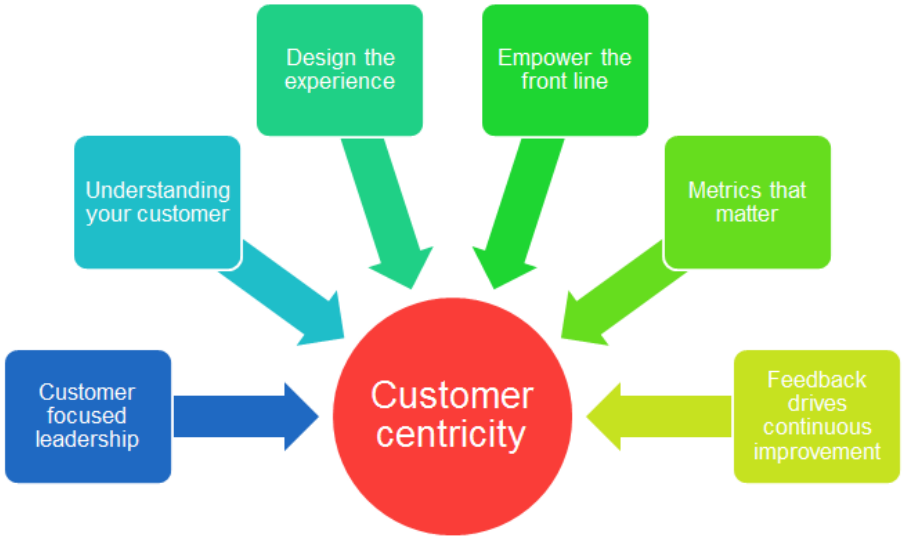
- ***Quality (PQ & SQ)***
- ***Cost***
- ***Delivery.***

If we focus on achieving these super-ordinate goals (i.e. the Q.C.D. goals) through cross – functional cooperation then profits will follow on an on-going basis.

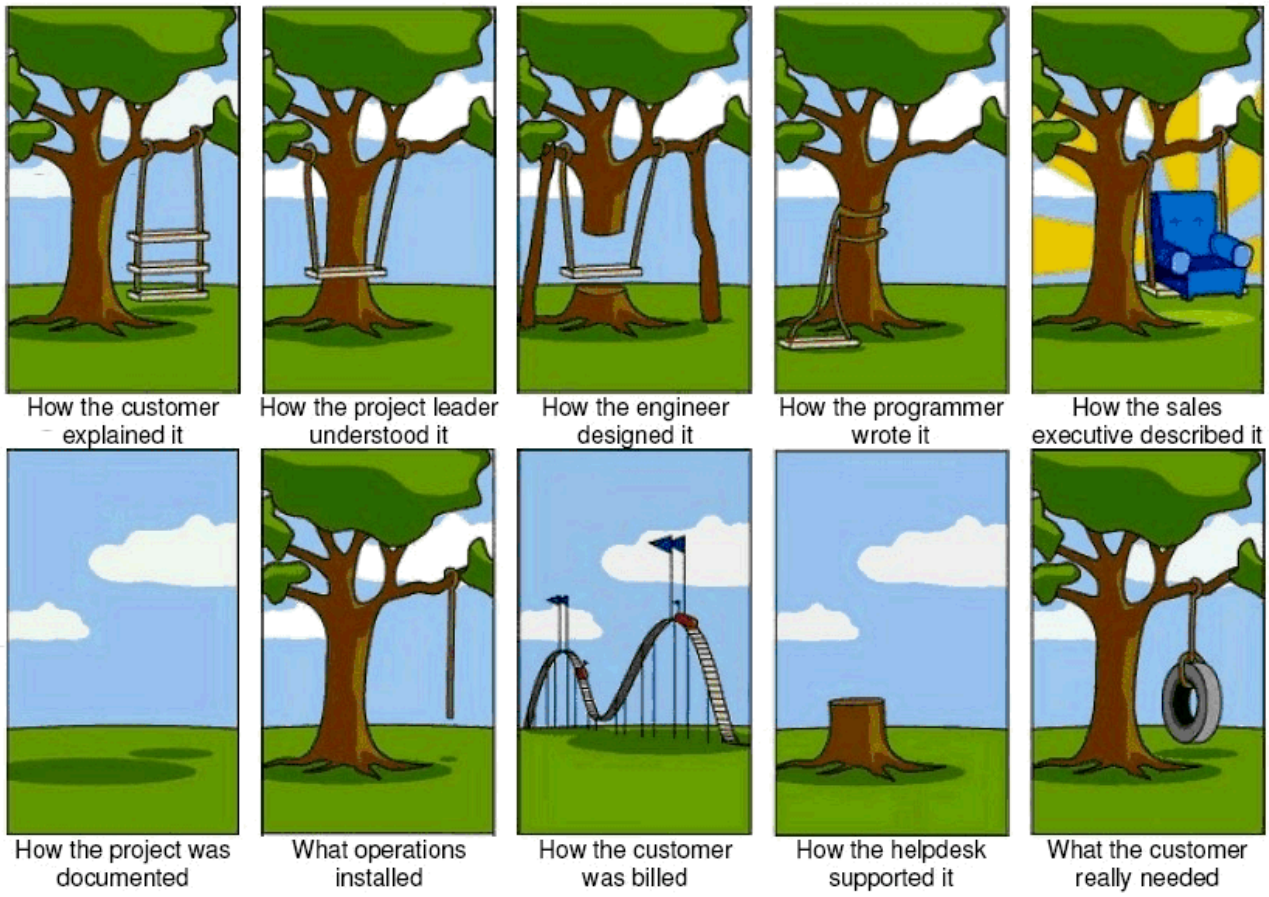
3.4 TRADITIONAL MANAGEMENT VS SIX SIGMA MANAGEMENT:

Traditional Management	Focus is on achieving Functional / Departmental Goals	**Organization-Centric**	**Management Goals achieved:**	This Strategy will work in situation of less or no competition.
	(Conflict between departments may exist)	(Seeks to provide Value for Organization)	Profit Sales-Turnover Market-Share Share-Prices	**(May not create goodwill and loyalty for organization in the long-run)**
Six Sigma Management	Focus is on achieving Q. C. D. Goals	**Customer Centric**	Profit Sales-Turnover Market-Share Share-Prices	This Strategy ensures long-run goodwill and loyalty of customer.
	(Achieved through cross-functional cooperation)	(Seeks to provide Value for Customer)		**Will succeed even in situation of high competition.**

3.5 EXAMPLE OF CUSTOMER CENTRIC ORGANIZATION:



3.6 DELIVERING VALUE TO CUSTOMER:

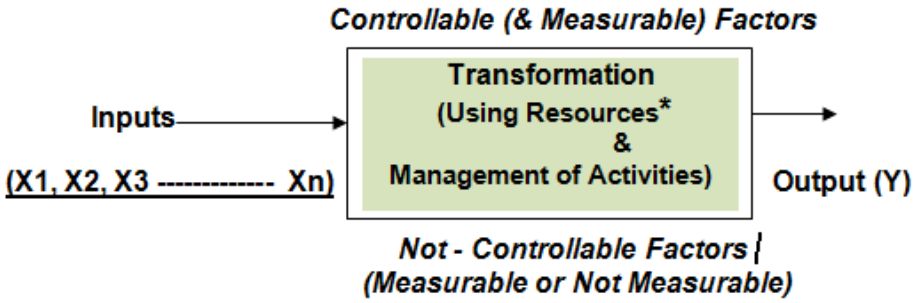


Chapter 4
THE PROCESS APPROACH – CTPs, DASHBOARD

THE RIGHT PROCESS WILL PRODUCE THE RIGHT RESULTS
TOYOTA PHILOSOPHY

4.1 THE PROCESS APPROACH AND PROCESS MODEL:

The Process Model:



Y	X1, X2, X3, . . . XN
Dependent Variable	Independent Variables
Output	Input & Controllable Factors
Effect	Causes
Symptom	Problem
Monitor	Monitor

IF WE UNDERSTAND THAT X1, X4, X6 ARE THE CAUSES, WHY DO WE CONSTANTLY TEST AND INSPECT Y?

4.2 EXERCISE:

- ***THINK OF YOUR IMMEDIATE CUSTOMER (INTERNAL OR EXTERNAL)***
- List two of his CTQs
- List two (measurable & controllable) CTPs for each of these CTQs.

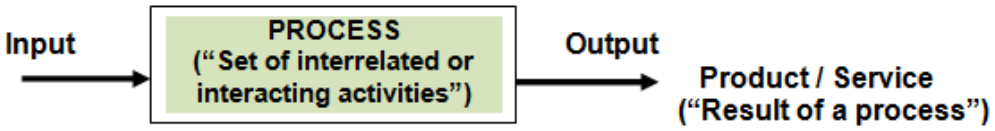
4.3 THE PROCESS APPROACH: Y = F(X1, X2, X3 ---------- XN)

The application of a **system of processes** in an organization, **along with identification** and interactions of these processes, and their management called as the process approach.

EFFECTIVENESS OF PROCESS = Ability to achieve satisfaction of customer

is

Effectiveness is "ability" of process to achieve the CTQ



Efficiency is results achieved versus resources used (i.e. at what cost?)

(The lesser the resources* used for achieving say X – Level of effectiveness, the more the process is efficient').

Resources includes 5 – Ms i.e. Men, Money, Machines, Methods, Materials.

EFFICIENCY OF PROCESS =

Results achieved Vs quantum of resources used

4.4 TO IMPROVE ANY PROCESS WE NEED TO :

- ✓ **Identify the Measurable outputs i.e. the CTQs.**
- ✓ **Identify the Measurable & Controllable inputs / factors that have major impact on achievement of the CTQs (i.e. the CTPs).**
- ✓ **Find ways to improve the CTPs using techniques like benchmarking, root cause analysis, etc.**
- ✓ **Focus on improving the CTPs to achieve the CTQs.**
- ✓ **Ensure that the process must have an owner.**

Chapter 5

DPU & DPMO – CALCULATING SIGMA LEVEL

If you don't have time to solve problems, how come you always have time to do it wrong again!

5.1 DEFECTS PER UNIT (DPU) AND DPMO –

DPU is the number of defects in a given unit of product or process.

$$DPU = \frac{\text{No. of defects detected (at given review point)}}{\text{No. of units processed at that review point}}$$

Defects Per Million Opportunities (DPMO):

$$DPMO = \frac{DPU \times 1{,}000{,}000\ (1.0\ \text{Million})}{\text{Opportunities for error in that unit}}$$

Example: *A purchase order has 20 opportunities for error. The person who enters the order makes one defect on an average. Compute the Sigma level for this process,*

It means: DPU = 1 / 1 = 1

$$\text{So, DPMO} = \frac{1 \times 1{,}000{,}000}{20} = 50{,}000$$

What is the Sigma Level?

5.2 UNDERSTANDING DEFECTS, UNITS & OPPORTUNITIES:

In order for any process capability to be calculated accurately, one must properly define and quantify the process defect, unit and opportunity. Every process should have definitions for defect, unit and opportunity.

a) **Start With The Customer:**

Before you can define your process defects, units and opportunities, you need to understand the needs of your customers. Voice of Customer is the process of gathering customer comments/quotes and translating them into issues and specifications. From these comments, issues and specifications come the customer CTQ (Critical To Quality) – a product or service characteristic that must be met to satisfy a customer specification or requirement.

b) **Define Your Product/Service Defects:**

A defect is defined as any part of a product or service that:

- does not meet customer specifications or requirements, or
- causes customer dissatisfaction, or
- does not fulfill the functional or physical requirements.

It should be noted that the term “customer” refers to both internal and external customers.

c) Define Your Product/Service Units:

A unit is something that can be quantified by a customer. It is a measurable and observable output of your business process. It may be seen as a physical unit or, if a service, it may have specific start and stop points.

d) Define Your Product/Service Opportunities for Error:

Opportunities are the total number of chances per unit to have a defect. Each opportunity must be independent of other opportunities and, like a unit, must be measurable and observable. The final requirement of an opportunity is that it directly relates to the customer CTQ. The total count of opportunities indicates the complexity of a product or service.

e) **Examples – Sigma Level Calculation**

Area: Call Center

Customer Quote: 'I consistently wait too long to speak to an Executive.'

CTQ Name: Executive Responsiveness

CTQ Measure: Time on hold (seconds)

CTQ Specification: Less than 60 secs. from call connection to the automated response system

Defect: Calls with hold time equal and greater than 60 secs.

Unit: Call

Opportunity: 1 per call

CALCULATE THE SIGMA LEVEL

Defects: 263 calls **Units:** 21,501 calls **Opportunities:** 1 per call

Area: Book Publisher

Customer Quote: 'I can't stand any typing errors in books I purchase.'

CTQ Name: Typographic Quality

CTQ Measure: Number of typographical mistakes

CTQ Specification: Zero typographical mistakes

Defect: Any typographical mistakes

Unit: A word

Opportunity: No. of letters per word (Average)

CALCULATE THE SIGMA LEVEL

Defects: 35 typographical mistakes

Units: 100,000 (500 words/page x 200 pages/book)

Opportunities: 5 per word (average)

Calculating Sigma Level of An Entire Organization

EXAMPLE - School Process:

Sub-Process	No. of Students	No. of Defects	Opportunities for Error	DPU	DPMO	Sigma Level
Admission	200	20	6			
Admin.	1500	600	17			
Teaching	1500	500	13			
Homework	1500	450	7			
Extra Curricular	1200	550	12			
Sports	1000	200	4			
Exam	1500	900	19			
Library	1400	30	7			
			Total Opportunities	Total DPU		

Chapter 6

COST OF QUALITY – IMPACT ON SIGMA LEVEL OF A PROCESS

> **It is always cheaper to do it right first time**
>
> ***Dave Crosby***

6.1 COST OF QUALITY:

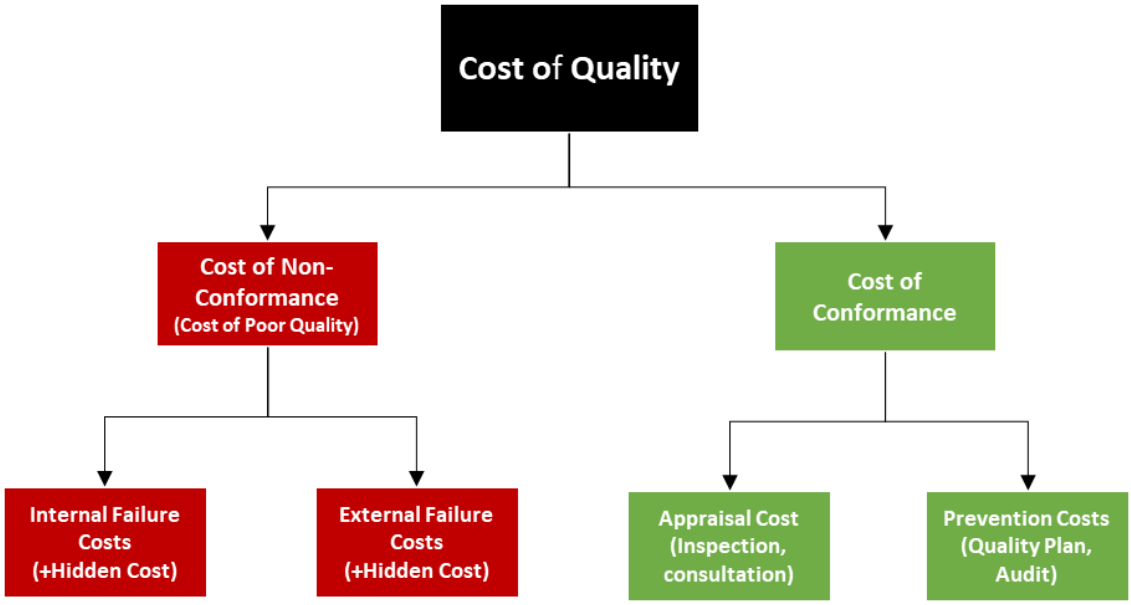
The effective cost component of a product or service that is **attributable to the quality aspects** can be called as cost of quality. The costs of quality are:

a. Failure costs – Internal & External

b. Hidden costs

c. Appraisal costs

d. Prevention costs.



The effective cost component of a product or service that is attributable to the quality aspects can be called as cost of quality.

6.2 FAILURE COSTS:

a) Internal failure costs:

These are costs resulting from defects, before delivery of an organization's product or service or communication to external party. Typical examples are:

- costs of labor or machines hours lost in scrapped items,
- cost of rework,
- cost of re-testing and re-inspection,
- cost of machine / server downtime,
- cost of corrective actions,

b) External failure costs:

These are costs on defects that an organization incurs after delivery of its product or service or communication to external customers. Typical examples are:

- cost of attending to customer complaints and repairs (service costs),
- cost of replacement,
- cost of returned goods,
- cost of product recalls,
- cost of mistake in a product advertisement.

6.2 HIDDEN COSTS:

Hidden costs are generally present in all cases of internal and external failures.

Typical examples are:

- Potential lost sales,
- Extra processing costs due to defects,
- Legal claims on the organization.

Cost of Non-Conformance = Cost of Making Mistakes (Cost of Poor Quality)

= Internal Failure Cost + External Failure Cost + Hidden Cost

6.3 APPRAISAL COSTS :

These are the costs of determining the degree of conformance to quality requirements.

Typical examples are:

- ✓ Cost of inwards, in-process and final inspection,
- ✓ Cost of destructive test losses, if any,
- ✓ Cost of preparation conducting audits,
- ✓ Cost of maintenance and calibration of test instrumentation and facilities,
- ✓ Cost of administrative machinery and organization for inspection, testing and appraisal.

6.4 PREVENTION COSTS:

These are the costs of preventing errors / minimizing failures in an organization. Typical examples are:

- Cost of acquiring quality-related data and analyzing for prevention,
- Cost of pilot production,
- Cost of engineering quality at design stage,
- Cost of quality planning,
- Cost of process control and design of process control systems,
- Cost of training for quality,
- Cost of preventive maintenance.

Cost of Conformance = Cost of Appraisal + Cost of Prevention

Case Study – A: Consider the following situation:

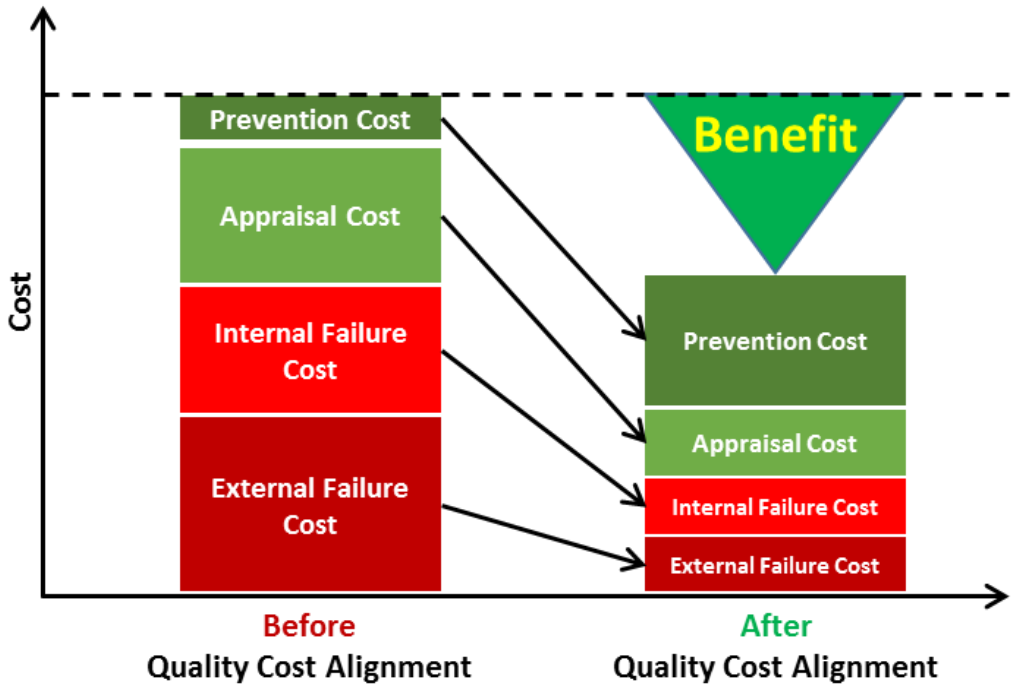
ITEM	JAN TO DEC' 17	JAN TO DEC' 18
Cost of Internal Failure (Rework, Scrap, Etc.)	SR / AED 210,000	SR / AED 440,000
Cost of External Failure	SR / AED 340,000	SR / AED 90,000
Appraisal Cost	SR / AED 120,000	SR / AED180,000 **(One additional inspector for checking outgoing quality was appointed from 1st Jan 2018).**

Q1. How would you compare Jan to Dec'18 with Jan to Dec'17? Why

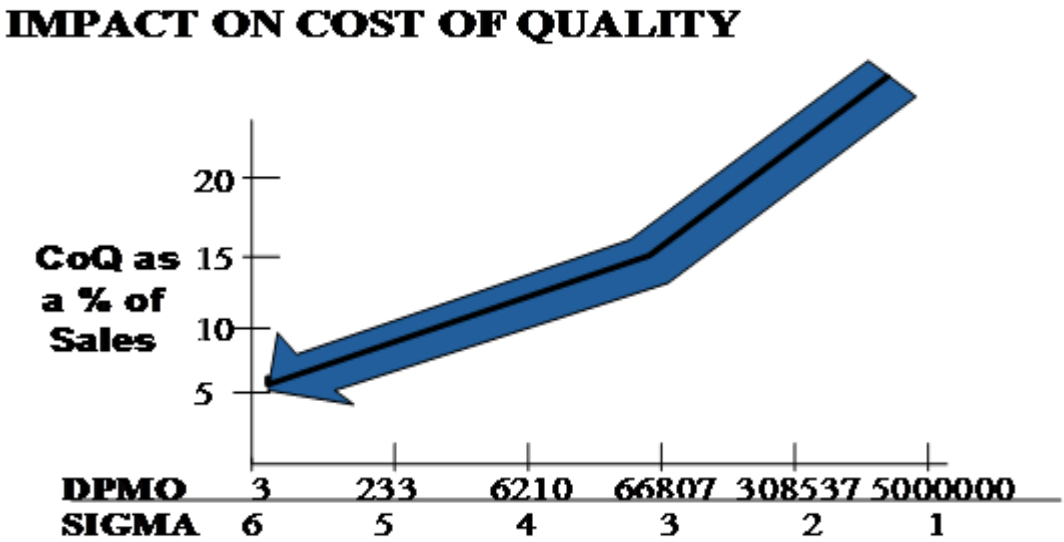
Q2. What should be the plan of action for Jan to Dec'19?

