Root Cause Analysis

OMNEX

325 E. Eisenhower, Suite 4
Ann Arbor, Michigan 48108 USA

734-761-4940
Fax: 734-761-4966

First Edition
July 2013

Omnex Worldwide

Omnex provides training, consulting and integrated, web-based software solutions to the global market with offices in the USA, Canada, China (PRC), Germany, India, Thailand, Mexico, and Venezuela. Worldwide, Omnex offers over 45 courses in business and quality management systems, while providing consulting solutions in all areas of business management and performance enhancement.

Internet email: info@omnex.com

Web: www.omnex.com

A BRIEF INTRODUCTION TO OMNEX

Omnex Introduction

- **International consulting, training and software development organization founded in 1985.**
- **Specialties:**
  - Integrated management system solutions.
  - Elevating the performance of client organizations.
  - Consulting and training services in:
    - Quality Management Systems, e.g., ISO 9001, IATF 16949, AS9100, QOS
    - Environmental Management Systems, e.g., ISO 14001
    - Health and Safety Management Systems, e.g., ISO 45001
- **Leader in Lean, Six Sigma and other breakthrough systems and performance enhancement.**
  - Provider of Lean Six Sigma services to Automotive Industry via AIAG alliance.

About Omnex

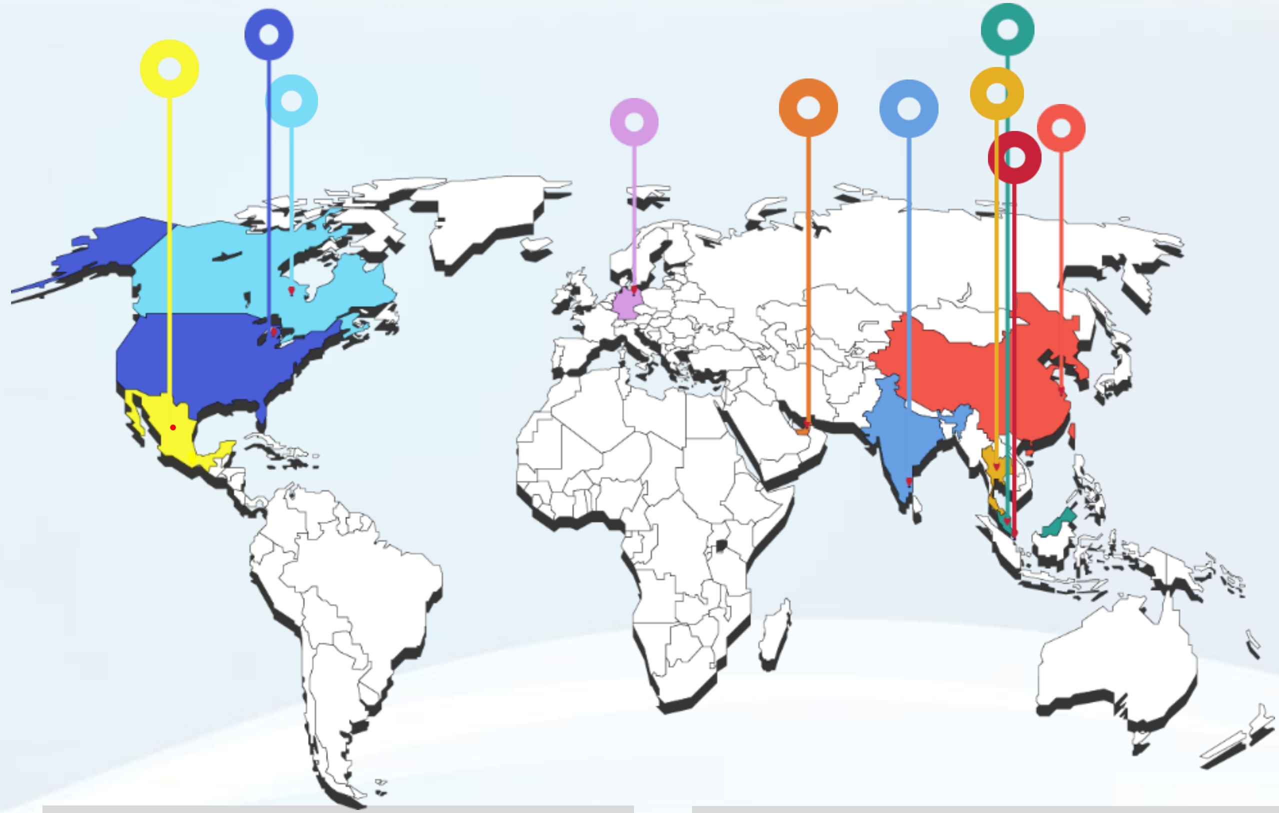
- Headquartered in Ann Arbor, Michigan with offices in major global markets.
- In 1995-97 provided global roll out supplier training and development for Ford Motor Company.
- Trained more than 100,000 individuals in over 30 countries.
- Workforce of over 700 professionals, speaking over a dozen languages.
- Former Delegation Leader of the International Automotive Task Force (IATF) responsible for ISO/TS 16949.
- Served on committees that wrote QOS, ISO 9001, QS-9000, ISO/TS 16949 and its Semiconductor Supplement, and ISO IWA 1 (ISO 9000 for healthcare).
- Former member of AIAG manual writing committees for FMEA, SPC, MSA, Sub-tier Supplier Development, Error Proofing, and Effective Problem Solving (EPS).