Exercise

EXERCISE (Workbook): COQ - CLASSIFICATION



According to Phil Crosby COQ as % of Sales can vary from 1% to 40% :



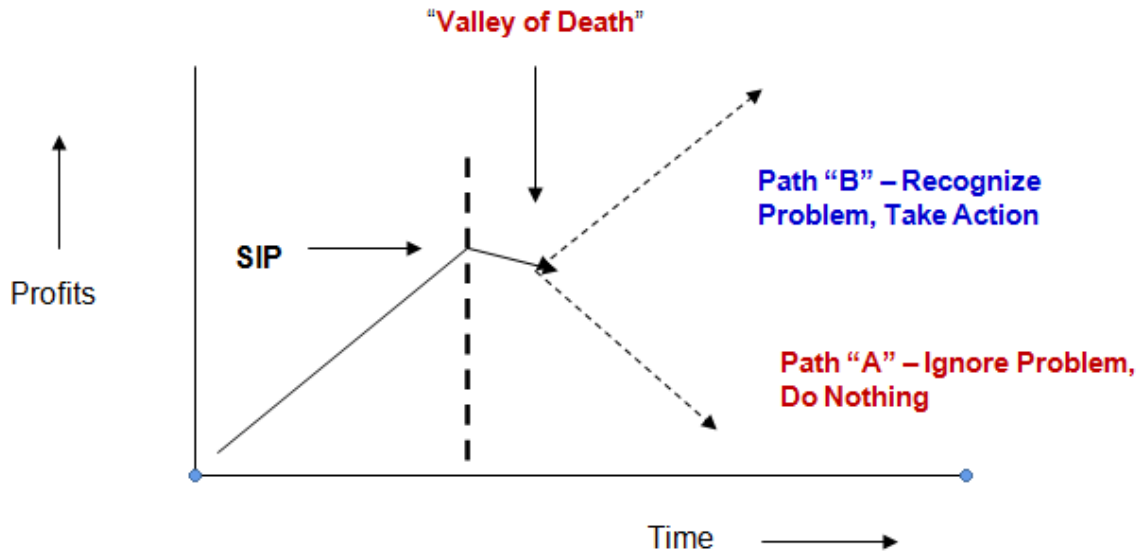
Chapter 7

MOTOROLA'S JOURNEY FROM 3.4 TO 6.0 SIGMA

7.1 MOTOROLA'S INITIATIVE

What drove Motorola towards the Six Sigma Initiative in the 1980's?

The Strategic point of Inflexion (SIP)



Motorola's Key Objectives:

- To survive in a Global Economy
- To Cut Waste (operating costs)
- To win more customers.

7.2 MOTOROLA'S DEFINITION OF SIX SIGMA?

Six Sigma is a **process improvement methodology** that aims to:

- Reduce defects to a rate of 3.4 defects per million defect opportunities,

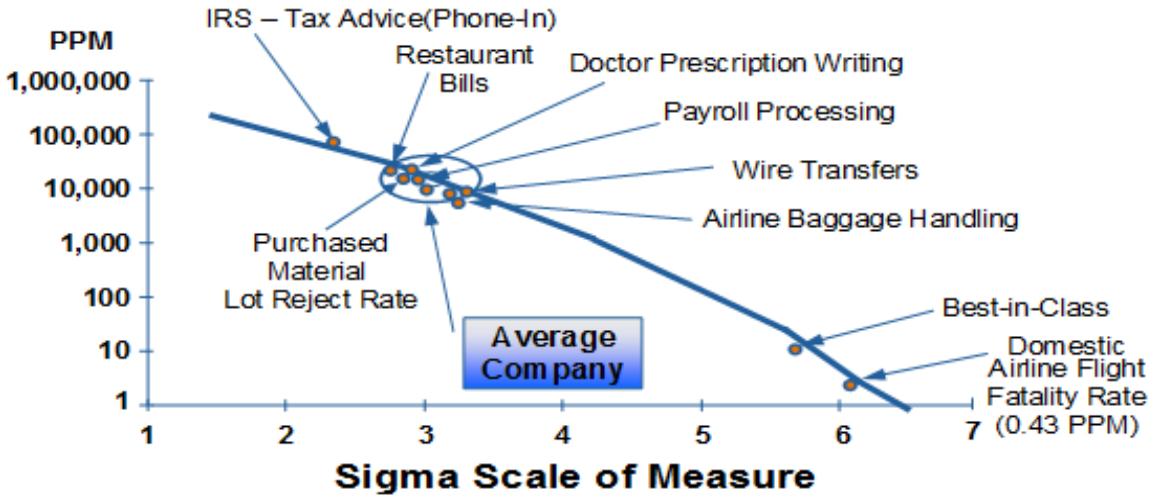
- By identifying and eliminating causes of variation in business processes,
- Using statistical processes, wherever required, and
- Focusing on development of a very clear understanding of customer requirements (Voice of Customer).

Sigma Level	Defects per Million	Defects as Percent	Improvement:
One Sigma	690,000.00	69.00%	
Two Sigma	308,000.00	30.80%	2 times
Three Sigma	66,800.00	6.68%	5 times
Four Sigma	6,210.00	0.62%	10 times
Five Sigma	**230.0**	**0.023%**	**30 times**
Six Sigma	**3.4**	**0.00034%**	**80 times**

Table: Comparison of 99.9 % Quality Vs 99.9997 %

Activity / Operation	Error (Nos.) With 99.9 % Quality	Error (Nos.) With 99.9997 % Quality
Delivery of 300,000 letters	300 mis – deliveries	1 mis – deliveries
Out of 5,00,000 computer restarts	500 crashes	< 2 crashes
Clearance of 200,000 cheques in a week	200 wrong clearances	< 1 wrong clearance
Handling of 60,000 nos. baggage by Airlines in a day	60 bags lost in a day	< 2 bags lost in a week

Sigma Quality Level with various services



A Sigma rating indicates the ability of a process to perform without defects

7.3 MOTOROLA'S VISION IN 1980'S:

- Saw the need to be Proactive (many other electronic companies were failing due to Japanese competition)
- Wanted to be world's best communication company just as Toyota wanted to be worlds best car company
- Translated Quality into quantifiable language (while other companies were talking about customer satisfaction and world class Quality)
- Began to impose the six Sigma (3.4 PPM) initiative everywhere throughout the organization (technical as well as non – technical) – This company initiative greatly impressed the Malcolm Balridge Examiners in 1980's.

What Motorola did?

Goal set: 3.4 PPM (i.e. DPMO).

This translated to a **10 time improvement every two years**, i.e. 10 times reduction in DPMO every two years.

(The Journey: 30,000 DPMO to 3 DPMO in 8 years).

Year	DPMO	Sigma Level (??)
1986	30,000	
1988	3,000	
1990	300	
1992	30	
1994	3	

7.4 SPECIFIC ACTIONS TAKEN BY MOTOROLA:

1. Strong emphasis on training (employees and key suppliers) – Motorola University started in Schaumburg, later worldwide,
2. Key goals announced to all employees and organizations,
3. 40 hour per year, per employee training mandate,
4. Executive bonuses tied to quality improvement demonstrated,
5. Training involved areas like :

   - ✓ Six Sigma Basics
   - ✓ Process Mapping
   - ✓ SPC
   - ✓ Risk Analysis (FMEA)
   - ✓ DMAIC
   - ✓ Design for Six Sigma
   - ✓ Design of Experiments.

   Effective Supply Base Management

   - ✓ Early Supplier Involvement
   - ✓ Schedule Sharing
   - ✓ Partnership for Growth,

6. Benchmarking on a Global Scale ("Bandit Programme"),
7. Total Customer Satisfaction programmes to foster employee involvement.

Chapter 8
SIX SIGMA – BASIC PRINCIPLES
(SELF-READING)

We are what we do repeatedly, excellence then is not an act, but a habit

Aristotle

8.1 PRINCIPLE 1: GENUINE FOCUS ON CUSTOMER

- Everyone talks of exceeding customer expectations, but very few really understand their customer needs / expectations.
- Sincere efforts to measure customer satisfaction (perception) on an on – going basis are necessary to identify correct CTQs, which would then lead to correct CTPs.
- In Six Sigma, customer focus is top priority.

8.2 PRINCIPLE 2: DATA – AND – FACT DRIVEN MANAGEMENT:

- It begins by clarifying which measures are key to achieving the business performance i.e. which are the CTPs?
- Then it applies data & analysis to build understanding of the CTPs to achieve optimization of the results.

:Six Sigma projects combine:
Process Knowledge (Critical Thinking) **+** **Analysis of Data (Statistical Thinking).**

8.3 PRINCIPLE 3: PROCESS FOCUS, MANAGEMENT & IMPROVEMENT:

Six Sigma focuses on “Process Approach” to achieve success.

We look at every activity as a process:

- Find the CTQs required by the customer for the process.
- Find the CTPs (controllable & measurable) factors that have major Impact on the CTQs
- Improve the CTPs to improve the CTQs
- Develop a Monitoring System (Control Chart) to ensure that the CTPs are performing at the required levels i.e. the Process Indicators (Dashboard).
- Develop a Monitoring System (Control Chart) to ensure that the CTQs are performing at the required levels i.e. the Quality Indicators.

8.4 PRINCIPLE 4: PRO – ACTIVE MANAGEMENT:

(Means acting in advance of events) such as:

- Focusing on problem prevention (Preventive Action)
- Questioning “Why” we do things in a certain way, instead of blindly defending them.

Instead of personnel reactively bouncing from crisis to crisis (and looking busy), Six Sigma talks of creative thinking to achieve on-going improvements.

8.5 PRINCIPLE 5: BOUNDARYLESS COLLABORATION:

- Six Sigma approach eliminates competition between groups who should be working for a common cause – (providing value to customers).

- It encourages work environment that supports true teamwork in companies between

  - ✓ Employees
  - ✓ Vendors (Suppliers)
  - ✓ Customers.

8.6 PRINCIPLE 6: DRIVE FOR PERFECTION, TOLERANCE FOR FAILURE:

- To improve performance i.e. (better service / lower cost / new capability)

  ↓

  Mistakes can occur

  Six Sigma allows for failure but through technique of Risk Management (ensuring only safe – failure).

  Approaches to Risk Management:

Risk Level	Gain	Loss
No	**No**	**No**
Low	**Low**	**Low**
High	**High**	**High**

  Six Sigma works on basis of Calculated Risk:

  Assessment of Risk and Reduction of Risk.

8.7 FACTORS WHICH CAN LEAD TO FAILURE IN SIX SIGMA IMPLEMENTATION:

a) Top management participation is missing

b) Champion is not interested in a particular six sigma project.

c) Impatience of Management / Employees:

- Stopping the six sigma initiative after a few quick wins,
- Expecting to reach six sigma level within a year.

d) Selection of wrong persons for the black belt's role:

Persons selected for Black Belt's Role need to be:

- ✓ Creative by nature – need to do more of lateral thinking,
- ✓ Effective in leading a cross-functional team
- ✓ Enthusiastic about finding solutions when none are clearly visible.

e) Resistance to change – not handled adequately.

Six Sigma methodology is successful mainly through involvement of people and their to give up old habits / methods of doing work. We may use very good methodologies, but these may not succeed if we cannot change the culture.

8.8 CULTURAL CHANGES REQUIRED WHILE IMPLEMENTING SIX SIGMA:

- **Willingness to collect & analyze data:**

  Processes are better understood only if we collect data and analyze data related to the process. We need to create a culture wherein people do not hesitate to collect data and analyze data.

- **Employees must question existing practices:**

  We need to encourage employees to question the "present way of doing thing during brainstorming sessions.

  "Is this the best way?" "How can we make it better?"

- **Employees must communicate openly about failures:**

Often people have a tendency to hide mistakes – Why? Due to fear of being blamed. When people hide mistakes, there will be no root cause analysis, no C.A.and no P.A.
Result: The same mistakes / defects will repeat.

We need to create a culture where employees "can openly talk of their mistakes". When a mistake occurs: we need to focus **on what went wrong and not on who went wrong.**

- **Proactive thinking across the organization:**

Instead of fire-fighting / reacting to problems, employees need to think in advance "what can go wrong in this process" and how can we prevent the mistakes proactively.

- **Positive attitude to internal & external Customers:**

Often the response to a customer complaint is to believe that *"the customer is complaining unnecessarily" or "whatever we are doing is right* – the customer simply trying to trouble us"

In a six sigma organization, it is very important to believe the customer complaint and respond to the same in a positive manner. Often this requires an attitudinal change.

- **Cross-functional cooperation:**

As an organization implementing six sigma, our main goal is to deliver value to customer in terms of achieving the Q.C.D. goals. This calls for excellent teamwork and cooperation between the departments.

In many situations, teamwork does not come naturally – it has to be taught.

- **Self Discipline:**

Quality management, TQM and Six Sigma go hand in hand with self-discipline. We may improve processes, make SOPs, train people on the SOPs but the process will not improve if people will not follow the SOPs consistently. This requires self-discipline. If we have to reduce variation (improve consistency) in our processes it **will happen only when everyone follow the SOPs and the audit plans.**

Chapter -9
UNDERSTANDING VARIATION IN PROCESSES

9.1 Understanding Variation:

*Consider the **situation-1** below:*

- You went grocery shopping only to select the slowest cash counter in the store,
- You received a haircut that was shorter or longer than usual, and definitely not what you asked for,
- You decided to go shoe shopping, but got stuck with the most ignorant salesperson available.

*Consider the **situation-2** below:*

- You went grocery shopping and reached the fastest cash counter in the store,
- You received a haircut that was exactly as you wanted,
- You decided to go shoe shopping, and met the best salesperson in the shop .

Sure, are you happy about being in situation – 2, but what about the times when you are in situation – 1? Often we wonder why this variation?

Let's examine a few ways to help us evaluate variation in processes:

Lets say that on your way home you stop at your local pizza shop to order a pizza that you (and your family) are waiting for. We will consider the general concept of variation by examining the preparation time (in minutes) of 10 pizzas being prepared by the two local shops. **The times are listed below.**

ABC Pizza	6.5	6.6	6.7	6.8	6.8	6.9	7.0	7.1	7.2	7.3
XYZ Pizza	4.2	5.4	5.8	6.2	6.7	7.2	7.2	8.5	9.3	10.0

If we use common statistical tools, such as mean, median, and mode we get the following results.

9.2 MEAN:

The mean is the **average data point** value within a data set.

To calculate the mean, add all of the individual data points then divide that figure by the total number of data points.

Calculating the mean (x-bar) in both cases, we get

- **Mean for ABC Pizza = 6.89**
- **Mean for XYZ Pizza = 7.05.**

9.3 MEDIAN:

Relating to or constituting the **middle value** in a distribution.

The median is the middle point of a data set; 50% of the values are below this point, and 50% are above this point. Median is the middle value, when all possible values are listed in an ascending order.

(If number of **data points (n) is even**, then median is the average of the n/2 th and (n/2 +1) th reading. If number of **data points (n) is odd**, then median is the (n + 1)/2 th reading).

In this example, median will be average of the 5^{th} and 6^{th} reading.

Calculating the median in both cases, we get

- **Median for ABC Pizza = 6.85**
- **Median for XYZ Pizza = 6.95.**

9.3 MODE:

The value or item occurring most frequently in a series of observations or statistical data.
The most often occurring value in the data set. So, the mode in both cases will be:

- **Mode for ABC Pizza = 6.8**
- **Mode for XYZ Pizza = 7.2**

	ABC Pizza	XYZ Pizza
Mean	**6.89**	**7.05**
Median	**6.85**	**6.95**
Mode	**6.8**	**7.2**

You can see from these results that the two pizza shops have nearly equal "means". So, **on an average**, customers wait for the same amount of time for pizzas at the two shops.

However, we can see a very clear difference: ABC Pizza has preparation times with **much less variation** than the times for XYZ Pizza.

(If all the other characteristics of the pizza like taste, temperature, size and topping quality are equal, a customer is likely to prefer ABC Pizza where he will not become annoyed by being the one person whose pizza preparation time is much slower than the others).

In other words, variation is what customers do not like.

Therefore, in six sigma the most important goal is to reduce variation.

One measure of variation in a process is the **difference in values of the Mean, Median and Mode.**

Another measure of variation are the **Range** and **Standard Deviation.**

9.4RANGE:

The easiest way to measure variation in a process is the **range**. It is simply the difference between the highest value and the lowest value among the data points.

By inspecting and comparing the differences in variation between the preparation times of the two pizza companies, we can get an idea of the variation. But in

business, we need more than an idea - we need to measure and quantify the process - variation.

Range and standard – deviation are typical measures of variation in a process.

Range in these 2 cases will be:

- **Range for ABC Pizza = 0.8**
- **Range for XYZ Pizza = 5.8**

ABC Pizza	6.5	6.6	6.7	6.8	6.8	6.9	7.0	7.1	7.2	7.3
XYZ Pizza	4.2	5.4	5.8	6.2	6.7	7.2	7.2	8.5	9.3	10.0

For the ABC Pizza data, the range is the difference between 7.3 minutes and 6.5 minutes, which is **0.8 minutes**.

The range for XYZ Pizza preparation time is 10.0 - 4.2 = **5.8 minutes**.

The much larger range in case of XYZ Pizza shows that their process has a much larger variation than the ABC Pizza.

9.5 STANDARD DEVIATION AS A MEASURE OF PROCESS VARIATION:

The standard deviation (*s*) of a set of sample data is a measure of variation of the data as compared to the mean, and is defined by the following formula:

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}}$$

Using this formula we can now compare the variation of the two pizza companies and note that

Standard Deviation in these 2 cases will be:

- **Standard Deviation for ABC Pizza = 0.26**
- **Standard Deviation for XYZ Pizza = 1.8**

Thus the standard deviation for ABC Pizza (**0.26 minutes**) is much lower than the standard deviation for XYZ Pizza (**1.8 minutes**). In other words, the variation in ABC Pizza process is much less than the variation in the XYZ Pizza process.

In our definition of standard deviation, we have referred to the **standard deviation of sample data as *'s'*.**

If we want to calculate the **standard deviation (σ) of a population**, we would divide by the population size *N*, instead of *n*-1.

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{N}}$$

Exercises:

Calculate the Mean, Median, Mode, Range and Standard Deviation in respect of the following data:
(Hint: First arrange the data in ascending order)

1. Heights of 20 persons in a room (in cms):

158, 158, 159, 160,160, 160, 155, 157, 162, 168,
162, 162, 164, 164, 160, 160, 165, 165, 168, 173

2. Time taken by a call center executive to resolve problems of 15 customers: (in minutes):

2.0, 2.6, 2.7, 2.7, 2.3, 2.3, 3.1, 3.1, 3.1, 3.6, 3.6, 3.6, 4.1, 3.1, 3.1

Chapter -10

THE SEVEN TOOLS OF QUALITY

10.1 THE SEVEN TOOLS OF QUALITY ARE:

1. Flowchart,
2. Check Sheet,
3. Pareto Chart,
4. Histogram,
5. Cause and Effect (Ishikawa / Fishbone diagram),
6. Scatter Diagram,
7. Control Chart.

Most of these tools help in visual presentation of the data, which is useful for presentation and discussion in Cross-Functional Teams (CFT's).

According to Ishikawa, 95% of quality-related problems can be resolved with these basic tools. The Pareto Chart and Cause & Effect Diagram are two tools that are used most widely by process improvement teams**.**

1. FLOWCHART:

Flowcharts describe a process in as much detail as possible by graphically displaying the steps in proper sequence.

A good flowchart should show the process - steps in the appropriate sequence.

The process team can analyze these steps:

- By **identifying the critical process points that need to be controlled** so that suitable appraisals and preventions can be added (to prevent likely

failure modes).

- By looking for **missing steps**, if any.

- By checking the **value-addition** provided by each step in the process.

2. CHECK SHEET:

Telephone Interruptions

Reason	Day					
	Mon	Tues	Wed	Thurs	Fri	Total
Wrong number	𝍸	||	|	𝍸	𝍸 ||	20
Info request	||	||	||	||	||	10
Boss	𝍸	||	𝍸 ||	|	||||	19
Total	12	6	10	8	13	49

Check sheet helps in organizing the data by category.

It is a data-collecting device.

They show how many times each particular value occurs, and their information is increasingly helpful as more data are collected.

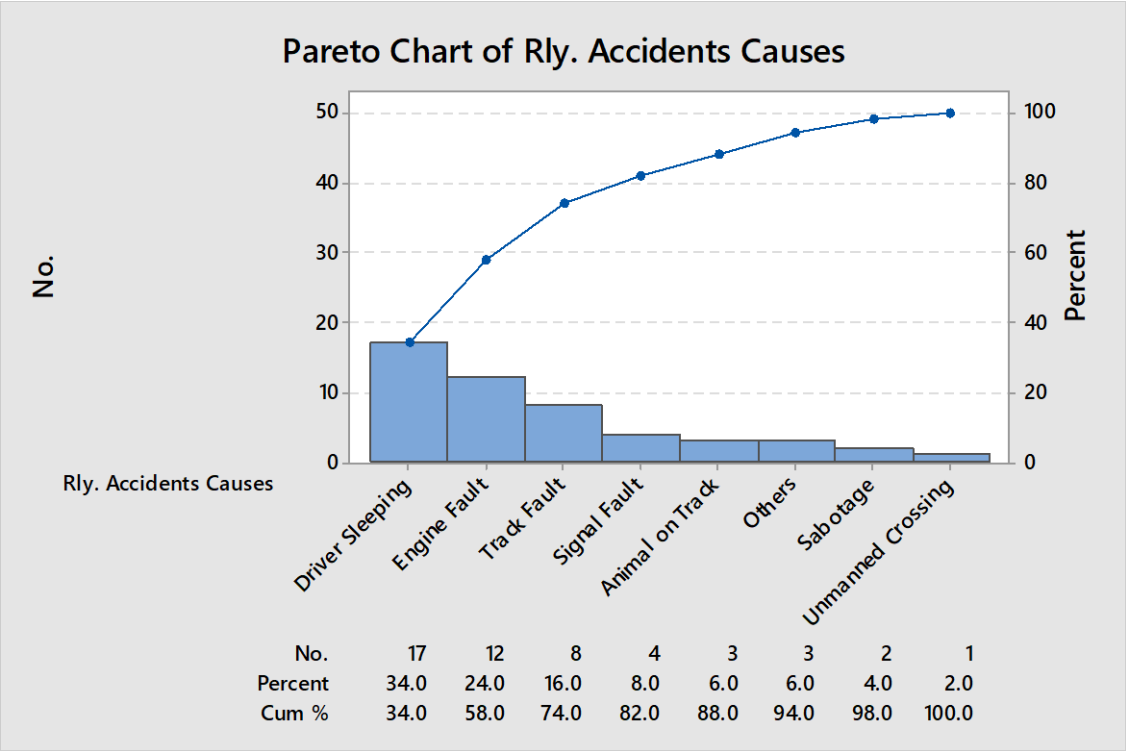
Check sheets minimize clerical work since the operator merely adds a mark to the tally on the prepared sheet rather than writing out digits. By showing the frequency of a particular defect and how often it occurs in a specific location, check sheets help operators to spot the problems.

One can easily see where to set priorities based on results shown on this check sheet. Assuming the production flow is the same on each day, the part with the largest number of defects carries the highest priority for correction.

Question:

Explain difference between "Check-Sheet" and "Check-List".

3. PARETO CHART:



Exercise: Causes for Railway Accidents (Out of 50 cases):

Driver Sleeping – 17, Signal Fault – 4, Track Fault – 8, Engine Fault – 12, Animal on track – 3, Unmanned crossing – 1, Others – 3, Sabotage – 2.

4. HISTOGRAM:

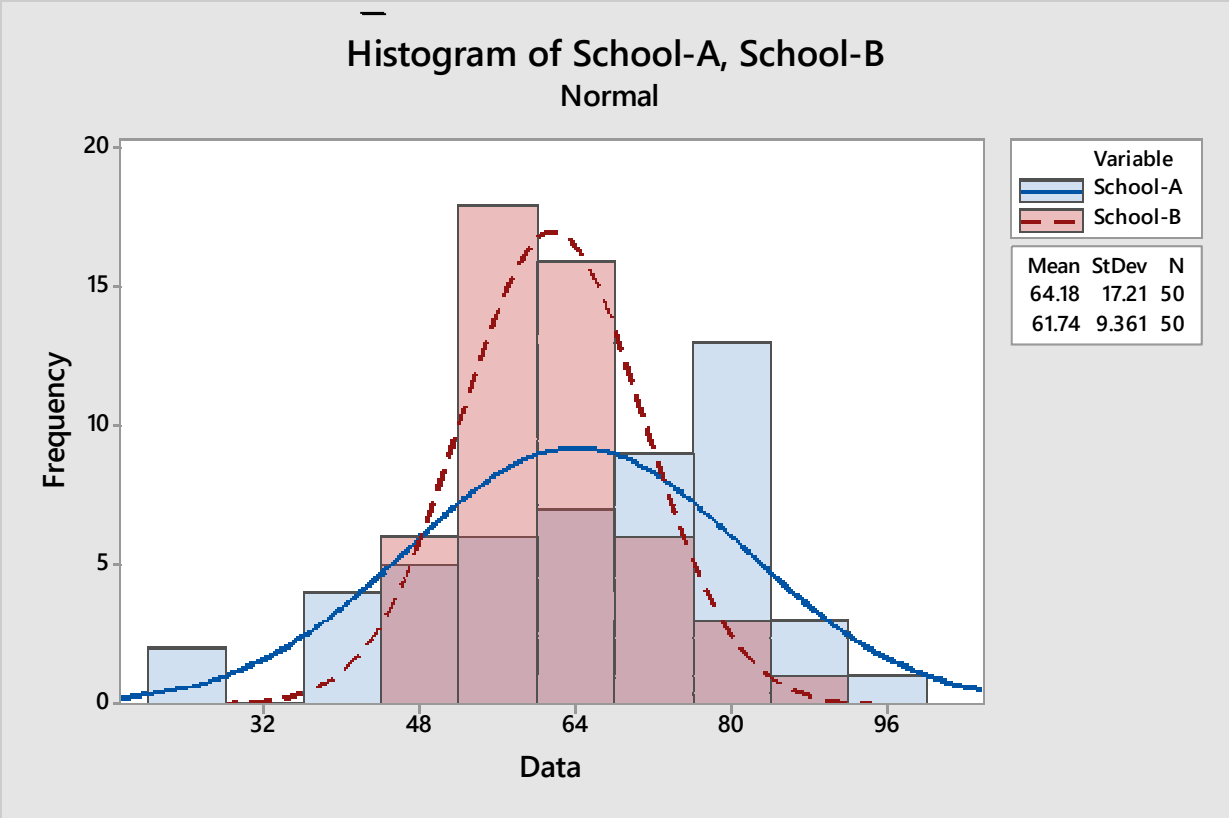
Is used to display the frequency of distribution of continuous / variable data.

Lets Compare the Process in School – A and School – B as per data given below:

- % marks obtained by the students
- No. of students in each school = 50
- Pass percentage is 50%.

% Marks Obtained	
School-A	**School-B**
96	90
91	81
91	81
91	81
82	73
82	73
82	73
82	73
82	73
82	73
77	66
77	66
77	66
77	66
77	66
77	66
77	66
68	61
68	61
68	61

68	61
68	61
68	61
68	61
68	61
68	61
62	58
62	58
62	58
62	58
62	58
62	58
62	58
55	55
55	55
55	55
55	55
55	55
55	55
47	53
47	53
47	53
47	53
47	53
38	51
38	51
38	51
38	51
23	50
23	50



TYPICAL CONCLUSIONS FROM HISTOGRAM:

i. A strong "central tendency " (i.e. Mean, Median, and Mode are close to each other) indicates less 'assignable cause' variation in the process.

ii. If the bars are more spread out, it means that "range" is higher i.e. presence of a higher 'non-assignable' cause variation in the process.

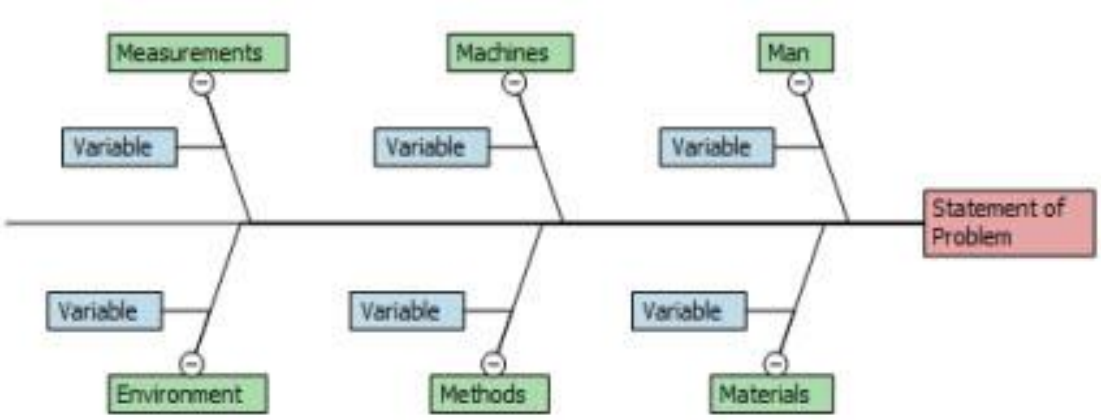
iii. More than one "Mode" indicates presence of another distribution imposing on the main distribution and also needs to be investigated as an 'assignable cause' of variation.

5. FISHBONE / ISHIKAWA DIAGRAM / CAUSE & EFFECT DIAGRAM:

a. 5-M Fishbone:

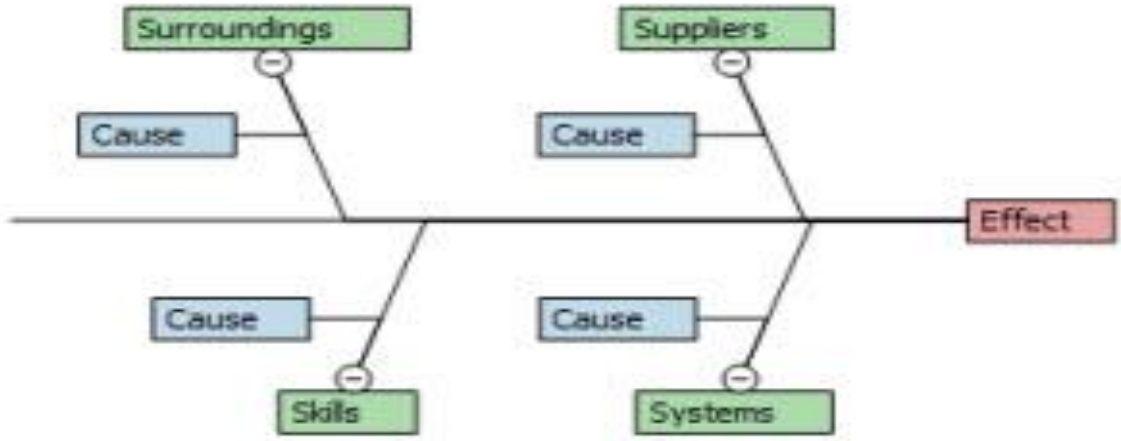
This fishbone is **commonly used for manufacturing situations**. It allows you to organize potential causes of a problem into following categories:

Men, Materials, Machine, Methods, Measurements, and Environment. In some cases, two additional categories are included: Money and Maintenance.



b. 4S Fishbone:

This type of cause & effect diagram is **commonly used in the service industry**.
It organizes information about potential causes into four common categories: Suppliers, Systems, Surroundings, and Skills.



6. CO-RELATION DIAGRAM / SCATTER DIAGRAM:

i) PURPOSE: TO FIND THE **CTPs** IN THE PROCESS

Y : Dependent Variable

Xs (X1, X2, X3, …….Xn): Independent variables.

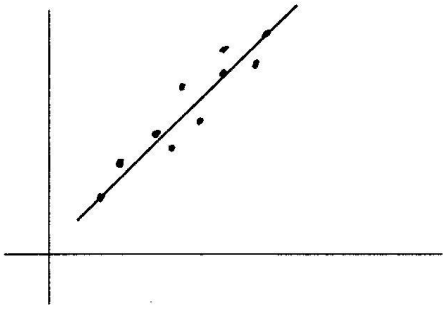
ii) We draw Scatter Diagram to see the kind of relationship of Y with each of the Xs i.e. X1, X2, X3,…….Xn.

After plotting the data points for (say) Y Vs X1, we draw a best fitting line.

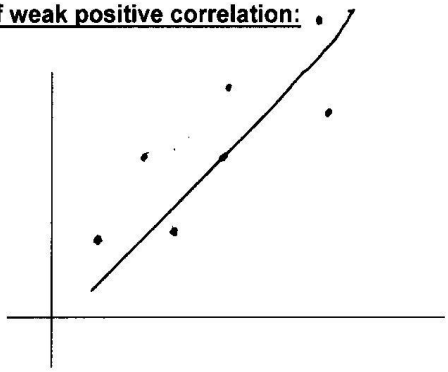
a) If Y increases as X1 increases, it's a **POSITIVE Co-relation.**

b) If Y decreases as X1 increases, it's a **NEGATIVE Co-relation.**

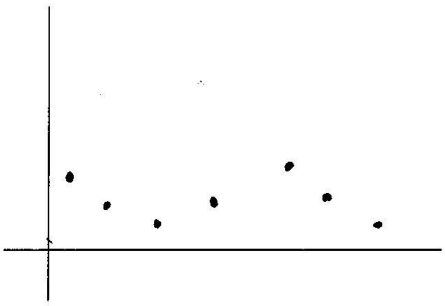
iii) **Example of strong positive correlation:**



iv) **Example of weak positive correlation:**



v) **Example of no correlation:**



Scatter diagram only shows correlation. To study Cause & Effect more carefully, we need to use the Fishbone Diagram.

Exercise:

a. Draw Scatter Plot for the following data:

Car Name	Weight Kg	Km / lit
Camry	1600	14.5
Sonata	2400	8
Civic Honda	1200	17.5
Landrover	2300	8.5
Mercedes	2100	10
Cheverlot	1900	11.5
Dodge	3000	6
Hyundai Ascent	1500	13.5
Alto	900	22.5
Fiat Uno	1100	18.5

b. *Calculating & Interpreting Correlation Coefficient 'r':*

Correlation coefficient [r] calculation is used to find how strong a relationship is between data.

- **r = + 1** indicates a strong positive relationship.
- **r = -1** indicates a strong negative relationship.
- **r = 0** indicates no relationship at all.

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[\, n\Sigma x^2 - (\Sigma x)^2 \,][\, n\Sigma y^2 - (\Sigma y)^2 \,]}}$$

c. *Calculating & Interpreting Correlation Coefficient 'r' in Excel*:

	Weight Kg	*Km / lit*
Weight Kg	**1**	
Km / lit	**- 0.96631**	**1**

Strong Correlation	Weak Correlation	No Correlation
Most of the points in Scatter Diagram are very close to the best fitting line.	Most of the points in Scatter Diagram are far from the best fitting line.	You cannot draw any type of best fitting line.
Co-relation Coefficient 'r' lies between - 0.7 to -1.0 OR 0.7 to 1.0	Co-relation Coefficient 'r' lies between - 0.3 to – 0.69 OR 0.3 to 0.69	Co-relation Coefficient 'r' lies between 0.0 to – 0.29 OR 0.0 to 0.29
CTP	NOT CTP	NOT CTP

:SUMMARY:

FLOWCHART – MAKES PROCESS STEPS VISIBLE

- **VALUE ANALYSIS, APPRAISAL, PREVENTION**

CHECKSHEET – DATA RECORDING DEVICE (ATTRIBUTE / COUNT DATA)

PARETO CHART – PRIORTIZATION TOOL (COUNT DATA)

- **VITAL FEW, TRIVIAL MANY**
- **HELPS TO FIND ROOT CAUSES**
- **HELPS TO FIND CTQs and CTPs**

HISTOGRAM – FREQ. OF DATA DISTRIBUTION (CONTINUOUS DATA)

- **CENTRAL TENDENCY: MEAN / MEDIAN / MODE**
- **RANGE**
- **MULTI MODES**

FISHBONE DIAGRAM – BRAIN STORMING

- **ROOT CAUSE ANALYSIS**
- **MULTI-VOTING (NOMINAL GROUP TECHNIQUE)**

SCATTER DIAGRAM – CORRELATION BETWEEN TWO VARIABLES [RELATION OF CTQ WITH CTP(s)]

- **CORRELATION COEFFICIENT (r)**

CONTROL CHART – EXPLAINED IN NEXT SECTION.

Chapter- 11

USE OF SPC (STATISTICAL PROCESS CONTROL) IN SIX SIGMA:

:CONTROL CHARTS ARE USED FOR:

Process Capability Calculations (ANALYZE Phase of DMAIC)	Monitoring The Process After Improvement (CONTROL Phase of DMAIC)
To study nature of variation *** Extent of Non-Assignable Cause Variation in the process**	***To monitor the process performance on an on-going basis*** **ICD system to warn for occurrences of Assignable Causes**

11.1 Understanding Specification Limits:

While we say that customer does not like variation, does it mean that our process must achieve ZERO variation?

Not really: Customer is willing to accept variation within certain limits. These are called as the:

- . Upper Specification Limit (**USL**)
- Lower Specification Limit (**LSL**).

11.2 Understanding Control Limits:

a) To monitor our process, we create a control chart with the use of statistically determined upper and lower control limits drawn on either side of a process average.

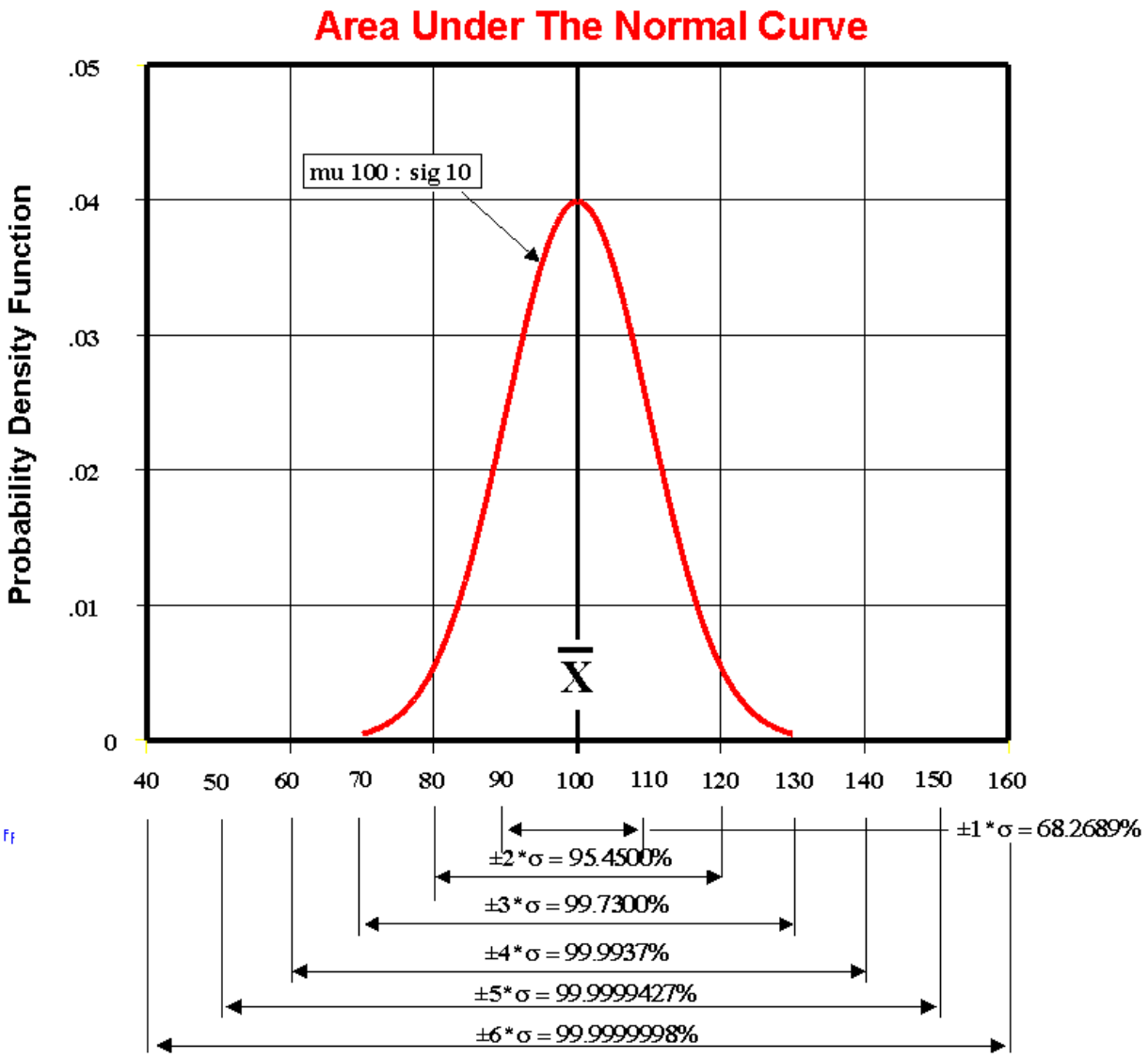
These are called:

- . Upper Control Limit (UCL) = x-bar + 3σ
- Lower Control Limit (LCL) = x-bar - 3σ

CAPABLE PROCESS:

The control limits are determined by the data of our process.

These are used as WARNING LIMITS and if the process is capable, these control limits must be within the specification limits.



11.3 CAPABILITY OF A PROCESS:

The characteristics of any process are dependent on two elements:

- *Mean i.e. x-bar*
- *Standard Deviation (SD) i.e. "s" or "σ"*

Dr. Shewhart chose the control limits as:

- Upper Control Limit (UCL) = x-bar +3SD
- Lower Control Limit (LCL) = x-bar - 3SD

because 99.73 % of the data under the normal distribution curve is corresponding to these limits.

He calculated:

a) *Specification Width* $(SW) = USL - LSL$

b) *Process Width* $(PW) = UCL - LCL$

$$= (x\text{-}bar + 3\sigma) - (x\text{-}bar - 3\sigma) = 6\sigma.$$

So: **Process Capability Index** is defined as:

Cp = SW / PW = SW / 6σ

Process Is Said To Be Capable Only If Cp Is > 1.