Omnex Worldwide Offices

Omnex is headquartered and operates from the United States through offices in Michigan.

The company maintains international operations in many countries to provide comprehensive services to clients throughout Western Europe, Latin America and the Pacific Rim.

www.omnex.com
info@omnex.com



- Omnex Global Head Quarters (Michigan, USA)
  West Coast Operations (San Jose, CA)
- Asia Pacific HQ (Chennai, Pune, Delhi, Bangalore)
- China (Shanghai, Guangzhou, Wuhan, Chengdu)
- Canada (Mississauga)
- Europe (Berlin, Germany)
- Middle East (Dubai, Saudi Arabia, Bahrain)
- Thailand (Bangkok)
- Mexico (Monterrey)
- Singapore
- Malaysia (Kuala Lumpur)

Rules of the Classroom

- ✓ Start and end on time
- ✓ Return from breaks and lunch on time
- ✓ All questions welcome
- ✓ Your input is valuable and is encouraged
- ✓ Don't interrupt others
- ✓ One meeting at a time
- ✓ Listen – and respect others' ideas
- ✓ No "buts" – keep an open mind
- ✓ Phones in Do Not Disturb (silent) mode
- ✓ No e-mails, texting or tweeting during class

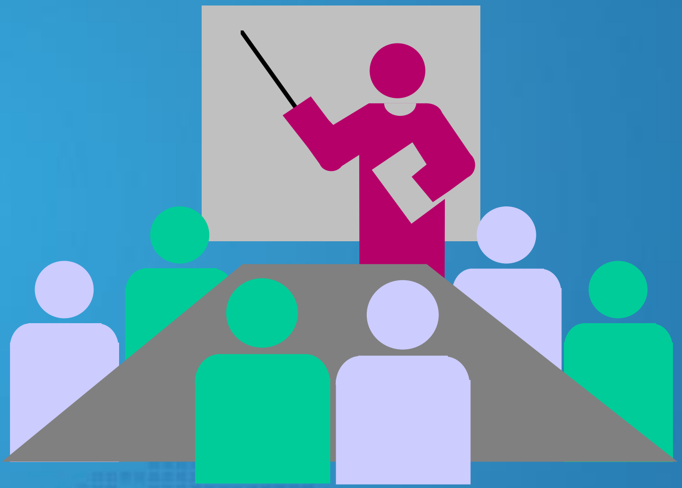
If you must take a phone call or answer a text please leave the room for as short a period as possible

Icebreaker

- **Instructor Information:**
  - Name
  - Background
- **Student Introductions:**
  - Name
  - Position / Responsibilities
  - What is your involvement in the Quality Management System and the auditing process?
  - What do you expect to take away from this class?
  - Please share something unique and/or interesting about yourself.