Note: Cp is inversely proportional to value of SD (σ)
which is a measure of the SPREAD /inherent cause variation in the process

Exercise:

a) ***Calculate UCL, LCL*** *for both persons in the example below and plot on a graph against the USL, LSL.*

b) *Also* ***calculate Process Capability Index Cp****:*

(USL = 72 Kg, LSL = 68 Kg as specified by the doctor)

Weights of 2 patients are given below in Kgs*:*

Mr. Waseem	***Mr. Peter***
70	*70*
70.4	*71*
70.5	*72*
70.3	*71*
69.8	*70*
69.4	*69*
69.6	*68*
70	*69*
x-bar = 70	***x-bar = 70***
SD = 0.39	***SD = 1.31***

Exercise:

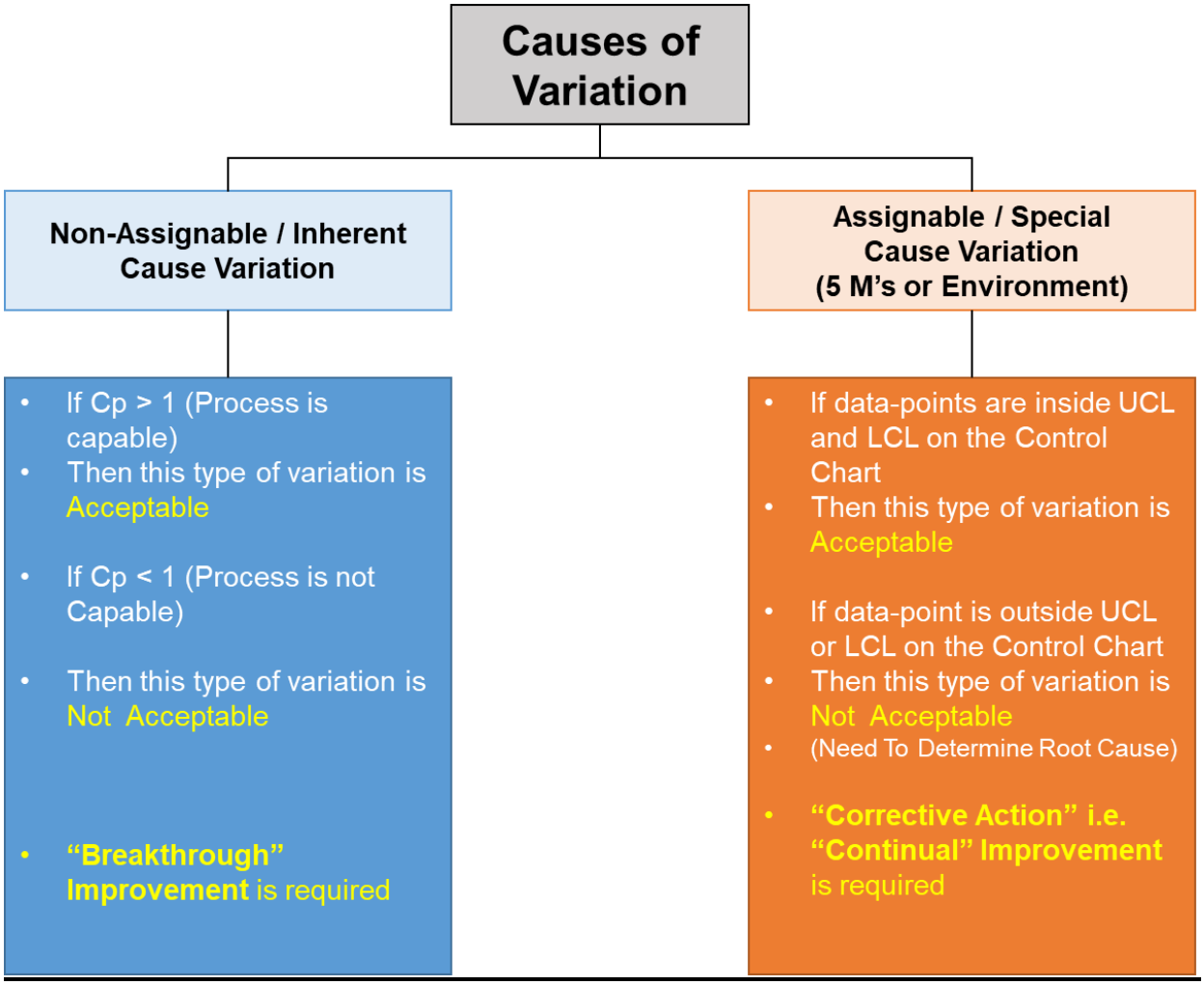
Calculate Process Capability Index Cp for the following:

Arrival time in office:

USL = 9.05 am (545 Min),
LSL = 8.55 am (535 Min),
T = 9.00 am (540 Min)

	A	B
Day-1:	**543**	**541**
Day-2:	**544**	**540**
Day-3:	**536**	**539**
Day-4:	**537**	**540**
Day-5:	**540**	**542**
Day-6:	**541**	**538**
Day-7:	**545**	**539**
Day-8:	**538**	**541**
Day-9:	**540**	**540**
Mean:	**539.8**	**540.1**
σ :	**3.6**	**1.05**

11.4 CAUSES OF VARIATION – 2 TYPES:



11.5 TRANSFORMING DATA TO CHARTS:

Consider a process which cuts rubber bands. These rubber bands are required to be 4.0 cm in length with a given plus and minus tolerance of 0.7 cm specified by the customer.

It means that USL= 4.7, LSL= 3.3.

As these rubber bands are produced, the operator randomly selects 3 samples every hour, measures them and enters the average reading in the table below.

Time	8 AM	9 AM	10 AM	11 AM	12:00	1 PM	2 PM	3 PM	4 PM
Length	4.2	4.4	3.8	4.3	4.1	4.2	4.5	3.9	3.8

The process owner has determined a set of limits for the product length.
These limits are UCL = 4.5 and LCL = 3.5 cms.

The operator has been instructed to stop the process and alert the line supervisor if any measurement should go "outside" these limits. If the measured values stay within these limits, the operator lets the process run.

A basic control chart may be developed with the data in the table above**.**

Rules for Interpreting Control Charts:

The typical rules as to when the process is considered as "out of control" OR is "likely to go out of control" are:

1. **One point** outside the UCL or the LCL

2. **Seven (or nine) points** in a row on the same side of the center line

3. **Six (or eight) points in a row**, all increasing or all decreasing.

*These are indications of an "**assignable cause**".*

THE CONTROL CHART ACTS AS AN ICD

11.6 SHIFT OF THE MEAN:

Motorola observed that the processes (normal distribution curve) tend to shift over a period of time.

This is again due to assignable causes.

Hence we need to also look at **one more process capability index Cpk**

*(**Cp** is valid only for a non-shifted process and is called Short Term Capability Index.*

***Cpk** is calculated for a shifted process and is called Long Term Capability Index.*

$$Cpk = Min.\ of \quad \frac{USL - Mean}{3\sigma} \quad OR \quad \frac{Mean - LSL}{3\sigma}$$

Note: Cpk also must be >1 for process to be considered as capable (after shift of mean).

Exercise:

Calculate Cp, Cpk and comment if Process is Capable or not?

Sr.	USL	LSL	T	Mean	σ
1.	+5	-5	0	-1	1.0
2.	+5	-5	0	+3	1.0
3.	+5	-5	0	+4	1.0
4.	+5	-5	0	0 (No Shift of Mean) Cp=Cpk	1.0
5.	+10	0	5	+3	0.8
6.	+10	0	5	+3	1.2
7.	+10	0	5	+7	1.2

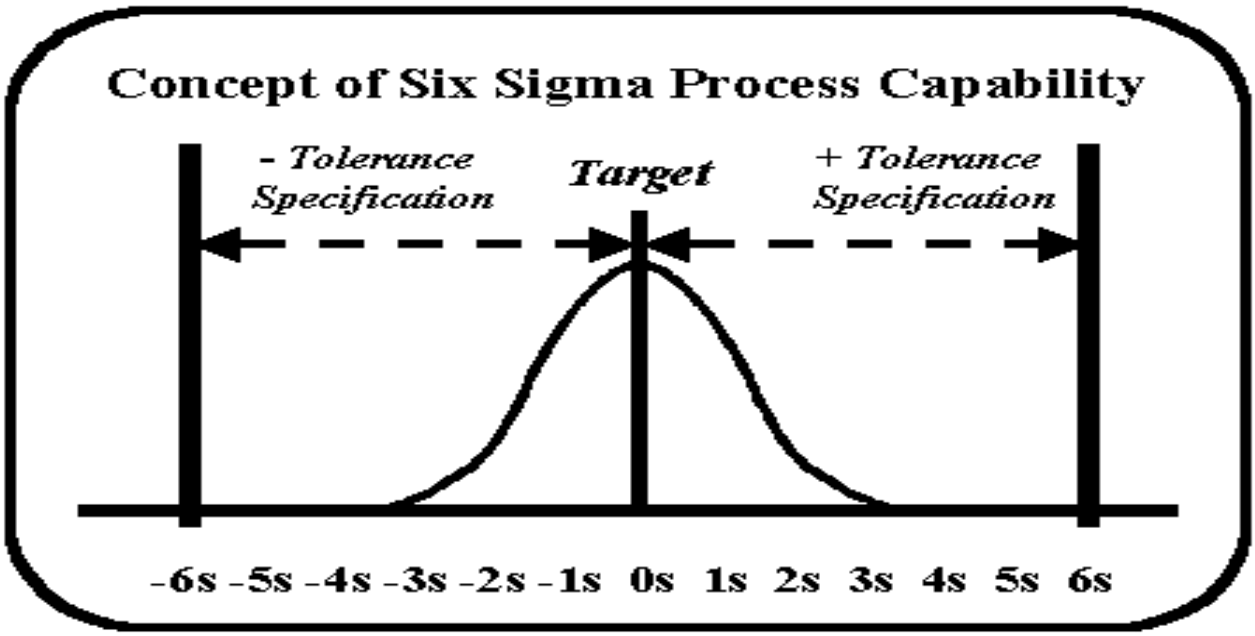
Further, Motorola was not contented with Shewhart's fitting +/- 3 σ within USL and LSL.

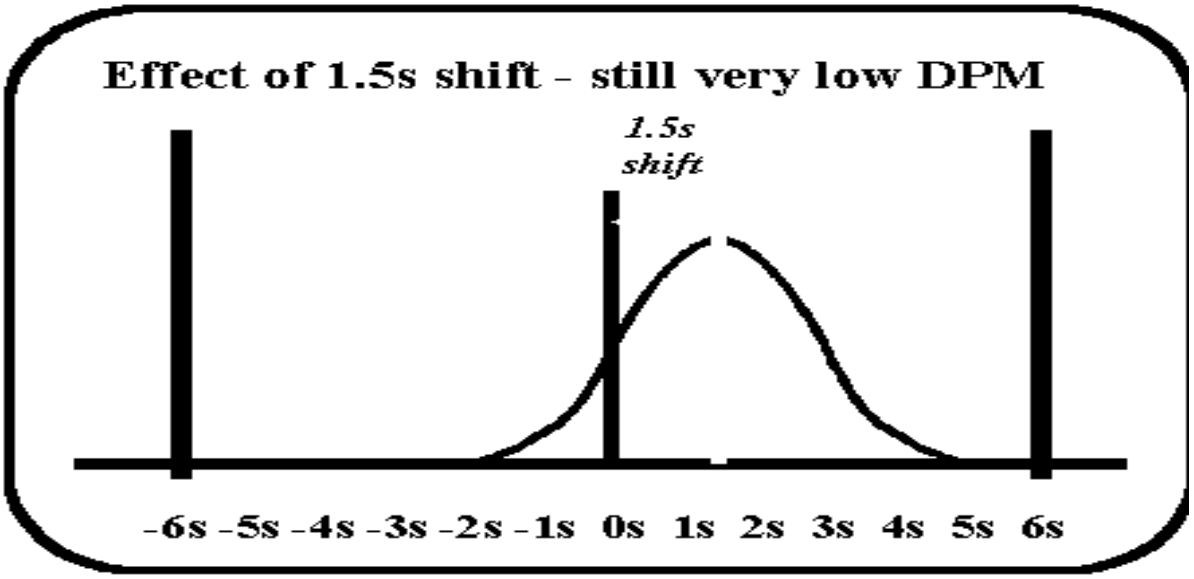
They targeted a much higher level of process capability i.e. to fit +/- 6 σ within USL / LSL.

i.e. we reduce the SD so much that PW becomes ½ of SW. (see figure below).

In this situation, Cp = SW / PW = SW / ½ SW = 2.

Motorola defined this as a SIX SIGMA PROCESS.




Effect of 1.5s shift – still very low DPM
1.5s
shift
-6s -5s -4s -3s -2s -1s 0s 1s 2s 3s 4s 5s 6s

11.7 CONTINUAL IMPROVEMENT Vs BREAKTHROUGH IMPROVEMENT:

When do we need Continual Improvement	**When do we need Breakthrough Improvement**
Process is out of control (Data point outside UCL or LCL) OR	**Cp is < or = 1**
Process is likely to go out of control (6-points / 7-points rule) OR	**i.e. Process is not capable to meet requirements of customer i.e. Variation due to Inherent Causes is High**
Mean has shifted (i.e. Cpk is not equal to Cp).	**------**
ACTION: Remove 'assignable' causes using root cause analysis, Corrective & Preventive Action.	**ACTION:** **Reduce Std. Dev. which is directly dependent on the 'non-assignable' cause variation in a process.**

11. 8 TWO MEANINGS OF SIGMA:

a) The term "Sigma (σ)" is used to represent "Standard Deviation [SD]".

b) For a business process, the "Sigma Capability (Cp) or Sigma Level" is a measurement that indicates how well that process is performing.

Sigma Level	***Cp***	***Defect Count without Shift***	***Cpk (After 1.5 Sigma Shift)***	***Defect Count considering 1.5 Sigma Shift***
3.0	*1.0*	*2700*	*0.5*	*66,810*
4.0	*1.33*	*63*	*0.83*	*6,210*
5.0	*1.66*	*0.57*	*1.16*	*233*
6.0	*2.0*	*0.002*	*1.5*	*3.4*

Chapter 12
DMAIC METHODOLOGY

Improvement usually means doing something that we have never done before. *Shigeo Shingo*

12.1 SIX SIGMA PROJECT METHODOLOGIES:

8- Discipline Methodology (by Ford)	DMAIC Methodology	DFSS
		(Design for Six Sigma) Methodology
Used for:	**Used for:**	**Used for:**
• Problem Solving	• Problem Solving	• Design of new product / process
(Root Cause Analysis, Permanent Corrective Action, Systemic Action)	• Process Improvement	• Re-design of existing product / process
Leads to:	Leads to:	Leads to:
• Continual Improvement	• Continual Improvement +	Design / Redesign of product / process with fewer defects (goal is to start at a higher sigma level like 4.5)
	• Breakthrough Improvement	

12.2 DMAIC PHASES:

DMAIC is a **five – phase improvement cycle** as under:

D – Define

M – Measure

A – Analyse

I – Improve

C – Control

12.2 THE DMAIC PROCESS – MAIN STEPS & KEY DELIVERABLES:

A) DEFINE PHASE:

PURPOSE: To prepare a PLAN for the LSS project, an Overview Process Map (SIRPORC) and Assign Responsibilities.	
Define Phase	**Steps / Tools**
• **Define Customers and their Requirements (CTQs)**	• V. O. C Gathering, Kano and CTQ definition
• **Develop Project Charter** ***(Example in Section 12.3)***	• - Problem Statement - Goal Statement - Business Need Addressed - Scope / Boundaries of the Project - Constraints - Resources Needed - Team Guidelines - Team Composition - Preliminary Project Milestones
• **Develop High Level Process Map** ***(Example in Section 12.4)***	• SIRPORC (SIPOC)
• **Specify Responsibilities & Authorities for the Project**	• Roles of the team members: – who will give **Inputs** - who will **Review** - who will be **Accountable** - who will **Signoff**
Define Tollgate Review (as per checklist)	

B) MEASURE PHASE:

PURPOSE: Gather data to establish the "current / baseline status" – Understand how the process runs today.

Measure Phase	Steps / Tools
• Define Defect, Opportunity, Unit and Metrics	• Based on CTQs and Process Knowledge, Benchmarking
• Identify the CTPs	• Using Pareto, Correlation Analysis, CT Matrix
• Develop Data Collection Plan & Formats to collect data related to the CTQs and CTPs	• Questionnaires, Sampling-plans
• Validate the Measurement System	• Measurement System Analysis (MSA) - CALIBRATION
• Collect the Data, Tabulate the Data, Present the data in form of Graphs / Charts	• Check Sheet, Data Sets
• Calculate Process Capability and Sigma Baseline.	• Cp, Cpk, DPMO / Sigma Level Calculations.
Measure Tollgate Review (as per checklist)	

C) ANALYZE PHASE:

PURPOSE: Analyze and determine the root cause(s) of the defects. Interpret the data to establish cause – and – effect relationships and analyze the process maps.	
Analyze Phase	**Steps / Tools**
• Identify Value / Non-Value Added Process Steps and Critical Points in the process	• Value Analysis and Review of Process Map / Flowcharts
• Identify Sources of and Understanding nature of Variation	• Histogram, Control Chart, Box & Whisker Plot
• Determine Root Cause(s)	• Cause and Effect / Fishbone Diagram, Ask why 5 times, Pareto
• Determine Vital Few X's, Y=f(X) Relationships	• Correlation Analysis, Regression Analysis, Design of Experiments, Hypothesis Testing
• Prepare Action Plan to explore various solutions for the causes.	• Brainstorming, SWOT analysis.
Analyze Tollgate Review (as per checklist)	

D) IMPROVE PHASE:

PURPOSE: Finalize the solutions after FMEA, Pilot-test the solution and Implement the solutions.	
Improve Phase	**Steps / Tools**
• Develop Potential Ideas & Solutions	• Brainstorming, DOE,
• Assess Failure Modes of Potential Solutions	• FMEA
• Reduce risks associated with potential solutions	• Mistake Proofing
• Plan & Execute solution on Pilot basis	• Verification
• Fine-tune the Potential Solution	• Brainstorming
• Implement Complete Solution	• Validation
• Check Performance Levels after Improvement.	• Cp, Cpk, DPMO, Sigma levels.
Improve Tollgate Review (as per checklist)	

E) CONTROL PHASE :

PURPOSE: Ensure that the improvements / gains are sustained.	
Control Phase	**Steps / Tools**
• Authenticated Calculations of Savings Achieved	• Determining improvement in process capability & process sigma
• Develop & Implement the Documentation Plan	• Standardized Work (SOPs, Flow Charts, etc.)
• Develop & Implement the Training Plan	• Develop New Competencies
• Developing & Implementing the Control Plan	• Control Charts for monitoring the critical CTQs and CTPs
• Plan the Audit Schedules & Audit Requirements.	• PDCA
• Transfer of Project to Process-Owner.	
Control Tollgate Review (as per checklist)	

12.3 SAMPLE PROJECT CHARTER – (TPM Printers)

a) Problem Statement:

WHAT IS A PROBLEM STATEMENT?

The problem statement is a **QUANTIFIED description** of the problem that we are facing in the process. It includes baseline data about the current state in terms of the baseline metrics. For Example:

40% of orders delivered to corporate clients of TPM Printers' are not meeting customer requirements, including 23% rejected due to "uneven color of ink" and 17% noted as "late deliveries".

b) Goal Statement:

(Goal statements must be **SMART**)**:**

- *Specific*
- *Measurable*
- *Achievable*
- *Realistic*
- *Time-Bound.*

For Example:

*Reduce "**delivery errors**" by 60% and cut "**rework costs**" by 50% in the next 5 months.*

c) Business Need Addressed:

These defects are costing the organization nearly AED / SR 80,000.00 per month. Also, continued high levels of delivery errors threaten our position as leader in this growing industry.

d) Scope / Boundaries of the Project:

In-Scope	Out-Scope
Orders delivered to Corporate Clients	Orders delivered to clients other than Corporate Clients

e) Constraints:

Team members will be expected to devote 25 to 30% of their time to the project . They will need to be relieved accordingly from their existing jobs.

f) Team Guidelines:

- The team will meet at least once a week. Tuesday mornings from 9 am to 10 am.
- Decisions will be made by consensus.
- If consensus can't be reached, the Team Leader will make the final call.

g) Team Members:

The team is comprised of the following members:

- ✓ M. Usman, Production Manager (Champion)
- ✓ T. Peter, Product Design (Team Leader i.e. Black Belt)
- ✓ Mohammed S., Manufacturing (Green Belt)
- ✓ Ayub Khan., Manufacturing (Green Belt)
- ✓ K. Rehman, Sales (Green Belt)
- ✓ S. Yezdi, Procurement (Green Belt)

h) Preliminary Project Plan:

To achieve our goal and results by our target date, the team will have to work aggressively and rapidly.

The following are **milestones** for completing each phase of the DMAIC process:

- *DEFINE* – Aug 16 (Approx. 3 weeks)
- *MEASURE* – Oct 14 (Approx. 8 weeks)
- *ANALYZE* – Nov 20 (Approx. 3 weeks)
- *IMPROVE* – Dec 31 (Approx. 8 weeks)
- *CONTROL* – Jan 28 (Approx. 3 weeks).

✓ In many ways, the Define phase is a very important phase of the DMAIC cycle.

✓ If this phase is not done thoroughly, teams may move on to subsequent phases only to stall and cycle back through “Define.”

✓ This phase should be emphasized and teams should not move forward until the Sponsor / Process Owner signs off on it.

EXERCISE:

- Doctor to Mr. Thomas:

  "You are overweight by 15 kg. You need to reduce your weight from present 87 kg to 72 kg. else you are prone to heart-attack due to hereditary reasons".

  Mr. Thomas runs a proprietary business.

- Write down the problem statement
- Write down the goal statement
- What is the business need?
- What is the CTQ?
- What are the controllable CTPs?
- What will you measure during the "Measure" phase?
- What calibration will be required to eliminate error due to measurement?
- Will it be possible to establish a relationship between the CTQ and the CTPs in this case?
- What will Mr. Thomas control during the "Control" phase?

12.4 PREPARING A SIRPORC – EXAMPLE

(PROCESS: CUSTOMER COMPLAINT RESOLUTION PROCESS)

S	I	R	P	O	R	C
Supplier	Input (for process Sub-step)	Requirements (to be fulfilled by supplier)	Process (Sub-Steps)	Output (from process Sub-step)	Requirements (of customer)	Customer
External Customer	Details of the problem	Clear Description	Record Complaint	Complaint Registration Number	Minimum Time taken to issue Registration Number	* Resolution Team Member-1 * External Customer
Resolution Team Member-1	Details of complaint	Should understand the problem	Arrange Correction	Action taken to rectify the problem	Problem should be resolved in first attempt	* External Customer
Resolution Team Members 2,3,4	Details of complaint	Accurate	Analyze complaint for root causes	Root Causes	Correct root causes found	Resolution Team Members 2,3,4
			Prepare Corrective Action Plan			
			Implement Corrective Action			
			Prepare Preventive Plan			
			Implement Preventive Plan			

12.5 TYPICAL CHECK LISTS FOR TOLL-GATE REVIEWS:

A. Checklist for "Define" stage:

If you can respond "yes" to each statement below, you're off to a good start with your project, and are ready to move into the "Measure" phase of DMAIC.

For our project we have….

1. Confirmed that our project is a worthwhile improvement priority for our organization and is supported by business leaders.
2. Been given (or written) a brief project Rationale explaining the potential impact of our project on customers, profits, and its relationship on the company's business strategies.
3. Composed and agreed to a two to three sentence description of the problem as we see it- the problem statement – focusing on symptoms only (not causes or solutions).
4. Prepared a Goal statement defining the results we're seeking from our project, with a measurable target. No solutions are proposed in the Goal Statement.
5. Prepared other key elements of a DMAIC project charter, including a list of constraints and assumptions, a review of players and roles, a preliminary plan and schedule , and a process scope.
6. Reviewed your charter with your sponsor for this project and confirmed his/her support.
7. Identified the primary customer and key requirements of the process being improved.
8. Prepared a detailed process map (SIPOC) of areas of the process where we expect to focus our initial measurement.

B) Checklist for "Measure" stage:

If you can respond "yes" to each statement below, you're doing well with measurement, and are ready to move into the : Analyze" phase of DMAIC.

For our project we have….

1. Determined what we want to learn about our problem and process and where in the process we can go to get the answer.
2. Identified the types of measures we want to collect and have a balance between effectiveness/efficiency and input /process/output.
3. Developed clear, unambiguous operational definitions of the things or attributes we want to measure.
4. Tested our operational definitions with others to ensure their clarity and consistent interpretation.
5. Made a clear, reasonable choice between gathering new data or taking advantage existing data collected in the organization.
6. Developed and tested data collection forms or check sheets which are easy to use and provide consistent, complete data.
7. Identified an appropriate sample size, subgroup quantity and sampling frequency to ensure valid representation of the process we're measuring.
9. Prepared and tested our measurement system, including training of collectors and assessment of data collection stability.
10. Used data to prepare baseline process performance measures.

C. Checklist for "Analyse" stage:

Can you respond "yes" to each statement below:

For our project we have…

1. Examined our process and identified potential bottlenecks, disconnects and redundancies that could contribute to the problem on which we are focusing.

2. Conducted a value and cycle time analysis, locating areas where time and resources are devoted to tasks not critical to the customer.

3. Analyzed data about the process and its performance to help stratify the problem, understand reasons for variation in the process, and identify potential root causes.

4. Evaluated whether our project should focus on process design or redesign, as opposed to process improvement, and confirmed our decision with the project sponsor.

5. Ensured that we understand the key working of the process so we can begin creating a new process to meet the needs of the customer efficiently and effectively.

D. Checklist for "Improve" stage:

If you can respond "yes" to each statement below, you've achieved success with your improvement, and are ready to plan to "Control" your process/solutions.

For our project we have…

1. Created a list of innovative ideas for potential solutions.

2. Used the narrowing and screening techniques to further develop and quality potential solutions.

3. Created a "Solution Statement" for at least two possible proposed improvements.

4. Made a final choice of our solutions based on success criteria.

5. Verified our solutions with our sponsor and received buy-in and the go-ahead.

6. Developed a plan for piloting and testing the solutions, including a pilot strategy, action plan, results assessment, schedule, etc.

7. Evaluated pilot results and confirmed that we can achieve the result defined in our Goal Statement.

8. Identified and implemented refinements to the solutions based on lessons from the pilot.

9. Created and put in place a plan to the solution - with refinements – to a complete implementation.

10. Considered potential problems and unintended consequences of the solutions and developed preventive and contingent actions to address them.

E. Checklist for "Control" stage:

If you can respond "yes" to each statement below, you've completed all key steps in your DMAIC project and are ready to celebrate and maintain your improvement.

For our project we have….

1. Compiled results data confirming that our improvement has achieved the Goal defined in our DMAIC team Charter.

2. Selected ongoing measures to monitor performance of the process and continued effectiveness of our solutions.

3. Determined key charts / graphs for a "process Scorecard" on this process.

4. Prepared all essential documentation of the revised process, including key procedures and process maps.

5. Identified an "owner" of the process who will take over responsibility for our solutions and for managing continuing operations.

6. Developed (with the Process Owner) Process-management charts detailing requirements, measures and responses to problems on the process.

7. Prepared a story documenting the team's work and data collected during our project.

8. Forwarded other issues / opportunities which we were not able to address to senior management.

9. Celebrated the hard work and successful efforts of our team.

Chapter 13.
FAILURE MODE AND EFFECT ANALYSIS (FMEA)

> Living at risk is jumping off the cliff and building your wings on the way down.
>
> Ray Bradbury

13.1 KEY CONCEPT:

Capture defects in YOUR shop so that the customer will not detect them in his operation. That is, “gate” the defects.

Surfacing the problems early on in the production cycle will enable you to solve them with a minimum expenditure of your resources (time, money).

13.1 Why perform an FMEA?

Why (Objective)	:	To prevent Design / Process related problems during Product Launch and / or subsequent production.
How	:	By attempting to surface problems early before they have chance to occur.
Benefit	:	Save Time (a key factor today) and valuable resources (money, effort,--)

13.2 Questions which will need to be asked:

1. How can the System or Design fail?
2. What will the consequences be?
3. How serious will the consequences be?
4. What can be done to prevent the failure or minimize the probability of its occurrence?

13.3 Organization's Cost Analysis for Problem Resolution:

- Product Design Stage	:	US $ 1,000 /-
- Process Design Stage	:	US $ 10,000 /-
- Product Pilot Build	:	US $ 100,000 /-
- Field Failure	:	US $ 1,000,000/-

13.4 Information to have before starting an FMEA:

- Customer requirements (specifications)
- Engineering drawings, if applicable
- Information of previous failures in product or process
- Previous (or similar) FMEA's
- Process Capability data (if available)
- Prototype Test data (if available)
- Defect / Failure information for other similar product / process.

13.5 Product in – use Conditions:

While performing the FMEA it may be advantageous to know:

a) How and where customer will use end product.

Example: Product will in all likelihood be used in a high temperature salt atmosphere environment – a good promoter of corrosion.

b) How customer may “abuse” end product.

Example: Lap top computer falls from overhead luggage rack in airplane.

13.6 TO CARRY OUT AN FMEA, WE NEED TO CALCULATE THE:

Risk Priority Number:

It is a numerical and relative “measure of overall risk” corresponding to a particular failure mechanism and is computed by multiplying the Severity, Occurrence and Detection numbers.

RPN = S x O x D

The RPN provides priority levels to potential failure mechanisms in terms of which need to be addressed first, second and so on.

a) Severity:

A numerical measure of how serious is the effect of the failure to the customer or violation of government law.

Example: Will the component or system failure result in a mere nuisance or can it result in serious injury.

The degree of severity is measured on a scale of 1 to 10, where 10 is most severe.

Critical and Significant Characteristics:

Critical Characteristics:

A failure mode which can conceivably result in personal injury, loss of life or violate a government mandate (eg. Automobile emission standard) is considered Critical.

Such a failure mode will be assigned a severity level (S) of 9 or 10 regardless of the level of occurrence or detection.

Significant Characteristics:

A failure mode which is not deemed to be critical but likely to affect the process. Such a failure mode will be assigned a severity level (S) of 5 to 8 regardless Of the level of occurrence or detection.

b) Occurrence:

A measure of probability that a particular failure mode will actually happen. The degree of Occurrence is measured on a scale of 1 to 10, where 10 signifies the highest probability of occurrence.

c) Detection:

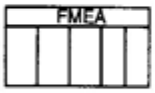
A measure of probability that a particular failure mode would be detected in our own operation and not reach the customer.

The level of Detection is measured on a scale of 1 to 10, where 10 signifies virtually no ability to detect the defect.

Failure Modes & Effects Analysis

Process FMEA

PFMEA



PFMEAs help analyze a process to: 1) identify potential failures, 2) rank these failures, and 3) find ways to eliminate these problems *before* they occur. FMEAs proactively, rather than reactively, reduce the defects, time, and cost associated with potential errors by preventing crises.

PFMEA Process

Step	Activity
1.	Flowchart the process
2.	Describe process and function
3.	List each potential failure mode
4.	Describes effects of each type of failure
5.	Rank severity of failure
6.	Classify any special characteristics
7.	List every potential cause or failure mechanism for each failure mode.
8.	Estimate the likelihood of occurrence of each failure/cause
9.	List prevention/detection controls
10.	Rank detection
11.	Identify actions to reduce severity, occurrence, and detection.

Benefits

- Assists in designing controls to reduce or prevent the production of unacceptable products
- Establishes priorities for improvement efforts
- Documents the rationale for process choices

Severity of Effect:
1. None
2. Very Minor
3. Minor
4. Very Low
5. Low
6. Moderate
7. High
8. Very High
9. Hazardous with warning
10. Hazardous w/o warning

Occurrence Rating
1. Remote <.01/1000
2. Low - 0.1/1000
3. Low - 0.5/1000
4. Moderate - 1/1000
5. Moderate - 2/1000
6. Moderate - 5/1000
7. High - 10/1000
8. High - 20/1000
9. Very High 50/1000
10. Very High >100/1000

Detection:
1. Almost Certain
2. Very High
3. High
4. Moderate High
5. Moderate
6. Low
7. Very Low
8. Remote
9. Very Remote
10. Absolute Uncertainty

13.7 RECOMMENDED "ROAD MAP" FOR PERFORMING AN FMEA:

1. Select a process, sub – process or part,
2. List potential failure mode / s (i.e. how may it fail)
3. List the potential effect (or effects) of the failure
4. Estimate the Severity Number (S). Classify the Severity (i.e. is it critical).
5. List potential causes / s or mechanism / s of failure
6. Estimate the Occurrence Number (O)
7. What Design Verification measures were taken (eg. Prototype testing, pilot run)
8. Estimate the Detection Number (D)
9. If (D) is equal to or larger than 5, take closer look at measures for Detection (D = 5 or greater implies "high risk")
10. Compute the Risk Priority Number (RPN = S x O x D)
11. Can the system fail because of customer abuse or other in – use conditions. If so, re – estimate S, O, D, and re – compute the RPN
12. List recommended actions (where possible) to lower RPN
13. List individuals (or depts.) responsible for completing actions
14. List actual actions taken (eg., X -ray system installed to check for voiding in metal casting)
15. Recomputed RPN after corrective actions are completed
16. Repeat steps (1) through (15) for all processes, sub-processes, parts.
17. Develop a control plan and a contingency plan.

Chapter14.
LEAN MANAGEMENT

The most dangerous kind of waste is the waste that we do not recognize.

Shigeo Shingo

14.1 LEAN MANAGEMENT:

Lean management defines the value of a product or a service from the customer's point of view.

Customers do not care as to how hard you work
(or what is the technology that you use)
to create the product or service.

They will evaluate your product or the service by looking at how well it is going to fulfill their requirements.

"Waste", does not mean that it is "trash" and we should throw it out.
It just means that it is not adding any value for the customer

So in Lean Management, **WASTE is defined as anything that does not add value to the end product:**

For Example:

a) Repairs carried out on a product during warranty.

b) Rework at a customer's site.

c) Carrying excess inventory in your factory or warehouse.

The Lean Management approach is that **If there is any way to get rid of Waste, it should be done.**

If there seems to be no way to currently remove the waste, methods should be found to reduce the waste and eventually remove the waste altogether with use of creativity and technology.

To become lean it is very necessary to understand the fact that wastes are there. You must be able to find out where these wastes do exist.

In Lean Six Sigma the waste-elimination / waste-reduction goes parallel to the DMAIC steps as under:

There are four steps in waste elimination:

1. Identify the fact that there are wastes to be removed. (**MEASURE PHASE**)

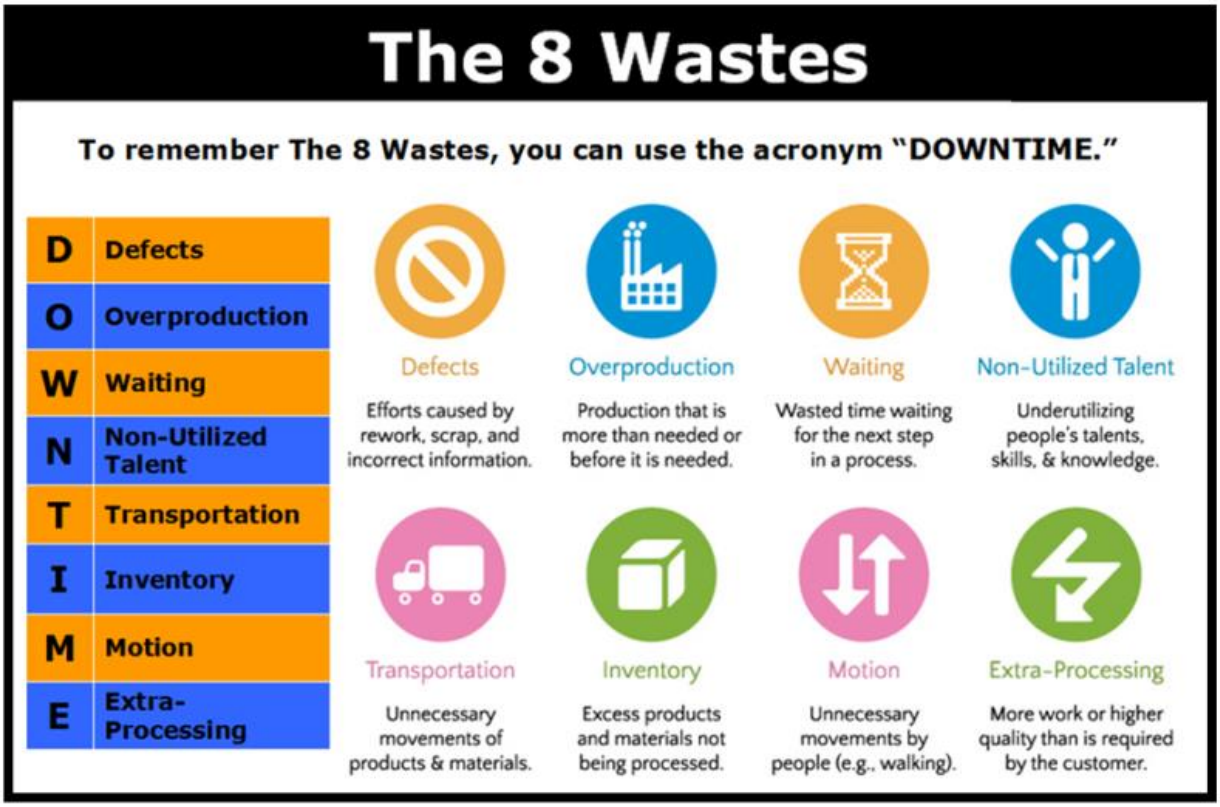
2. Analyze the wastes and finding the root causes for these wastes. (**ANALYZE PHASE**)

3. Find the solution for these root causes (**ANALYZE PHASE**)

4. Apply of these solutions and eliminate the waste (**IMPROVE PHASE**)

:HOW ORGANIZATIONS ACHIEVE COST – REDUCTION:

Traditional company	Organization implementing Lean- Management
• Reduce cost of materials / parts used in production • Reduce labor cost – wages, expenses for welfare, etc. • Reduce expenses on electricity, water, gas, insurance, communication, etc.	**Focus on eliminating the 8-wastes:** • Waste of OVERPRODUCTION • Waste of making DEFECTS • Waste of WAITING • Waste of MOTION • Waste of TRANSPORTATION • Waste in way of doing the PROCESS • Waste due to excess INVENTORY • Waste due to UNUSED EMPLOYEE CREATIVITY / TALENT



EXAMPLE:

We can apply the framework of the 8 types of waste to the **way meetings are conducted in organizations:**

Overproduction:

- Too many topics in one meeting.
- Too many PPT slides.
- Involving too many people.
- Repeating the same point again and again.
- More frequent meetings than needed.

Defects:

- Lack of attention by team members leads to requests like: “please repeat the last point”. This is a kind of re-work for the speaker.
- Every member in the team must have a purpose to be included. Including a non-contributing member is another form of defect.
- Trying to take a decision without having sufficient data could lead to wrong decision-making.
- Record of the information and decisions has to be made accurately, else this can lead to defects and re-work. The person who writes down the minutes / notes must be very attentive and accurate in the reporting.

Waiting:

- Meeting starts late, so people have to keep on waiting.
- Disinterested persons, waiting for the meeting to end.
- Chairperson in a meeting takes a call on the cell phone, whereby everyone else in the group is waiting for him to finish.

Motion:

Examples of excess motion during a meeting would be:

- Searching for a file or PPT during the presentation
- Looking for some paper or document during the discussion.

Transportation:

While conveying ideas, people tend to wander from topic to topic. Moving from Topic – A to Topic – B to Topic – C, back to Topic – B and so on.

This happens when agenda for the meeting is not prepared or the agenda is not strictly followed.

Inventory:

- More issues are raised and the group strays from the focus on existing projects.
- When more tasks are started (instead of completed) in a meeting, we can say that inventory has been generated.
- Meetings can lead to more inventory if the team keeps generating new ideas instead of focusing on review of the existing projects and resolving the issues that are slowing down these projects.

Processing:

- The manner in which a meeting is conducted.
  (Sometimes it is better to finish the points that can be completed easily and schedule a separate meeting for some point where more thought / data is needed).
- Should it be a face-to-face meeting or can we manage through a conference call?
- Should we circulate a detailed write-up in advance so that the team members can come well prepared?

Unused employee creativity:

- Some persons in the group dominate the discussion.
- Others are not given a chance to talk.
- Seniors are unable to find time to listen to the feedback / ideas of employees

Chapter 15.
VALUE STREAM PROCESS MAPPING

The average American worker has fifty interruptions a day, of which seventy percent have nothing to do with work.

W. Edwards Deming

15.1 USING PROCESS MAP TO IMPROVE A PROCESS:

- To improve any process, you must know what people are presently doing i.e. "Where are the contributions by these persons or functions in relation to the customer (internal or external)"

- A Process Map provides a Relationship Map View – how various functions and individuals interface with one another,

- The exercise of generating a process map often uncovers process steps previously not considered. Some of these steps may require additional attention or be non – value added and could therefore be eliminated,

- A Process Map may also be used as an Analysis tool to review where in the process, the customer complaints or defects are occurring.

Examples of Non-Value Added Processes:

1. Inspection is always considered to be a non-value added process. Because **if everything was done right in the first place** there would be no need to inspect. If you have a Six Sigma process, you could do away with inspection.

   Why bother inspecting when there will only be 3 defects for every million pieces you check? Chances are you will miss a good amount of the defects anyway…making the inspection process pointless (like the counting of G's).

2. Cutting of metal items and then going through a de-burring or finishing process to get rid of the rough edges of the cut. If smooth cuts could be made in the first place, those extra processes would not be required.

3. An example of the waste in an office is the requirement of having many signatures on a request. The time it takes to sign a piece of paper might just take a few seconds but by the time all the four or five signatures have been received it could take days. **There has to be some underlying root cause of why so many signatures are required. If we can find the root cause and eliminate it, you could be saving days on our lead time**.

   Value stream mapping and root cause analysis can help to reduce these types of waste.

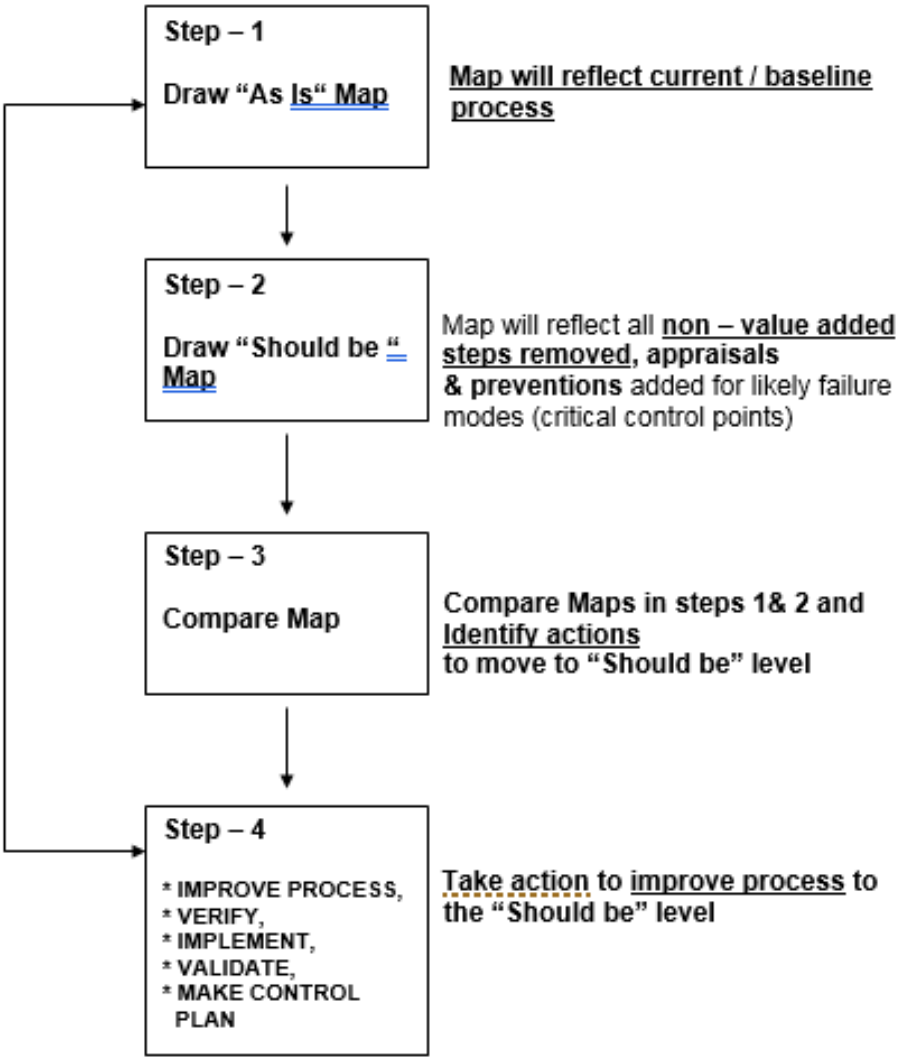
15.2 IDENTIFYING VALUE ADDITION (TIME SPENT IN HOURS):

- **RVA** – Real Value Adding activity.
- **BVA** – Business Value Adding activity (to be minimized)
- **NVA** – Non Value Adding activity (to be eliminated).