Contents

Introduction



Introductions

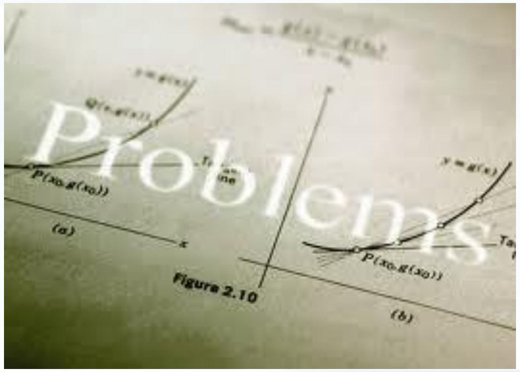
Participants

- **Names**
- **Roles**
- **Expectations for this training**

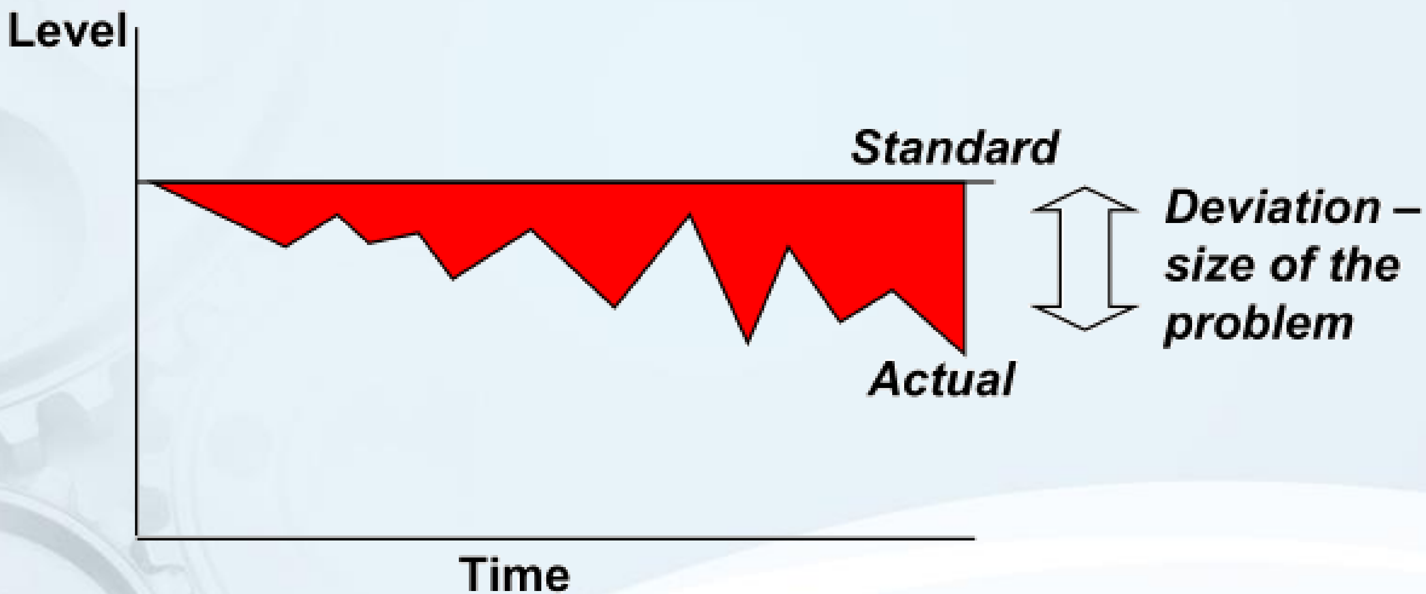
What is a Problem?

What is a Problem?

- Problem is an undesired result
- It is opposite condition of the desired outcome of a process
- Problem is the difference between the planned result and what is achieved actually (If target is not achieved)
- A problem will always affect the customer



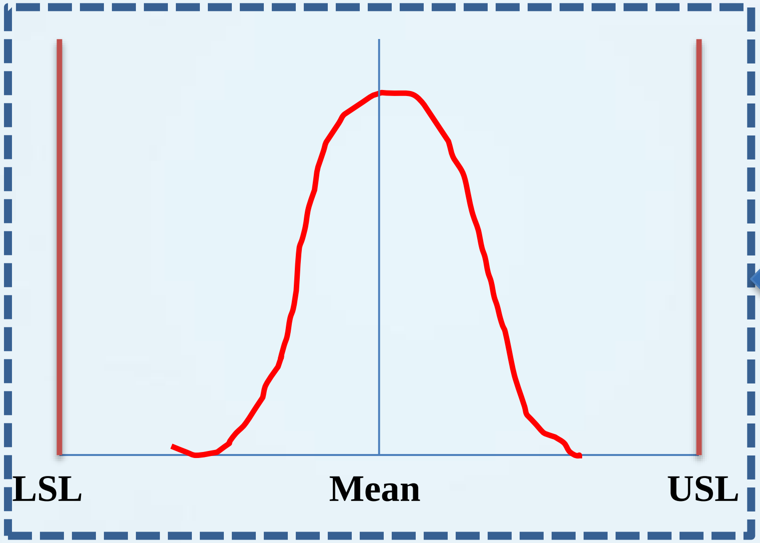
Understanding a Problem



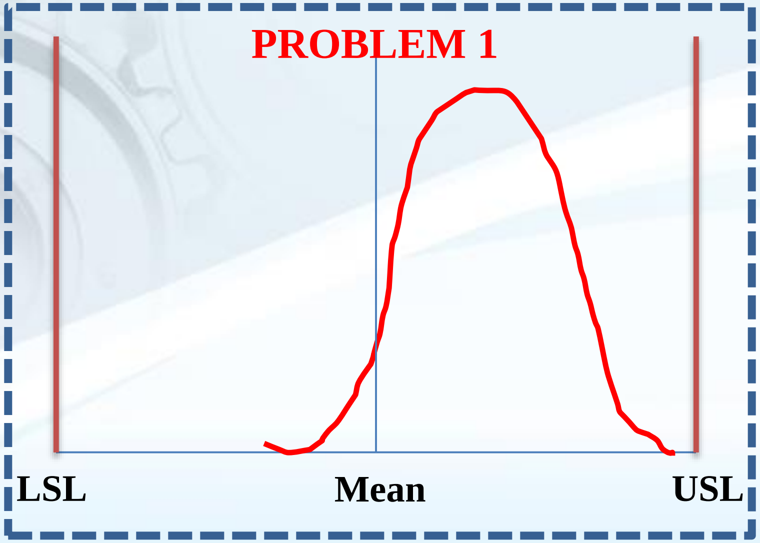
- ❑ **Problem is anything that deviates from the ideal situation or standard.**