Activity	RVA (Required by customer)	BVA (Not required by customer but useful for business)	NVA (Neither benefits Customer nor the business)
Understand Customer Requirements	15		
Checking by Customer		5	
Errors Corrected			7
Prepare Execution Plan		10	
Keep Plan aside to attend to another urgent activity			20
Refer Plan for Approval by Senior		5	
Implement Plan	20		
Arrange Proforma Invoice		8	

Await Delivery Clearance from Admin			**15**
Ship to customer	**5**		
Customer's sign		**5**	

15.3 IMPROVING A PROCESS MAP:



WORK BOOK

WORKBOOK CONTENTS

SECTION	DESCRIPTION	PAGE
1.	Count the G's	113
2.	How LSS teams are formed	114
3.	LSS Roles	118
4.	Cost of Quality Exercise	120
5.	Quiz SSGB – 01	121
6.	Types of data	124
7.	Process Mapping Case Studies	125
8.	DMAIC Steps & Case Study	128
9.	DMAIC (Service) Example	138
10.	FMEA Exercise	142
11.	Quiz SSGB – 02	146
12.	Statistical Calculations & Abbreviations	154
13.	DPMO to Sigma Conversion Chart	162

1. COUNT THE G's

Assuming that the letter "G" is a defect, count all the "Gs" within 3 minutes.

WHILE STROLLING A GLEN, A GIDDY ENGLISH GIRL TRIPPED ON A RATHER LARGE, ALMOST GIGANTIC FROG. THE GIRL STAGGERED BUT REGAINED HER FOOTING AND WAS ABOUT TO GO ON WHEN THE FROG BEGAN TO SPEAK AND GESTICULATE TO GAIN THE GIRL'S ATTENTION. "I HAVE NOT ALWAYS BEEN A FROG", HE CROAKED. THE FROG'S GREEN COLORING SEEMED TO GLOW BRIGHTLY AS HE CONTINUED "I WAS ONCE A GRACIOUS KNIGHT, A GENTLEMAN CALLED GALLANT GEORGE GRENVILLE, BUT WAS CHANGED INTO THIS GHASTLY FROG YOU NOW SEE BY AN UNGODLY, MAGICAL GENIE. THE SPELL CAN ONLY BE BROKEN IF I GAIN A GIRL'S GOOD GRACES AND SPEND A NIGHT IN HER GARDEN. " THE AGOG GIRL WAS SKEPTICAL, OF COURSE. SHE GAZED AT THE FROG'S PLEADING EYES AND SOON HER GIDDY NATURE GAVE WAY TO HER DOUBTS. GIGGLING, SHE DECIDED TO GRANT THE FROG'S WISH AND TOOK HIM HOME STRAIGHTWAY, PUTTING HIM BY HER GARDEN GATE. THAT NIGHT THE GIRL SLEPT GRANDLY AND SURE ENOUGH, WHEN SHE AWOKE THE FOLLOWING MORNING, THERE ALONGSIDE HER GARDEN GATE WAS THE GRACIOUS KNIGHT, GEORGE GRENVIILE. WELL STRANGELY ENOUGH, FOR A LONG, LONG TIME THE GIRL'S MOTHER DID NOT AGREE TO THE NARRATION OF THIS HAPPENING.

2. HOW LEAN SIX SIGMA TEAMS ARE FORMED

Once management has chosen to go for Six Sigma initiative, the real work is up to a collection of business leaders, team members, team leaders, and facilitators. Some people's roles may have martial arts names: Black Belt, Green Belt, and Master Black Belt. (Reportedly, these titles were coined by a Motorola improvement expert with a passion for karate.) Other roles will have more familiar titles.

BLACK BELT:

This is probably the most critical role in Six Sigma. The Black Belt is the full-time person dedicated to tackling critical change opportunities and driving them to achieve results.

The Black Belt leads, inspires, manages, delegates, coaches, and "baby-sits" colleagues and becomes almost expert in tools for assessing problems and fixing or designing processes and products.

Normally, the Black Belt works alongside a team assigned to a specific Six Sigma project. He or she is primarily responsible for getting the team started, building their confidence, observing and participating in training, managing team dynamics, and keeping the project moving to successful results.

Without a strong and tireless Black Belt, Six Sigma teams are usually not effective. The Black Belt must possess many skills, including strong problem solving, the ability to

collect experience, and good administrative sense. Moreover, he or she must be adept at project management – the art and science of getting things done on time through effort of others.

Black Belts – many of whom are drawn from the ranks of middle management or are high future managers – typically serve a term of eighteen months of two years, completing four to eight projects and/or handling special assignments.

Most companies view Black Belt – hood as a springboard to other opportunities, including promotions and bonuses.

MASTER BLACK BELT:

In most organizations, the Master Black Belt (MBB, pronounced em-bee-bee) serves as a coach and mentor or consultant to Black Belts working on a variety of projects. In most instances, the MBB is a real expert in Six Sigma analytical tools, often with a background in engineering or science or an advanced degree in business.

In some companies, the MBB plays more of an organizational change agent role, helping promote use of Six Sigma methods and solutions. The MBB may also become a part-time Six Sigma trainer for Black Belts and other groups. The MBB may also get involved in special Six Sigma – related projects like, investigating customer requirements or developing measures for key processes.

Like most coaches, the MBB will have several Black Belts under his or her care. As a coach, the MBB's job is to ensure that the Black Belt and his/her team stay on track, complete their work properly, and pass the "tollgates" i.e. the key tasks for each step of the Six Sigma improvement process. Often too, the Master Black Belt provides advice and even hands – on help for such tasks as collecting data, doing statistical analysis, designing experiments, and communicating with key managers.

Black Belts are more in number and are fundamental to most Six Sigma efforts. MBB's play a critical role in sustaining the momentum of change, cost -savings, and improved customer experience.

GREEN BELT:

A Green Belt is someone trained in the basic Six Sigma skills. But the Green Belt still has a "real" job and serves as either team member or a part-time Six Sigma team leader. Some companies, most notably GE, have required large segments of their populations to be trained as Green Belts.

The role of the Green Belt is to bring the new concepts and tools of Six Sigma right to the day-to-day activities of the business.

CHAMPION AND/OR SPONSOR:

These titles are common to Six Sigma efforts. Usually, a Champion is an executive or a key manager who initiates and supports (sponsors) a Black Belt project.

Having a champion or a Sponsor is very important. This role sends a critical message: The Champion, a fairly senior person, is ultimately accountable. In other words, Six Sigma results are not delegated down many layers in the business but remain in the hands of senior and key middle management.

The responsibilities of the Champion include:

- Ensuring that projects stay aligned with overall business goals and provide direction when they don't,
- Keep other members of the leadership team informed on the progress of projects,
- Provide or cajole needed resources, such as time, money and help from others, for the team,
- Conduct the tollgate reviews,
- Negotiate conflicts, overlaps, and linkages with other Six Sigma projects.

In many cases it is seen that the Champion/Sponsor role tends to get the least training and preparation, so it could become one of the weakest links in the Six Sigma efforts.

IMPLEMENTATION LEADER:

This role may go by other names like Vice President of Six Sigma or Chief Sigma Officer. This individual directs the entire Six Sigma effort. He or she is often at the corporate vice president level, reporting directly to the CEO, president, or another top executive. The Implementation Leader is either a seasoned professional in organizational improvement or quality or a respected inside executive with significant company experience and strong leadership and administrative abilities. This is a high-stress, high-demand job with short-term goals, long-term visions, and significant accountability.

Like the Black Belt, the Implementation Leader is often a temporary position, with the leader moving on to another executive or management position after a few years. The ultimate goal of the Implementation Leader is to drive Six Sigma thinking, tools, and habits across the organization and to help the effort reap financial and customer benefits.

In many ways, the Implementation Leader serves as the conscience of the top-management team, helping its members keep Six Sigma practices and priorities high on their agenda. He or she will also be primarily responsible for executing implementation plans.

Note:

In order to realize the gains of six sigma, it is essential to recognize that a significant cultural shift must occur in the organization. Achieving this cultural shift is best accomplished by:

a) Start with six sigma training for all the senior managers.

b) Then extend the training to various other management levels & functions creating six sigma specialists in the form of "Green Belts", and "Black Belts".

c) Then include several people at operational levels for “Yellow Belt” training.

3. LEAN SIX SIGMA ROLES

(EXAMPLE 1000 EMPLOYEES IN ORGANIZATION)

	Employee-Level	***MD/ CEO / VP / Director***	***Responsibilities***
	Top Management	**(Implementation Leader)**	**Short-listing BB Projects**
	(About 20 Nos.)		**Providing Resources**
	- Champion Training		**Timely Decisions About Changes in processes**
Master Black Belt	***H.O.D. /***	**Process-Owner**	***Responsibilities***
(Outside Consultant OR an Insider)	***Sr. Management***	**OR**	
	(About 20 Nos.)	**Champion**	**Providing Process Knowledge (Critical Thinking) to the Six Sigma Team**
	- Champion / Green Belt Training	**OR**	
		Sponsor	
			Arranging Resources and Timely Decisions from Top Management

<table>
<tr><td rowspan="8">Responsible for Mentoring Support to Black Belt</td><td></td><td></td><td>Motivate the Six Sigma Team</td></tr>
<tr><td rowspan="2">Middle Management</td><td>Six Sigma Black Belt (Team Leader)</td><td>Responsibilities</td></tr>
<tr><td rowspan="4"></td><td>Works Full Time on BB Projects (3 to 5 Projects / Year)</td></tr>
<tr><td rowspan="3">(About 20 Nos.)
- Black Belt Training</td><td>Use SS Tools and Statistical Techniques (Statistical Thinking)</td></tr>
<tr><td>Leads the GBs & YBs</td></tr>
<tr><td rowspan="2">Middle& Junior Management</td><td rowspan="2">Six Sigma Green Belts
(Form a Cross-Functional Team)</td><td>Responsibilities</td></tr>
<tr><td>(About 80 Nos.)
- Green Belt Trainin</td><td>(Work Part-Time on BB Projects)</td></tr>
<tr><td>Supervisor / Team-Leader</td><td>Six Sigma Yellow Belts</td><td>Responsibilities
Data Collection, Brainstorming</td></tr>
<tr><td></td><td></td><td>Responsibilities</td></tr>
</table>

Operator / Worker	***Six Sigma White Belts***	***Participate in Brainstorming***

4. COQ EXERCISE

Listed below are different types of cost of quality.

Identify these as cost of -

External Failure **(EF),** Internal Failure **(IF),** Appraisal **(A),** Prevention **(P),** and Hidden **(H).**

1. Planning
2. Rework
3. Quality Auditing
4. Correction of Invoice
5. Inaccuracy in Data - Sent for Rework
6. Process Capability Study
7. Review of Customer Requirements
8. Wrong Despatch
9. Failure on Installation
10. Testing a Beta Version
14. Training on Programming Standards
15. Penalty due to late Delivery
16. Attrition of Employees
17. Training as a Corrective Action
18. Corrective Action
19. Preventive Action
20. Legal Liability due to incorrect functioning of product

11. Refund to Customer

12. Product Recall

13. Use of Information Security Management

5. *QUIZ SSGB – 01*

1. Satisfying CTQs of internal customers helps to achieve Quality Assurance.

Explain how.

2. For upper-income (rich segment) customers of a builder of residential flats, what would be the requirements in respect of:

a. Product Quality:

b. Support Quality:

3. For a business-executive buying 'medical insurance' what would be the requirements in respect of:

a. Product Quality:

b. Support Quality:

4. If we increase cost of conformance, what will be the effect on cost of non-conformance? Explain with help of a graph.

5. What are the 3 major goals in lean six sigma methodology?

6. List three CTQ characteristics for McDonalds Restaurant separately for following customer segments:

Housewives	**Working Executives**	**Teenagers**

(College Students)

7. Explain "Poka Yoke" with help of an example

8. Explain Corrective Action and Preventive Action with an example

6. TYPES OF DATA

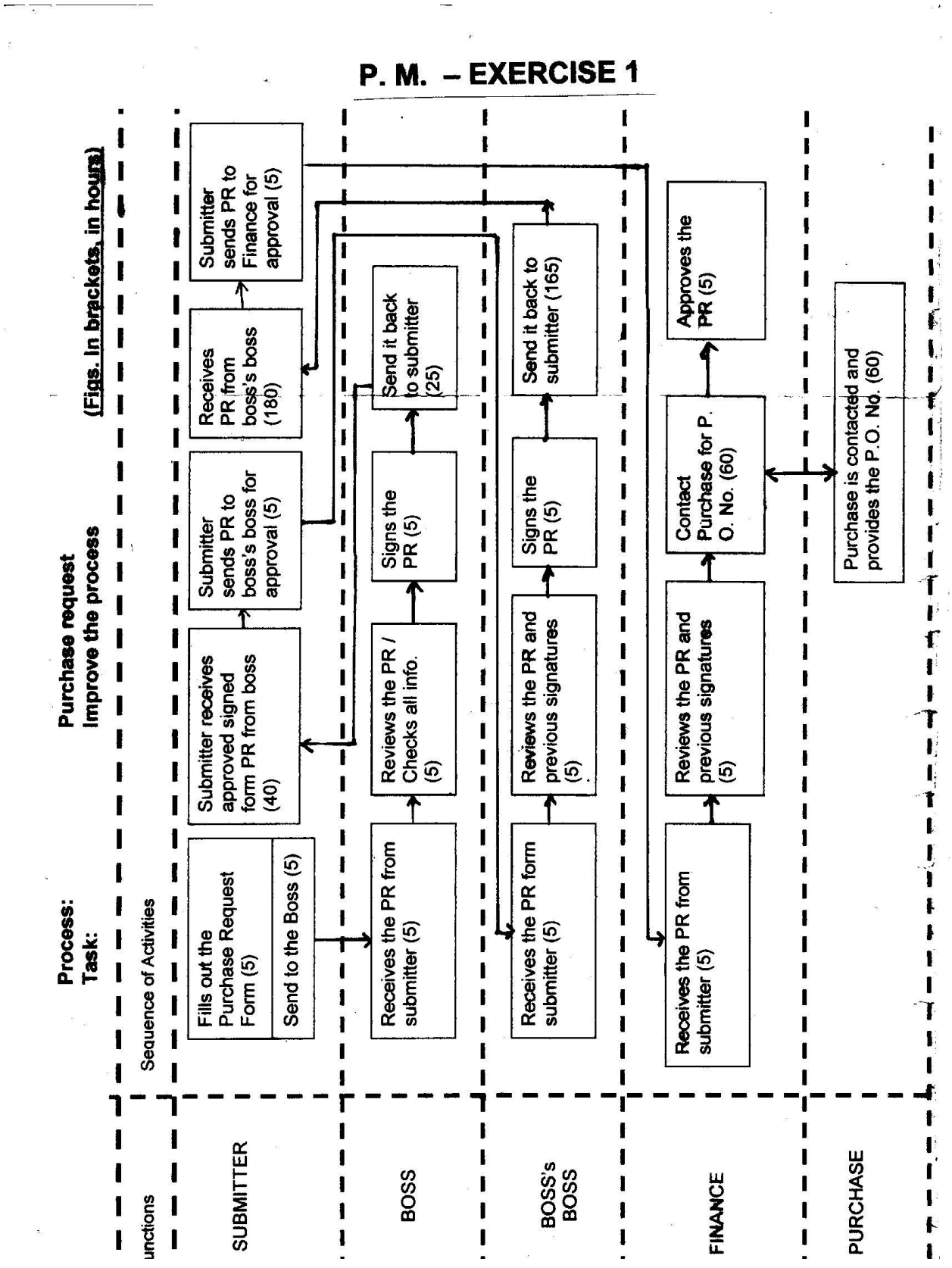
Variable Data	Discrete Data	
(Continuous data)	**Attribute Data**	**Count Type Data**
• Measured on a continuous scale e.g. height, weight, time taken for a call, diameter • Example: Time taken to stitch one shirt.	• Classification (Defective/Not Defective) e.g. good/bad, pass/fail, accept/reject or order delivered in 30 mins /not delivered in 30 mins. • Example: 14 defective shirts out of 300 stitched	• Counting no. of special events e.g. no. of calls in one hour, no., of break downs, no. of accidents, no. of hits on website. • Example: 33 defects in 14 defective shirts

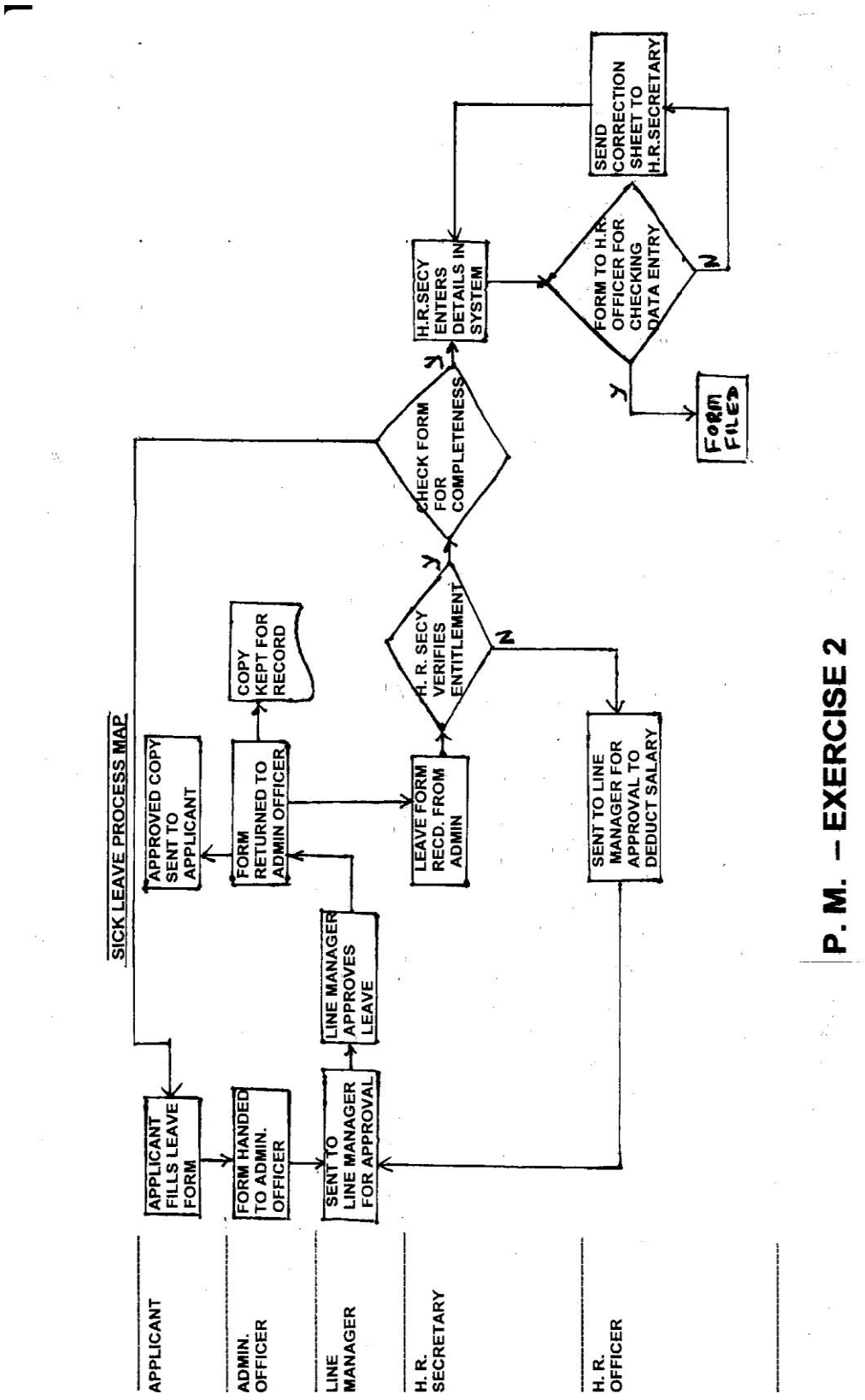
Exercise: Identify the data type in following examples:

- **Height of trees in a garden.**

- **No. of rejected boxes in a store.**
- **No. of spots, scratches, and wrinkles in a material.**
- **No. of errors in handling service calls / complaint calls**
- **Temperature in a room**
- **Time taken to produce an item.**

7. PROCESS MAPPING - CASE STUDIES


P. M. – EXERCISE 1
Process: Purchase request
Task: Improve the process
(Figs. In brackets, in hours)
Sequence of Activities
unctions
SUBMITTER
BOSS
BOSS's BOSS
FINANCE
PURCHASE
Fills out the Purchase Request Form (5)
Send to the Boss (5)
Receives the PR from submitter (5)
Submitter receives approved signed form PR from boss (40)
Submitter sends PR to boss's boss for approval (5)
Receives PR from boss's boss (180)
Submitter sends PR to Finance for approval (5)
Reviews the PR / Checks all info. (5)
Signs the PR (5)
Send it back to submitter (25)
Receives the PR form submitter (5)
Reviews the PR and previous signatures (5)
Signs the PR (5)
Send it back to submitter (165)
Receives the PR from submitter (5)
Reviews the PR and previous signatures (5)
Contact Purchase for P. O. No. (60)
Approves the PR (5)
Purchase is contacted and provides the P.O. No. (60)



P. M. – EXERCISE 2

8. DMAIC STEPS AT A GLANCE

+

DMAIC CASE STUDY

DMAIC STEPS: CTQs – CTPs

DEFINE: PURPOSE – TO MAKE A PROJECT PLAN:

- FIND CTQs – FROM VOC, KANO, BENCHMARKING
- MAKE PROJECT CHARTER
- MAKE OVERVIEW PROCESS MAP (SIRPORC)
- DEFINE RESPONSIBLITIES.

MEASURE: PURPOSE – TO MEASURE BASELINE DATA (CURRENT STATUS):

- FIND CTPs
- MAKE SAMPLING PLAN
- COLLECT BASELINE DATA FOR CTQs AND CTPs
- CALCULATE CURRENT PROCESS CAPABILITY (SIGMA LEVELS).