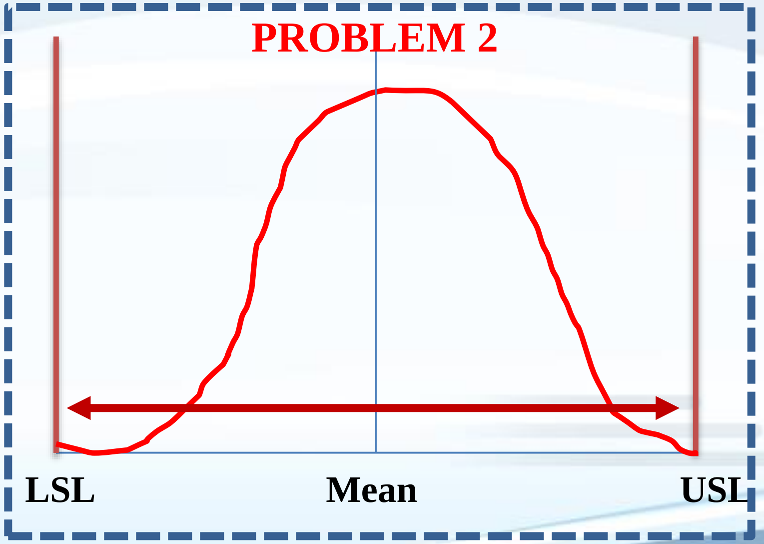
- ❑ **Three main factors to consider:**
  1) **The standard**
  2) **The deviation away from the standard**
  3) **Time elapsed**

Two Types of Problems



Expected Process Performance

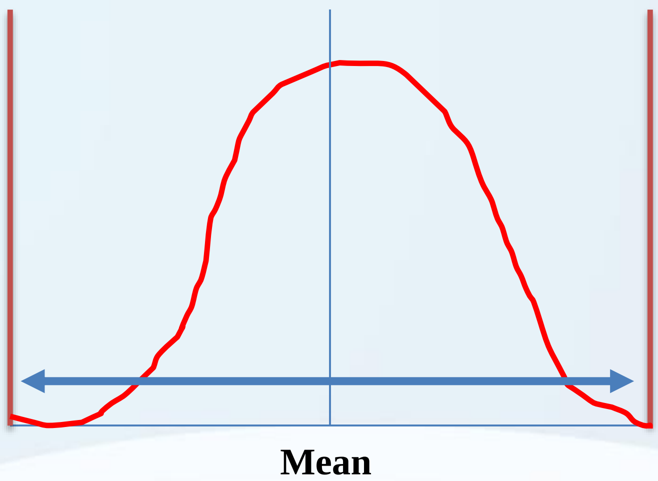




OMNEX

WWW.OMNEX.COM

Signal or Noise?



- Mean shift
- Signal problem
- Solution: Optimization of parameters
- Tools: DOE, Linear Programming

- High Spread
- Noise problem
- Solution: Root Cause Analysis
- Tools: 7 QC tools, Six Sigma, Hypothesis Testing

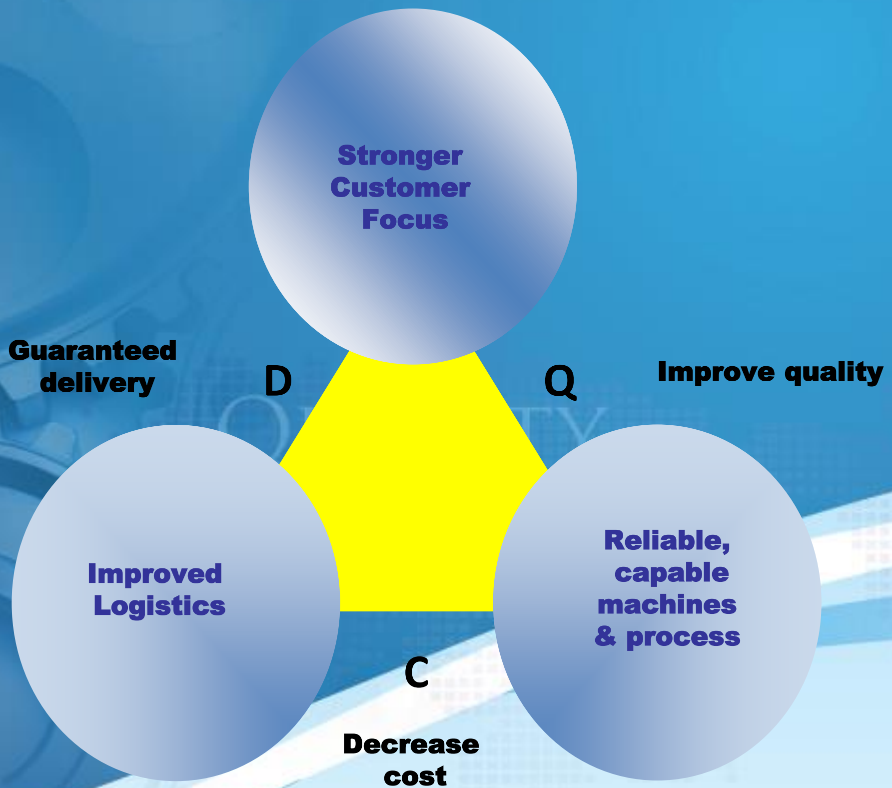
Examples of problem - Manufacturing

- Operational losses
- Equipment failure
- Process failure
- Rework
- Scrap

Examples of problem- Transactional

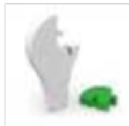
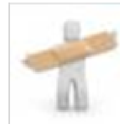
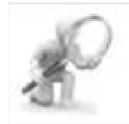
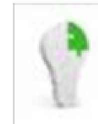
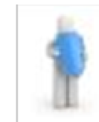
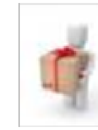
- Customer request for quotes
- Order handling
  - Order errors
  - Order administration & cycle time
- Accounts receivable
- Costing / pricing
- Software defects

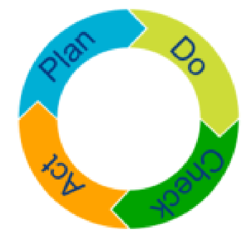
Problem Solving Steps



o.m.n.ex

Problem solving steps

0	1	2	3	4	5	6	7	8
								
Implement immediate containment and prepare	**Form the team**	Define the Problem	Develop containment action	Identify and verify Root Cause	Identify Corrective Action	Implement Corrective Action	Define and plan Preventative action	Recognise the team



Step-wise - Action items

D0: Prepare for Problem Solving Process

- Evaluate the need for the problem solving process when a symptom is noted.
- Determine if there is a need for an Emergency Response Action to protect an internal or external customer.
- First steps in beginning the problem solving process.

D1: Form Team

- Establish an effective problem solving team.
- Establish objectives first.
- Establish team ground rules.

D2: Describe the problem

- The importance of problem definition to the problem solving process.
- The techniques used to arrive at the appropriate problem statement.
- The process used to define the customer's problem (creating Is/Is Not database).

Step-wise - Action items

D3: Contain Symptoms

- What constitutes effective interim action.
- Difference between interim and permanent corrective actions.
- Verification of interim action.

D4: Find and verify root causes

- How to define and verify root causes.
- How to narrow the focus of root cause analysis to minimize search and expense.

D5: Select permanent corrective actions

- The process of selecting and verifying permanent corrective action.

D6: Implement permanent corrective actions

- The process for the implementation of permanent corrective action.

Step-wise - Action items

D7: Prevent system problems

- How to address system root causes and permanently fix the problems.

D8: Closure and team congratulations

- Recognizing the collective efforts of the team.
- Management review of the problem solving activity.
- Concurrence of the activity completed.

Analysis v/s Action

The "disciplines" that make-up the problem solving process are divided into Analysis vs. Action steps.

Analysis Steps

- D2 Problem Description Analysis – a method to organize information about the s*ymptom* into a *Problem Description* through the use of repeated WHYs.

-D4 Root Cause Analysis – a process to arrive at *Root Cause* paths.

Analysis v/s Action

Action Steps

- **D3 Containment – an interim *Verified* action that will prevent the *Symptom* from reaching the customer.**

-**D5 Choose Corrective Action – the best corrective action which, when implemented in D6, permanently eliminates the *Root Cause* of the problem.**

- **D6 Implement Corrective Action – the best corrective action from D5 that is introduced into the process and *Validated* over time.**

- **D7 System Preventive Action – actions which address the system that allowed the problem to occur.**

OMNEX

WWW.OMNEX.COM

Individual exercise

The Production manager of company ABC calls for a department meeting. He says, “the performance of last 3 months of the department is substandard”. He asks for reasons from the audience and gets answers like:

1. **Problem is with individuals submitting work**
2. **Poor skills of workers**

As the Production manager, what would you conclude?