ANALYZE: PURPOSE – TO ANALYZE THE COLLECTED DATA:

- UNDERSTAND NATURE OF VARIATION
- ANALYZE PROCESS MAPS
- FIND ROOT CAUSES FOR BEHAVIOR OF CTPs
- FIND CORRELATION BETWEEN CTQ AND CTPs
- SHORT-LIST SOLUTIONS FOR IMPLEMENTATION.

IMPROVE: PURPOSE – TO IMPLEMENT THE CHOSEN SOLUTIONS:

- FINALISE THE SOLUTIONS TO BE IMPLEMENTED
- FMEA: RISK ASSESSMENT & RISK REDUCTION
- PILOT TRIALS OF THE SOLUTION - VERIFICATION
- FINE-TUNE SOLUTION BASED ON RESULTS OF PILOT
- FULL-SCALE IMPLEMENTATION: FOCUS ON IMPROVING THE CTPs – VALIDATION

CONTROL: PURPOSE - TO ENSURE THAT THE IMPROVEMENT IS SUSTAINED

- AUTHENTICATE THE SAVINGS
- PREPARE REVISED DOCUMENTATION FOR THE NEW PROCESSES (SOPs, WIs)
- TRAIN PEOPLE FOR THE NEW DOCUMENTATION
- PREPARE AUDIT PLAN –TO ENSURE COMPLAINCE WITH NEW DOCUMENTATION
- DEVELOP CONTROL CHARTS FOR CTQs AND CTPs.

DMAIC CASE STUDY 01: INCREASING ACCURACY OF "DAILY NEWS" NEWSPAPER

1. Introduction:

The management of "Daily News" a regional newspaper initiated an effort to improve quality of their newspaper.

The first question for the management was to identify the pain areas. A major pain area was identified as " Accuracy of names, facts, figures, and other information published by them." If a name is mis-spelled or the facts are wrong or calculation is incorrect, the credibility of the newspaper is reduced.

Benchmarking with other newspapers showed that actions taken by them to improve accuracy included:

a) Penalize reporters for mistakes

b) Incentives for reporters who kept the mistakes low.

However, the effectiveness of these actions was limited as sometimes these became causes for unhappiness and discontent.

The General Manager formed a Six Sigma team to " Find Ways to Improve the Story-Writing Process such that it enables the Reporters and others to Reduce Mistakes".

The team adopted the **DMAIC** methodology for process improvement.

2. Preliminary Study:

Very often six sigma projects fail because different people have different understanding about what the project will achieve.

In this case the Champion established "**Reduction in Errors**" **as the main goal**.

Preliminary study of the baseline data showed that at present:

a) The Copy Desk was catching and fixing 30 to 40 errors per day.

b) End of day, the typical error rate reaching the composing room was 20 errors per day.

The goal was set to reduce errors by 50% i.e. to less than 10 errors per day.

The financial impact **of an error was established as:**

- **$ 60 if caught at the copy desk**
- **$ 80 if caught in the composing room**
- **$ 750 if a page has to be redone**
- **$ 4000 if the press had to be stopped and re-started**
- **$ (Unknown) if the error was actually published.**

The Champion and BB identified some **secondary objectives** for the project:

a) Elimination of Rework & Duplication of work in the processes used to create stories, photographs and graphics.

b) Make the copy desk editors free for doing value added work rather than wasting time on NVAs like spell-checking, cross-checking and fact-checking. A copy editor had to call the library nearly 10 to 25 times a day to check the facts

3. Operational Definitions:

An operational definition for an “error” was created so that data could be collected and everyone would be talking the same language.

An error was defined as:

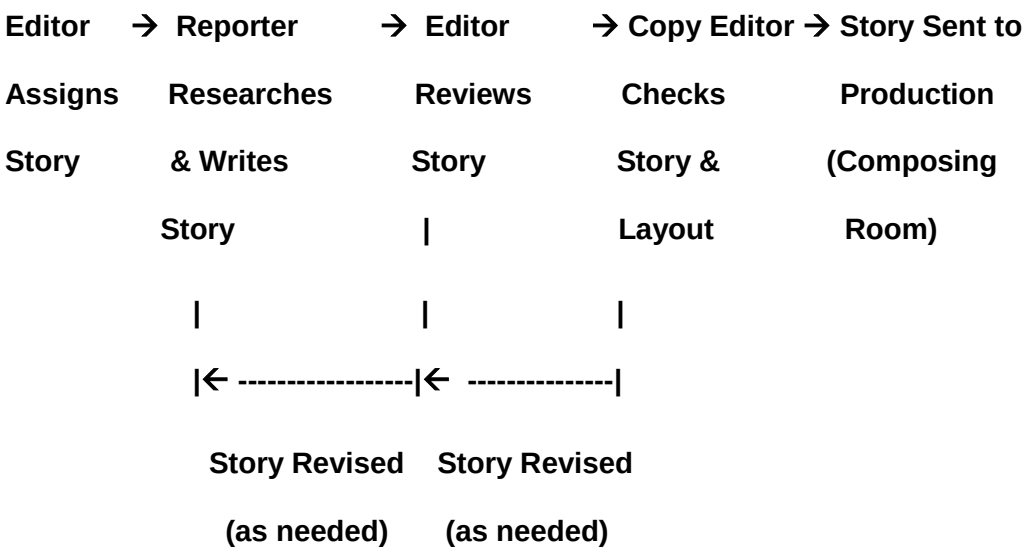
a) Any deviation from truth, accuracy, or widely accepted standards of English usage.

b) A departure from accepted procedures that causes delay or requires to rework a story or graphic.

Errors were divided into 8 categories:

- Wrong Spelling
- Wrong Number
- Wrong Name
- Bad Grammar
- Libel
- Word Missing
- Duplicated Word
- Wrong Fact.

4. Overview of the process was mapped as under:



5. Baseline Data:

A **Pareto Analysis** showed the occurrence of errors as under:

- Misspelling & Poor Grammar – 36 %
- Wrong Name – 22 %
- Wrong Fact – 21 %
- Word Missing – 4 %
- Duplicate Word – 6 %
- Others – 6 %.

Based on brainstorming within the team, the variables that would impact the number of errors in a day were as identified as:

- Size of the paper (number of pages)
- % of articles spell-checked by the reporters
- No. of times each copy editor had to call the library in a day
- No. of times the front cover story had to be changed in a month.

Data was collected for a **period 45 days**. The following observations were recorded:

SIZE OF PAPER:

Size of Paper	**24 pages**	**30 pages**	**36 pages**	**50 pages**
Average No. of Errors reaching composing room	**5**	**8**	**14**	**19**

% ARTICLES SPELL CHECKED:

Use of Spell Check	**Not used**	**40%**	**70%**	**100%**
No. of Errors reaching composing room	**44**	**28**	**18**	**8**

NO. OF TIMES COPY EDITOR CALLED LIBRARY:

Approx. No. of Times Calls Made	**10 times**	**15 times**	**20 times**	**25 times**
Average No. of Errors reaching composing room	**20**	**13**	**7**	**3**

AVERAGE NO. OF ERRORS WHEN FRONT COVER STORY WAS CHANGED

VS WHEN STORY WAS NOT CHANGED:

Change of Front Cover Story	**Days When Story Not Changed**	**Days When Story Was Changed**
No. of Errors reaching composing room	**16**	**29**

6. Analysis of data:

Root Cause - 1:

Reporters were not using the spell-checker. Their attitude was:

- I don't have time to spell check
- The copy editors will catch the error anyway.

Root Cause –2:

Reporters were not routinely checking their facts & sources which was a job requirement.

Also the data showed that:

a) As the size of the paper increases (more pages), the number of errors increases.

b) Changing the front cover story increased the error rate, as new stories had to be created under very tight schedules.

7. Improvements Made:

a) **Pilot:**

i) It was clarified to reporters that checking accuracy of his article was the responsibility of the reporter himself.

ii) Reporters were required to verify the correctness of every important element of the story or graphic. (This was not being done earlier).

This was to ensure that 90% of the facts are verified before they reach the copy desk.

iii) Three job-aids were created:

* Guidelines for Spell-Check

* Ten Rules of Grammar

* A "Trust-Table" which showed the sources that could be trusted for producing accurate names, facts, numbers.

iv) Reporters were trained on how to do mathematical calculations accurately.

v) Reporters were made aware that tendency for mistakes was more when:

* Cover story was changed at short notice

* The size of the newspaper was large (i.e. number of pages was more).

vi) The goal of less than 10 errors reaching the copy desk was discussed with the reporters after taking these steps. They agreed to accept this goal for improvement.

b) **Results of the Pilot:**

Data for one month was analyzed. Surprisingly, the result was that total errors did not change. The situation was reviewed and it was found that:

i) The new procedures were not being used.

ii) Many reporters felt that it was cumbersome to follow the new procedures and "is not going to help much".

(Often it is seen that there is a gap between deciding on improvements and actually implementing them effectively).

The General Manager called for another meeting of the management team and the reporters and emphasized that the new procedures had to be used. It was also clarified that concerned managers were personally responsible for this implementation.

(Finding that new procedures are not being used is quite a common occurrence).

It is the leadership's responsibility to ensure that people give up the old ways and adopt the new ways. Otherwise the benefit of the project will not be realized.

It may therefore be necessary to have regular project reviews and process audits).

c) **After one month:**

The total errors were found to have dropped by 40%.

d) **After the second month:**

The total errors dropped by 65% (against the goal of 50%).

8. Control Plan:

A control plan was now put in place to ensure that the gains were sustained.

The control plan focused on measuring and monitoring the following:

a) Total Errors

b) Errors by category

c) % of articles spell-checked by the reporters

d) No. of times each copy editor had to call the library in a day

e) No. of times the front cover story had to be changed in a month.

These charts were **displayed on a regular basis** for everyone to know how the process was performing.

9. Results:

a. 65% reduction in errors led to savings in time at the copy desk of more than $226000/- per year.

   (This was not a direct saving but the persons involved could use the saved time for more value-added work)./

b. Fewer missed deadlines.

c. Improved morale and job-satisfaction at the copy desk (copy editors were freed to make better use of their talents).

d. Considerable drop in re-work.

CASE QUESTIONS:

1. Write the problem statement, business-need and goal statement for this case.
2. According to you what would be the CTQs and the CTPs in this case?
3. List the deliverables achieved as per the DMAIC phases in this case study.
4. Identify the tools that would have been used in each phase to arrive at the given data.
5. What management lessons can we learn from this case?

9. DMAIC (Service Example):

Six Sigma -- it's not just for manufacturers anymore

(Edited version of case-study by Ali Kiran and Celal Kaplan)

During the past 10 years, businesses have deployed a wealth of information technologies to increase revenue, reduce operational costs, and improve customer service. Yet many CIOs find it difficult to tell whether these investments are producing satisfactory ROI.

To understand what really works, and why, these enterprises are turning to process-improvement methodologies like Six Sigma.

Developed in the 1980s by Motorola Inc. to reduce manufacturing defects, the Six Sigma methodology focuses on eliminating the defects that drive customer dissatisfaction and customer defections. (Indeed, some observers have characterized Six Sigma as a "defect-reduction" methodology.)

Users of the Six Sigma methodology have demonstrated that the surest way to improve performance is to systematically identify the causes of waste, lost productivity and customer dissatisfaction, and then adjust internal processes to eliminate them. **These successes have encouraged many retail and service businesses to apply Six Sigma to non-manufacturing operations.**

The Six Sigma methodology demands that a **company begin by identifying the defects that influence customer satisfaction the most**. For each factor, the company then determines an acceptable range.

Managers in any industry can improve any business operation by applying Six Sigma's DMAIC process -- to define, measure, analyze, improve and control the key processes that affect customer satisfaction.

To show how this method may be applied in a non-manufacturing business, we will use an example from retail banking.

During the past 10 years, retail banks have implemented numerous new technologies and marketing programs to improve service delivery and boost earnings. Banks offer an ever-widening range of financial products through constantly expanding branch networks.

To successfully market new products like investments and insurance, banks now find themselves cross-training branch employees for a much wider variety of roles. For a bank to make sure it has
the right people with the right skills available at the right time is a growing challenge.

Optimizing staff levels is only one example of the challenges that retail banks face as they struggle to improve branch-customer satisfaction while simultaneously reducing costs. Today's customers demand a positive service experience -- accurate, friendly and fast -- every time. If they don't get it, they won't hesitate to defect to a nearby competitor.

DEFINE:

The first step of the Six Sigma DMAIC initiative is to **clearly define the boundaries and objectives of a specific project.**

For retail banks, improved branch-customer satisfaction is usually a key objective.

The first step here is for the bank to define the core processes within the organization that involve customer interactions and are directly related to customer satisfaction. Specific examples might include:

- Teller window transactions
- New account openings
- Fixed Deposit rollovers
- Address changes.

The specific CTQ is chosen and a problem statement and goal statement are formulated. The boundaries of the problem are defined.

This paves the way for preparing a Project Charter.

MEASURE:

The second step is for managers to **establish quantitative measures that can yield statistically valid data.**

Not all factors have an equal impact on customer satisfaction. Retail banks generally find that **wait times typically have the strongest impact on customer satisfaction**.

To benchmark performance, the bank may set a key metric of servicing 85% of its retail customers within five minutes.

Accordingly a plan to collect the data can be made whereby the bank can then assign observers to measure wait times at various branches under differing conditions. **This would give us a measure of the current status / baseline status of the CTP(s)**.

ANALYZE:

Once the bank has defined the parameters, documented baseline performance and gathered data, it must then analyze results to identify opportunities for improvement. The analysis must examine all the activities that are part of each bank/customer interaction.

Activities involved in check cashing, for instance, may include the customer's preparations before coming to the window, the customer's request for cash back, and the teller's having to seek manager approval for the transaction. The bank must examine each of these activities to determine which have the greatest impact on overall transaction time.

It is important to apply accepted statistical tools to identify the root causes of problems in this business process.

Assume that the data gathered shows that customers were unprepared 50% of the time and that manager approvals were required in only 15% of all check-cashing transactions. Lack of customer preparedness might appear to be the greater contributor to longer transaction times.

Proper regression analysis, however, may reveal that managerial approvals – which usually require that tellers leave their windows – have a much greater impact, adding more than five minutes to actual wait times.

IMPROVE:

As soon as our bank identifies the factors that slow transactions, it should initiate actions to minimize the impact of these factors. The bank can, for example, design experiments to evaluate the impact of proposed improvements to every activity in the check-cashing process.

To eliminate the need for tellers to leave the window for manager approvals, the bank may set up an experiment where supervisors come to the teller window.

In a separate experiment, the bank may measure the impact of letting tellers approve more transactions on their own.

Careful measurement of wait times in these two experiments will indicate which new practice has the more beneficial effect on wait times.

CONTROL:

Control is the final step in the DMAIC cycle. **The control step demands that the bank continually monitor the metrics it has put into place in respect of the CTPs and the CTQs.**

This process requires periodic measurements using the same data-gathering protocols established at the beginning of the project during the Measure phase.

Perhaps the greatest strength of the Six Sigma method is that it produces objective, measurable results that can be monitored continuously.

In one case, a bank implemented a Six Sigma project to reduce customer wait times, just like in our example.

By **identifying and controlling the key factors** that did the most to increase transaction times, the bank was able to lower its average transaction time from 2.45 minutes to 1.80 minutes, significantly improving customer satisfaction while simultaneously reducing staffing costs.

But Six Sigma principles are not limited to reducing customer wait times. **Banks have also implemented Six Sigma programs to reduce theft and fraud, and to meet other objectives as well.**

The Six Sigma DMAIC process can be applied throughout the retail banking organization, wherever managers require measurable results, to design, validate and monitor business process improvements.

Applying Six Sigma's DMAIC process has enabled banks to implement corrective actions based on empirical evidence rather than on anecdotal evidence and gut feeling. In addition, a successful Six Sigma project establishes a precedent for evaluating new programs and technology investments.

CIOs face constant demands from senior management to document "results" for IT expenditures. Six Sigma offers a proven methodology for establishing such results.

More important, the quantitative results that Six Sigma provides will allow CIOs to propose and test continued improvements, both to their own IT operations and to the mission-critical business processes they support.

10. FMEA - EXERCISE

CASE-STUDY: SWIMMING POOL

You have bought a flat in a complex where builder has provided a club house and swimming pool. Your group represents the Managing Committee that has to take over from the builder.

The baseline status is as under:

What the Builder has provided	***What the Builder has not provided***
Large overhead tanks for 24 hours water availability	• No Floats • No Sign Boards
Anti-skid tiles around the pool	• No Lifeguard
• Anti-shock device i.e. an ELCB • Electrician appointed to check electrical connections around the pool once a week	• Agency for water cleaning not yet appointed • Meter for testing water not purchased
Security agency has been appointed for security of the society.	• No separate security arrangement for entrance to swimming pool • No id cards for residents

Q1: ***Using FMEA methodology identify the risks that need to be reduced and actions required to reduce these risks.***

Q2. ***Also make a control plan to sustain the situation of reduced risks.***

DESIGN / PROCESS FMEA WORKSHEET PART – 1

Process Sub-Steps/ Sub-Parts	*Potential Failure Mode (What can go wrong / fail)*	*Potential Effects Of the failure*	**C* / **S* / **NS*	*SEV. RATING*	*Potential Causes Of Failure*	*OCC. RATING*	*Arrangement For Detection*	*DET. RATING*	*RPN*	*Anticipated Abuse By Customer that might increase RPN*	*Overall (Revised) RPN (After adding weightage for likely abuse by customer)*

*C: **CRITICAL**	*S: **SIGNIFICANT**	*NS: **NOT SIGNIFICANT**

DESIGN / PROCESS FMEA WORKSHEET PART – 2

Process Substeps / Sub-parts	Action Planned to Improve RPN (Reduce Sev / Reduce Chance of Occ. / Increase Chance of Detection)	Responsibility for Completing Action (Names)	Action Completion		New RPN (After Improvement)			
			Planned Dates	Actual Dates	S	O	D	RPN

DESIGN / PROCESS FMEA WORKSHEET PART – 3: CONTROL PLAN

Process Substeps / Sub-parts	Process / Customer Requirements	Control Imposed to Ensure Sustained Performance	Equipment / Mechanism used for Control	Audited (Checked) By	Action Plan, if Out of Control Condition Occurs

11. QUIZ SSGB – 02

Note: Only one choice for each of the following questions is correct. You have to choose the answer that seems most applicable / correct to you.

Q1. A "Defect" is:

a. Something that the customer is willing to pay for
b. A feeling that the process is causing a problem.
c. Something we should ignore if possible
d. A measurable characteristic not conforming to a customer requirement
e. All of the above.

Q2. One of the standard approach for Six Sigma project methodology is:

a. CTQ
b. VOC
c. DPMO
d. CTP
e. DMAIC.

Q3. All of the following are phases in the DMAIC model except:

a. Measure
b. Control
c. Improve
d. Automate
e. Define.

Q4. What is variation?

a. Something that can be recognized from the mean value
b. Something that is good for a process
c. Something that should be reduced, to improve the process
d. All of the above
e. None of the above.

Q5. In the equation for process approach Y = f (X), which letter represents the effect for a cause?

a. Y
b. f
c. X

d. None of the above.

Q6. If we know that Y depends mainly on X1 and X3, then we know that:

a. X2, X4, and X5 are not so important
b. X1 and X3 are CTQs
c. X2, X4 and X5 are CTPs
d. Y has no relation to X1 and X3
e. None of the above.

Q7. This is a technique by which an organization measures the performance of a process against similar best-in-class processes and uses the information to improve its process.

a. Six Sigma
b. Cause and effect diagram.
c. Benchmarking
d. Gap analysis
e. 8-Discipiline methodology.

Q8. Examples of hidden loss include the following:

a. Capacity losses due to rework and scrap
b. Stockpiling of raw material to accommodate poor yield.
c. Rush deliveries
d. All of the above.

Q9. “Corrective Action” means:

a. Rectifying the mistake that has occurred
b. Preventing mistake from occurring again
c. Preventing potential mistake from occurring in the first place
d. None of the above.

Q10. “Correction” means:

a. Rectifying the mistake that has occurred
b. Preventing mistake from occurring again
c. Preventing potential mistake from occurring in the first place
d. None of the above.

Q11. “Preventive Action” means:

a. Rectifying the mistake that has occurred
b. Preventing mistake from occurring again
c. Preventing potential mistake from occurring in the first place
d. None of the above.

Q12. Training new employees in respect of their job is mostly a:

a. Cost of Appraisal
b. Hidden Cost
c. Cost of Prevention
d. Cost of Prevention + Internal Failure Cost
e. Internal Failure Cost + External Failure Cost.

Q13. Conducting Quality Management Audits is mostly a:

a. Cost of Appraisal
b. Hidden Cost
c. Cost of Prevention
d. Cost of Appraisal + Hidden Cost
e. Internal Failure Cost + Hidden Cost.

Q14. Test marketing a product / service before full-scale launch is mostly a:

a. Cost of Appraisal
b. Hidden Cost
c. Cost of Prevention
d. Cost of Appraisal + Hidden Cost
e. Internal Failure Cost + Hidden Cost.

Q15. Corrective Action is mostly a:

a. Cost of Appraisal
b. Hidden Cost
c. Cost of Prevention
d. Internal Failure Cost + Hidden Cost
e. Internal Failure Cost (Or External Failure Cost) + Hidden Cost.

Q16. Product Replacement due to customer-complaint is mostly a:

a. Cost of Appraisal
b. Hidden Cost
c. Cost of Prevention
d. Internal Failure Cost + Hidden Cost

e. External Failure Cost + Hidden Cost.

Q17. When we increase cost of conformance, the cost of external failure:

a. Might actually go up
b. Might go down
c. Will mostly not change
d. Will mostly come down sharply
e. None of the above.

Q 18. When we increase cost of conformance, the sigma level of the process:

a. Is likely to increase
b. Might go down
c. Will mostly not change
d. Will certainly come down
e. None of the above.

Q 19. When we increase cost of appraisal for outgoing goods, the cost of internal failure:

a. Is likely to increase
b. Might go down
c. Will mostly not change
d. Will mostly come down sharply
e. None of the above.

Q20. When we increase cost of conformance, the total cost of quality:

a. Is likely to increase
b. Might go down
c. Will mostly not change
d. Will certainly come down
e. None of the above.