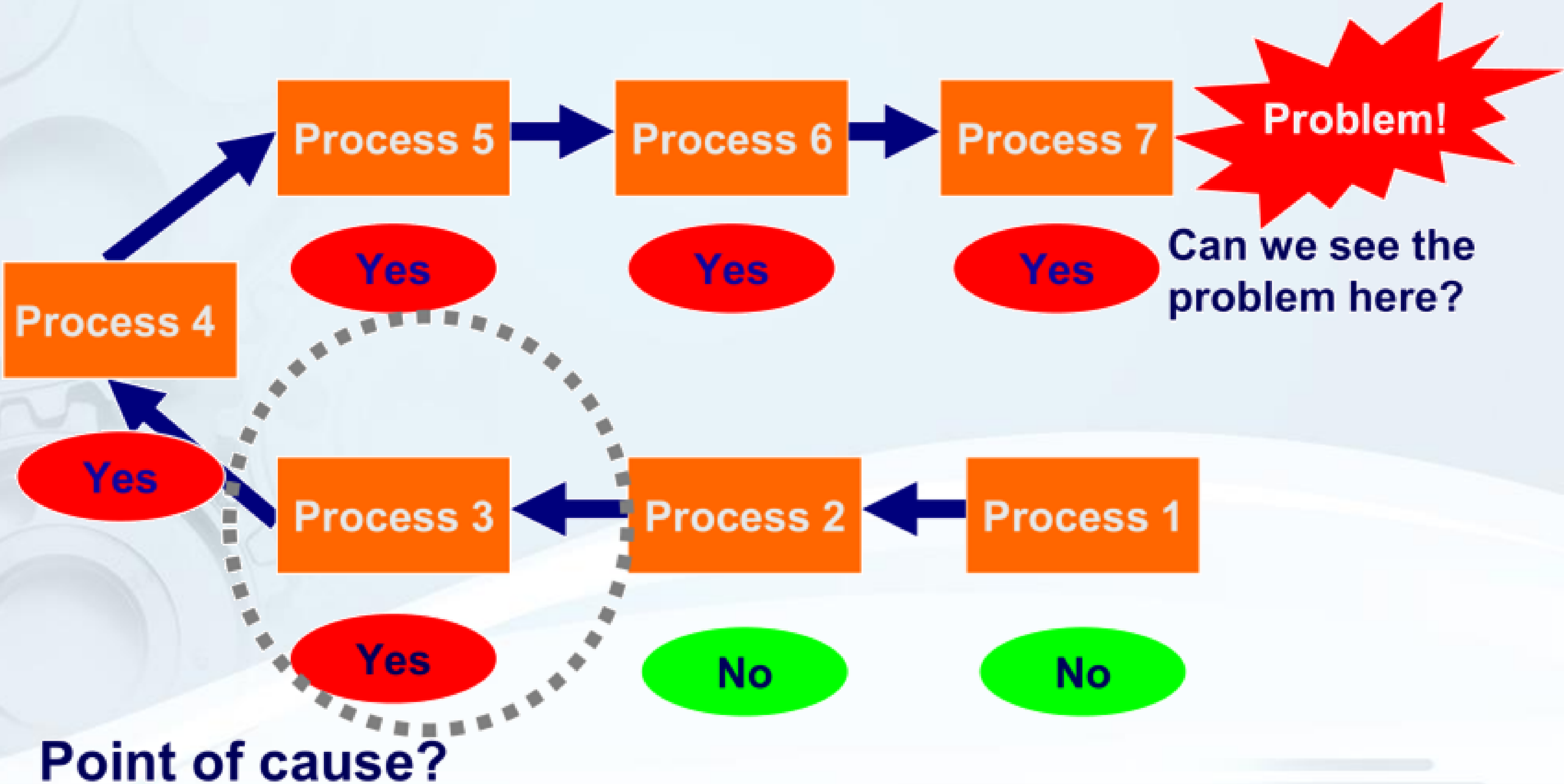
Problem definition

Problem prioritization

First task of the team is to choose a particular problem to decide based on the list of problems already identified. For this Nominal Group Techniques can be deployed.

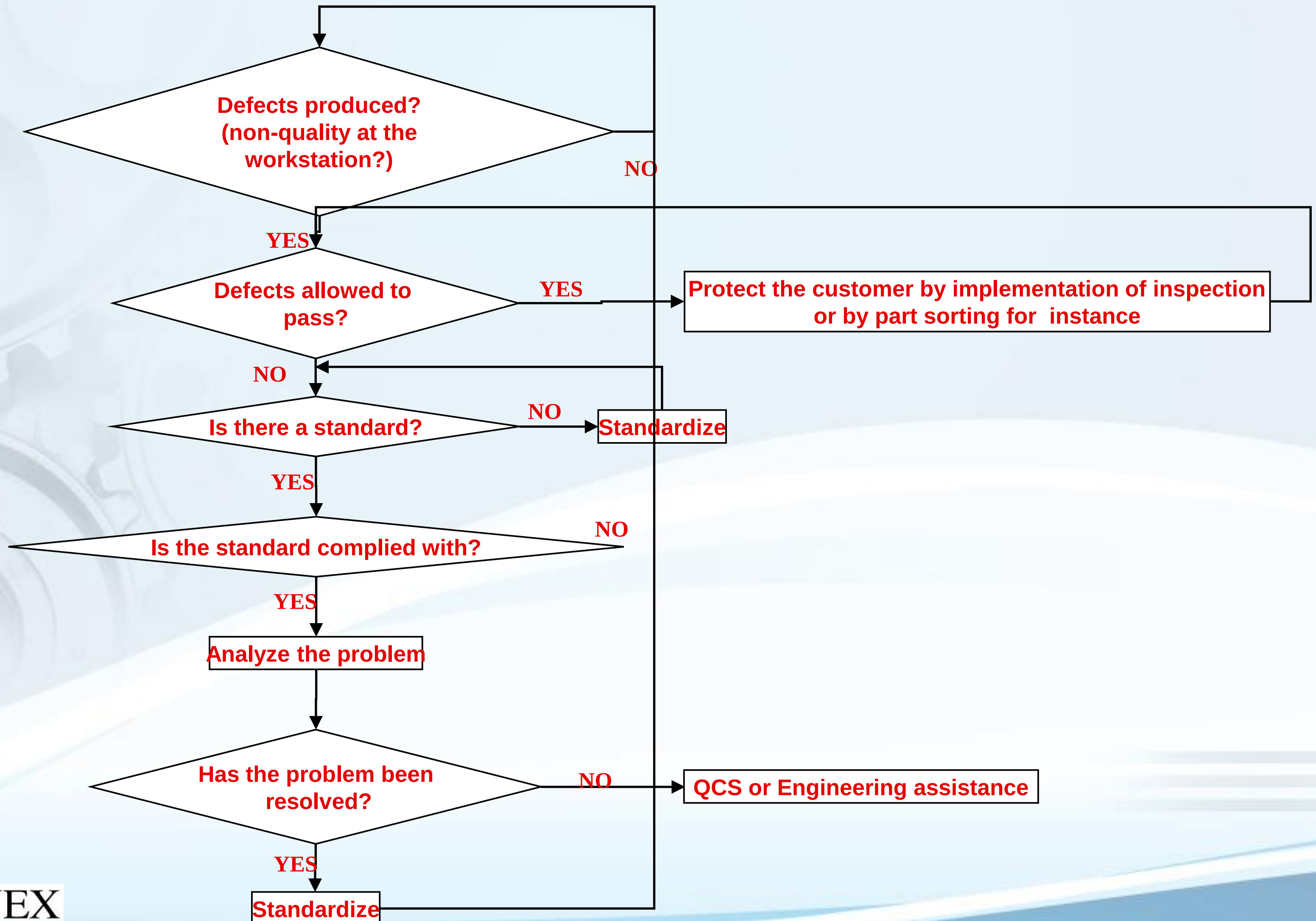
The Nominal Group Technique (NGT) is a decision making method for use among groups of many sizes, who want to make their decision quickly, as by a vote, but want everyone's opinions taken into account (as opposed to traditional voting, where only the largest group is considered). The method of tallying is the difference. First, every member of the group gives their view of the solution, with a short explanation. Then, duplicate solutions are eliminated from the list of all solutions, and the members proceed to rank the solutions, 1st, 2nd, 3rd, 4th, and so on.

Source of Problem



OMNEX
WWW.OMNEX.COM

Actions to be taken in the event of problem



OMNEX
WWW.OMNEX.COM

Checklist of basic points

Man

- Operator Trained ?
- Operator Skilled ?
- Operator Currently in Training ?
- Operator Able to do ?

Machine

- Machine out of Order ?
- Machine in Good Condition ?
- Machine Used Specified ?
- Machine Calibrated / Gauged ?

Tools

- Tools Calibrated?
- Tools Wear
- Tool Blunt
- Tools life over
- Tool specified

EFFECT

Method

- A Std. operation exists ?
- Company stds. respected ?
- MOS Respected ?
- Key Points Written ?
- Reasons of key points known ?
- Balancing of work station good ?
- Any sequence defined ?
- Any sequence followed ?

Material / Consumable

- Date Lapsing of product OK ?
- Problem of any specific vendor ?
- Problem follows the part ?
- Problem follows the product ?
- Part conformed ?
- Any Consumable Fault ?

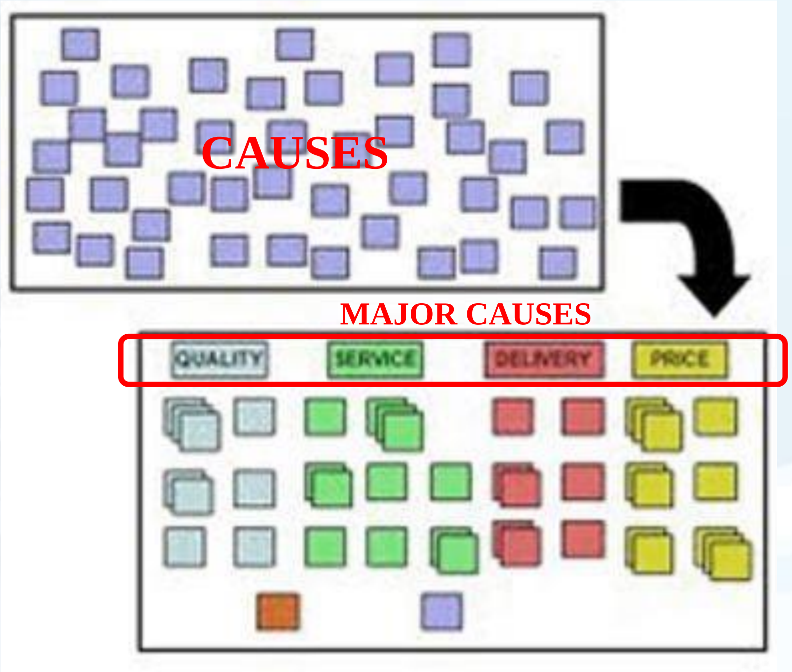
Environment

- Specified Temperature
- Specified Humidity
- Specified Dust Level
- Specified Light Intensity
- /LUX

OMNEX

WWW.OMNEX.COM

Affinity Diagram



- A simple tool for putting together a big number of detailed and inter-related causes and group them according to broad topics
- This helps in focusing on the bigger picture or Major root cause
- It is similar to zooming out!

OMNEX
WWW.OMNEX.COM

Problem definition – 5W/1H

Use the 5W/1H Questions

It is sometimes difficult to define the problem and sort out real differences. The first, most important step, however, is to determine that the customer complaint is fully understood.