Q21. CTPs are inputs that are critical to process and

a. Measurable but not Controllable
b. Controllable but not Measurable
c. Measurable and Controllable both
d. Neither Measurable, nor Controllable
e. None of the above.

Q22. Which of the following fields defines quality as “satisfaction of customer requirements”?

a. Economics
b. Production Management
c. Personnel Management
d. Quality Management
e. None of the above.

Q23. Identify the true statement out of the following:

a. CTP must have a strong relationship with CTQ
b. CTP can have a weak relationship with CTQ
c. CTP must be developed from the VOC
d. CTP has no connection with VOC
e. None of the Above.

Q24. A process has 33 defects in 350 units produced and opportunities for error are 9 nos. The DPU is:

a. 0.084
b. 0.081
c. 0.077
d. 0.094
e. none of the above.

Q25. A process has 21 defects in 3300 units produced and opportunities for error are 13 nos. The DPMO is:

a. 490
b. 590
c. 450
d. 460
e. none of the above.

Q26. A process has 3 defects in 34000 units produced and opportunities for error are 17 nos. The process sigma level is:

a. 5.1
b. 4.5
c. 5.2
d. 5.95
e. 5.55.

Q27. A process has 20 defects in 310 units produced and opportunities for error are 11 nos. The process sigma level is:

a. 5.865
b. 58.65
c. 4.44
d. 4.20
e. 3.09
f. 4.02

Q28. Finding the _____ is the most natural step at the beginning of any six sigma project.

a. Risks
b. Correlation Coefficient
c. CTPs
d. CTQs
e. None of the above.

Q29. Y is normally used to represent:

a. The variation in a process
b. The independent variable
c. The non-controllable factor in a process
d. The output of a process
e. None of the above.

Q30. In a loan process, which of the following is not a CTP:

a. Number of documents to be verified
b. Number of forms to be completed
c. Time taken to process the loan
d. Number of pending applications at the bank
e. All are CTPs.

Q31. Customer-Supplier Relationship normally implies:

a. Customer and supplier must stretch each other to achieve best of negotiations
b. Supplier must plan to maintain under the table dealings with the customer's employees
c. Supplier and customer must work together to add value for the external customer

d. Supplier and customer must work together to add value for the owners of the business
e. None of the above.

Q 32. SIRPORC is a view of the process taken at:

a. The Overall process level
b. The Customer level
c. The Supplier level
d. None of the above.

Q33. Which of the following is true about Six Sigma Methodology:

a. Major focus is on increasing supplier satisfaction
b. Major focus is on cost reduction
c. Major focus is on drawing flow charts
d. Major focus is on improving the way things are done.

Q34. Cross-Functional goals for an organization include:

a. Sales Turnover
b. Profitability
c. Market Share
d. All of the above
e. None of the above.

Q35. Opportunities for error:

a. Are the different types of mutually exclusive defects that can occur in a process
b. Are generally less than 10 as a thumb rule
c. Are generally less than 15 as a thumb rule
d. Are both (a) and (c).

Q36. SIRPORC is a must in _____ phase of DMAIC:

a. Measure
b. Improve
c. Analyse
d. Define
e. All of the above.

Q37. CTPs must be identified during the _____ phase of DMAIC:

a. Analyze
b. Improve
c. Control
d. Define
e. None of the above.

Q38. Pilot solution is verifed during _____ phase of DMAIC.

a. Measure
b. Improve
c. Analyse
d. Define
e. Control
f. None of the above.

Q39. Standardization of work and its documentation are done during _____ phase of DMAIC.

a. Measure
b. Improve
c. Analyse
d. Define
e. All of the above
f. None of the above.

Q40. Training for six sigma implementation should generally begin:

a. At operator level
b. At top and senior management level
c. At middle-management Level
d. With suppliers / contractors
e. With important customers of the organization.

12. STATISTICAL CALCULATIONS & ABBREVIATIONS

a) Central Tendency:

*** Mean:**

The mean is the **average reading of the** values within a data set.

*** Median:** is the Midpoint of the distribution of the data
i.e. 50% readings above and 50% readings below.

- If number of **data points (n) is even**,
  then median is the average of the n/2 th and (n/2 +1) th reading.
- If number of **data points (n) is odd**, then median is the (n + 1)/2 th reading.

*** Mode:** The most often occurring value in the data set.

b) Range = (**X** max – **X** min) represents = **spread** of the distribution.

c) Standard Deviation represented by **Greek letter Sigma (σ) or "s":**

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{N}}$$ ***for a Population data.***

Where: N = number of observations (population size).

$$s = \sqrt{\frac{(x_1 - \bar{X})^2 + (x_2 - \bar{X})^2 + \text{----------} + (x_n - \bar{X})^2}{(n-1)}}$$ ***for a sample data.***

where, x_1 , x_2 , ---------- x_n are the observations

and n = number of observations (sample size).

d) Defects Per Unit (DPU) and DPMO:

DPU is the number of defects in a given unit of product or process.

$$\textbf{DPU} = \frac{\text{No. of defects}}{\text{No. of units processed}}$$

Defects Per Million Opportunities (DPMO):

$$\textbf{DPMO} = \textbf{DPU} \times \frac{1{,}000{,}000\ (1.0\ \text{Million})}{\text{Opportunities for error in that unit}}$$

e) Total Cost of Quality:

TOTAL COST OF QUALITY			
Cost of Non-Conformance (Cost of POOR Quality)		**Cost of Conformance**	
Internal Failure Cost	**External Failure Cost**	**Cost of Appraisal**	**Cost of Prevention**
+ Hidden Cos	**+ Hidden Cost**	**---**	**---**

f) Seven Tools of Quality:

FLOWCHART – MAKES PROCESS STEPS VISIBLE

- VALUE ANALYSIS, APPRAISAL, PREVENTION

CHECKSHEET – DATA RECORDING DEVICE (COUNT DATA)

PARETO CHART – PRIORTIZATION TOOL (COUNT DATA)

- VITAL FEW, TRIVIAL MANY
- HELPS TO FIND ROOT CAUSES

- HELPS TO FIND CTQs and CTPs

HISTOGRAM – FREQ. OF DATA DISTRIBUTION (FOR CONTINUOUS DATA)

- CENTRAL TENDENCY: MEAN / MEDIAN / MODE

- RANGE

- MULTI MODES

FISHBONE DIAGRAM – BRAIN STORMING

- ROOT CAUSE ANALYSIS

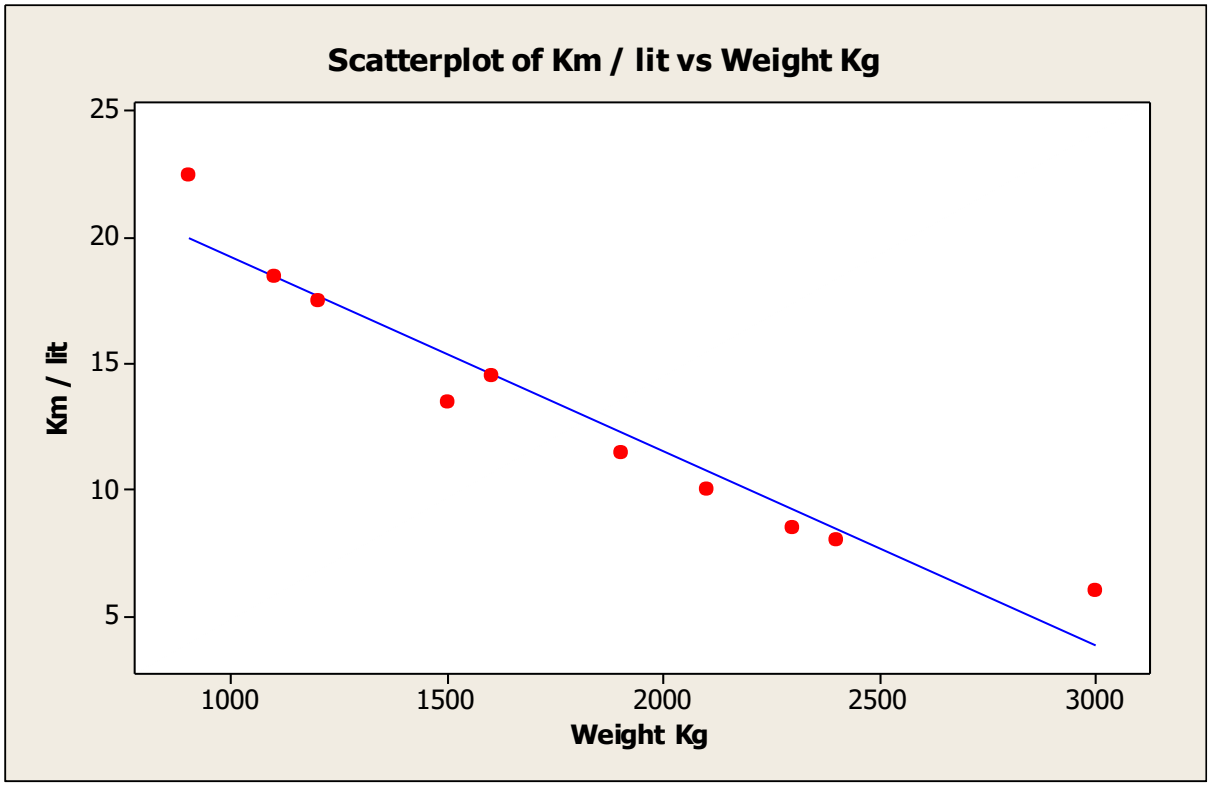
- MULTI-VOTING (NOMINAL GROUP TECHNIQUE)

CONTROL CHART – TO CHECK IF PROCESS IS CAPABLE

– TO CHECK IF PROCESS IS IN CONTROL.

SCATTER DIAGRAM – CORRELATION BETWEEN TWO VARIABLES
[RELATION OF CTQ WITH CTP(s)]

- CORRELATION COEFFICIENT (r).



g) Co-relation Coefficient – How to Interpret:

Strong Co-relation	**Weak Co-relation**	**No Co-relation**
Most of the points in Scatter Diagram are **very close** to the best fitting line.	Most of the points in Scatter Diagram **are far from** the best fitting line.	You cannot draw any type of best fitting line.
Co-relation Coefficient 'r' lies between **- 0.7 to -1.0** **OR** **0.7 to 1.0**	**Co-relation Coefficient 'r' lies between** **- 0.3 to – 0.69** **OR** **0.3 to 0.69**	**Co-relation Coefficient 'r' lies between** **0.0 to – 0.29** **OR** **0.0 to 0.29**
CTP	**NOT CTP**	**NOT CTP**

h) Short Term Process Capability Index:

$Cp = SW / PW = SW / 6\sigma$

Where: ***Specification Width*** *(SW)* **=** *USL – LSL*

Process Width *(PW)* **=** *UCL – LCL* **=** 6σ

PROCESS IS SAID TO BE CAPABLE ONLY IF Cp IS > 1.

i) Long Term Capability Index:

Cpk = ***Minimum (Lower) of:***

(USL – MEAN) / 3σ **OR** ***(MEAN – LSL) / 3σ***

PROCESS IS SAID TO BE CAPABLE ONLY IF Cpk IS > 1.

j) Kano Model:

—

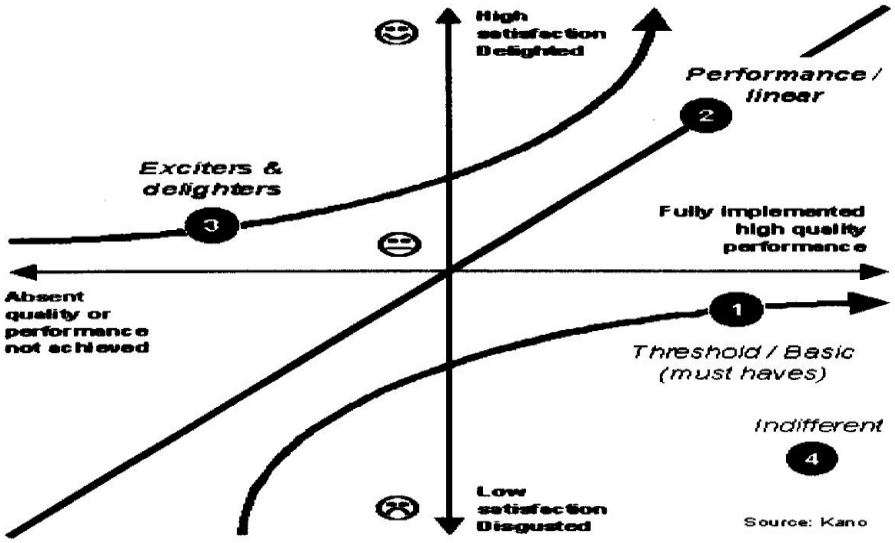


Figure -1: the Kano model

Method:

Kano developed a structured user-questioning methodology to help characterize different features and remove ambiguity by ensuring that categorization is based on user research.

k) F.M.E.A.:

Risk Priority Number (RPN) = Severity x Occurrence X Detection

<u>Rating Scale</u>: **Very High → Very Low:**

* Severity : **10 → 1**

* Chances of Occurrence : **10 → 1**

* Chances of Detection : **1 → 10**

I) ABBREVIATIONS:

1. VOC – Voice of Customer

VOB – Voice of Business.

2. CTQ - Critical to Quality (Characteristics)

3. CTP - Critical to Process (Inputs & Factors)

4. RCO Prevention:

– Reduce Chance of Occurrence: Does not Allow defect to occur.

5. ICD Prevention:

– Increase Chance of Detection:
Warning arrangement to warn us before defect occurs.

6. C.A.: Corrective Action

7. P.A.: Preventive Action

8. Q (PQ + SQ): Quality (Product Quality + Service / Support Quality)

C: Cost

D (S): Delivery (Schedule).

9. DMAIC: Define – Measure – Analyze – Improve – Control.

10. DMADV: Define – Measure – Analyze – Design – Validate.

11. SIRPORC (SIPOC):

Supplier – Input – Requirements (of Process) – Process Substep –Output – Requirements (of Customer) – Customer

12. MSA:

Measurement System Analysis for calibration before measurement / collection of data.

13. RVA: Real Value Addition

BVA: Business Value Addition

NVA: Non Value Addition

14. SOP: Standard Operating Procedure

15. WI: Work Instruction

16. PDCA: Plan – Do – Check – Act (Developed by Dr. Deming)

17. Tollgate Review:

Review carried out jointly by Champion, MBB, BB, GBs during the DMAIC phases.

18. FMEA:
Failure Mode & Effect Analysis
(Used for Risk Assessment & Risk Reduction).

19. EFFECTIVENESS OF PROCESS:

Reducing defects in a process, increases its effectiveness.

20. EFFICIENCY OF PROCESS:

Reducing waste in a process, increases its efficiency.

13. DPMO TO SIGMA CONVERSION CHART

Six Sigma Conversion Table

Yield	DPMO	Sigma	Yield	DPMO	Sigma	Yield	DPMO	Sigma
6.6%	**934,000**	**0**	**69.2%**	**308,000**	**2**	**99.4%**	**6,210**	**4**
8.0%	920,000	0.1	72.6%	274,000	2.1	99.5%	4,660	4.1
10.0%	900,000	0.2	75.8%	242,000	2.2	99.7%	3,460	4.2
12.0%	880,000	0.3	78.8%	212,000	2.3	99.75%	2,550	4.3
14.0%	860,000	0.4	81.6%	184,000	2.4	99.81%	1,860	4.4
16.0%	840,000	0.5	84.2%	158,000	2.5	99.87%	1,350	4.5
19.0%	810,000	0.6	86.5%	135,000	2.6	99.90%	960	4.6
22.0%	780,000	0.7	88.5%	115,000	2.7	99.93%	680	4.7
25.0%	750,000	0.8	90.3%	96,800	2.8	99.95%	480	4.8
28.0%	720,000	0.9	91.9%	80,800	2.9	99.97%	330	4.9
31.0%	**690,000**	**1**	**93.3%**	**66,800**	**3**	**99.977%**	**230**	**5**
35.0%	650,000	1.1	94.5%	54,800	3.1	99.985%	150	5.1
39.0%	610,000	1.2	95.5%	44,600	3.2	99.990%	100	5.2
43.0%	570,000	1.3	96.4%	35,900	3.3	99.993%	70	5.3
46.0%	540,000	1.4	97.1%	28,700	3.4	99.996%	40	5.4
50.0%	500,000	1.5	97.7%	22,700	3.5	99.997%	30	5.5
54.0%	460,000	1.6	98.2%	17,800	3.6	99.9980%	20	5.6
58.0%	420,000	1.7	98.6%	13,900	3.7	99.9990%	10	5.7
61.8%	382,000	1.8	98.9%	10,700	3.8	99.9992%	8	5.8
65.6%	344,000	1.9	99.2%	8,190	3.9	99.9995%	5	5.9
						99.99966%	**3.4**	**6**

Additional Chart (DPMO to Sigma Level Conversion)

Sigma Level	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2.0	308770.2	305249.8	301747.6	298263.7	294798.6	291352.3	287925.1	284517.3	281129.1	277760.7
2.1	274412.2	271084.0	267776.2	264489.0	261222.6	257977.2	254753.0	251550.2	248368.8	245209.2
2.2	242071.5	238955.7	235862.1	232790.8	229742.0	226715.8	223712.2	220731.6	217773.9	214839.2
2.3	211927.7	209039.5	206174.8	203333.5	200515.7	197721.6	194951.2	192204.6	189481.9	186783.0
2.4	184108.2	181457.4	178830.0	176228.0	173649.5	171095.2	168565.1	166059.2	163577.5	161120.1
2.5	158686.9	156278.0	153893.3	151532.9	149196.7	146884.7	144596.8	142333.2	140093.6	137878.1
2.6	135686.7	133519.3	131375.8	129256.3	127160.5	125088.6	123040.3	121015.7	119014.7	117037.0
2.7	115083.0	113152.2	111244.7	109360.2	107498.9	105660.5	103844.9	102052.1	100281.9	98534.3
2.8	96809.0	95106.1	93425.3	91766.6	90129.8	88514.8	86921.5	85349.7	83799.3	82270.1
2.9	80762.1	79275.0	77808.8	76363.2	74938.2	73533.6	72149.1	70784.8	69440.4	68115.7
3.0	66810.6	65525.0	64258.6	63011.3	61783.0	60573.4	59382.5	58210.0	57055.8	55919.6
3.1	54801.4	53700.9	52618.1	51552.6	50504.3	49473.1	48458.8	47461.2	464480.1	45515.3
3.2	44566.8	43634.2	42717.4	41816.3	40930.6	40060.2	39204.9	38364.5	37538.9	36727.8
3.3	35931.1	35148.6	34380.2	33625.7	32884.8	32157.4	31443.3	30742.5	30054.6	29379.5
3.4	28717.0	28067.1	27429.4	26803.8	26190.2	25588.4	24988.2	24419.5	23852.1	23295.8
3.5	22705.4	22215.9	21692.0	21178.5	20675.4	20182.4	19699.5	19226.4	18763.0	18309.1
3.6	17864.6	17429.3	17003.2	16586.0	16177.5	15777.7	15386.5	15003.5	14628.8	14262.2
3.7	13903.5	13552.7	13209.5	12873.8	12545.5	12224.5	11910.7	11603.9	11303.9	11010.7
3.8	10724.2	10444.1	10170.5	9903.1	9641.9	9386.7	9137.5	8894.1	8656.4	8424.2
3.9	8197.6	7976.3	7760.3	7549.4	7543.7	7142.8	6946.9	6755.7	6569.1	6387.2
4.0	6209.7	6036.6	5867.8	5703.1	5542.6	5386.2	5233.6	5084.9	4940.0	4798.8
4.1	4661.2	4527.1	4396.5	4269.3	4145.3	4024.6	3907.0	3792.6	3681.1	3572.6
4.2	3467.0	3364.2	3264.1	3166.7	3072.0	2979.8	2890.1	2802.8	2717.9	2635.4
4.3	2555.1	2477.1	2401.2	2327.4	2255.7	2186.0	2118.2	2052.4	1988.4	1926.2
4.4	1865.8	1807.1	1750.2	1694.8	1641.1	1588.9	1538.2	1489.0	1441.2	1394.9
4.5	1349.9	1306.2	1263.9	1222.8	1182.9	1144.2	1106.7	1070.3	1035.0	1000.8
4.6	967.6	935.4	904.3	874.0	844.7	816.4	788.8	762.2	736.4	711.4
4.7	687.1	663.7	641.0	619.0	597.6	577.0	557.1	537.7	519.0	500.9
4.8	483.4	466.5	450.1	434.2	418.9	494.1	389.7	375.8	362.4	349.5
4.9	336.9	324.8	313.1	301.8	290.9	280.3	270.1	260.2	250.7	241.5
5.0	232.6	224.1	215.8	207.8	200.1	192.6	185.4	178.5	171.8	165.3
5.1	159.1	153.1	147.3	141.7	136.3	131.1	126.1	121.3	116.6	112.1
5.2	107.8	103.6	99.6	95.7	92.0	88.4	85.0	81.6	78.4	75.3
5.3	72.3	69.5	66.7	64.1	61.5	59.1	56.7	54.4	52.2	50.1
5.4	48.1	46.1	44.3	42.5	40.7	39.1	37.5	35.9	24.5	33.0
5.5	31.7	30.4	29.1	27.9	26.7	25.6	24.5	23.5	22.5	21.6
5.6	20.7	19.8	18.9	18.1	17.4	16.6	15.9	15.2	14.6	13.9
5.7	13.3	12.8	12.2	11.7	11.2	10.7	10.2	9.8	9.3	8.9
5.8	8.5	8.2	7.8	7.5	7.1	6.8	6.5	6.2	5.9	5.7
5.9	5.4	5.2	4.9	4.7	4.5	4.3	4.1	3.9	3.7	3.6
6.0	3.4	3.2	3.1	2.9	2.8	2.7	2.6	2.4	2.3	2.2
6.1	2.1	2.0	1.9	1.8	1.7	1.7	1.6	1.5	1.4	1.4
6.2	1.3	1.2	1.2	1.1	1.1	1.0	1.0	0.9	0.9	0.8
6.3	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.5	0.5
6.4	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3
6.5	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
6.6	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
6.7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
6.8	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0