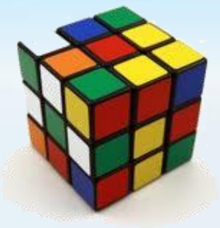
- Who? – Identify customers complaining.
- What? – Identify the problem adequately and accurately.
- When? – Timing… when did the problem start?
- Where? – Location… where is it occurring?
- Why? – Identify known explanations.
- How Many? – Magnitude… quantify the problem.

Define and understand the problem

Root causes are somewhere in the differences between "*Is*" and "*Is Not*."

	Is	Is Not
What	What is happening? What is the problem?	What could be happening, but is not. What could be the problem but is not?
Where	Where does the problem occur?	Where does the problem not occur? Does the problem cover the entire object?
	Where, geographically, was the problem observed? Where can you first see it?	Where else, geographically, could the problem have been observed, but was not?
When	When in time was the problem first observed?	When in time could it have been first observed, but was not?
	In a process flow diagram, at what step do you first see the problem?	Where else in the process might you have observed the problem, but did not?
	When does it recur (be specific about minutes, hours, days, weeks)?	What other times could you have observed the problem, but did not?
	What is the trend? Has it leveled off? Has it gone away? Is it getting worse?	What other trends could have been observed, but were not?
How Much	Who is affected by the problem?	Who is not affected by the problem?
	How big is the defect in terms of dollars, people, time or other resources?	How big could the problem be, but is not?

Team Breakout 1



- Select one customer complaint from existing or old rejections database
- Convert into clear problem statement using 5W2H and Is-Is Not analysis
- Locate the problem source in a Process Flow Diagram
- Present your problem statements with the group

OMNEX
WWW.OMNEX.COM

Understanding data & Decide targets

BASIC STATISTICS - Learning to talk to DATA

Statistics

The Science of:

- **Collecting,**
- **Describing,**
- **Analyzing,**
- **Interpreting data…**

And Making Decisions

WWW.OMNEX.COM

Why is Basic Statistics Important?

- Analyze data
- Numerically describe the data which characterize the process X`s and Y`s
- Make inferences about the future
- Foundation for problem solving
- Create a language based on numerical facts, Not Intuition

Types of Data

- **Attribute Data (Qualitative)**
  - Categories like Machine 1, Machine 2, Machine 3
  - Y/N
  - Go, No Go or Pass/Fail
  - Good/Defective O-M-N-E-X
  - On-Time/Late
  - Discrete (Count) Data
    - # of Maintenance Equipment Failures,
    - # of freight claims

- **Variable or Continuous Data (Quantitative)**
  - Decimal subdivisions are meaningful
  - Cycle Time, Pressure, Conveyor Speed

What to do with set of nos. ?

Types of Data

	Continuous	Discrete		
	aka quantitative data	aka qualitative/categorical/attribute data		
Measurement	**Units (example)**	**Ordinal (example)**	**Nominal (example)**	**Binary (example)**
Time of day	Hours, minutes, seconds	1, 2, 3, etc.	N/A	a.m./p.m.
Date	Month, date, year	Jan., Feb., Mar., etc.	N/A	Before/after
Cycle time	Hours, minutes, seconds, month, date, year	10, 20, 30, etc.	N/A	Before/after
Speed	Miles per hour/centimeters per second	10, 20, 30, etc.	N/A	Fast/slow
Brightness	Lumens	Light, medium, dark	N/A	On/off
Temperature	Degrees C or F	10, 20, 30, etc.	N/A	Hot/cold
<Count data>	Number of things (hospital beds)	10, 20, 30, etc.	N/A	Large/small hospital
Test scores	Percent, number correct	F, D, C, B, A	N/A	Pass/Fail
Defects	N/A	Number of cracks	N/A	Good/bad
Defects	N/A	N/A	Cracked, burned, missing	Good/bad
Color	N/A	N/A	Red, blue, green, yellow	N/A
Location	N/A	N/A	Site A, site B, site C	Domestic/international
Groups	N/A	N/A	HR, legal, IT, engineering	Exempt/nonexempt
Anything	Percent	10, 20, 30, etc.	N/A	Above/below

OMNEX
WWW.OMNEX.COM

Measures of Central Tendency

- **What is the Middle Value of Distribution ?**
  - Median

  - **What value represents the distribution ?**
    - **Mode**

  - **What value represents the entire distribution ?**
    - **Mean $(\bar{X})$**

What is the best measure of central tendency ?

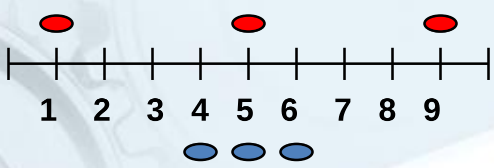
WWW.OMNEX.COM

Measures of Central Tendency

- **Mean: Arithmetic average of a set of values**
  - Reflects the influence of all values
  - Strongly Influenced by extreme values
- **Median: Reflects the 50% rank - the center number after a set of numbers has been sorted from low to high.**
  - Does not include all values in calculation
  - Is “robust” to extreme scores
- **The mean and median will be affected by the nature of the distribution of numbers.**
- **Why would we use the mean instead of the median in process Improvement?**

Is Central Tendency Enough to Represent Distribution ?

- **Find the value of "n" and "$\bar{X}$" for the following 2 distributions.**



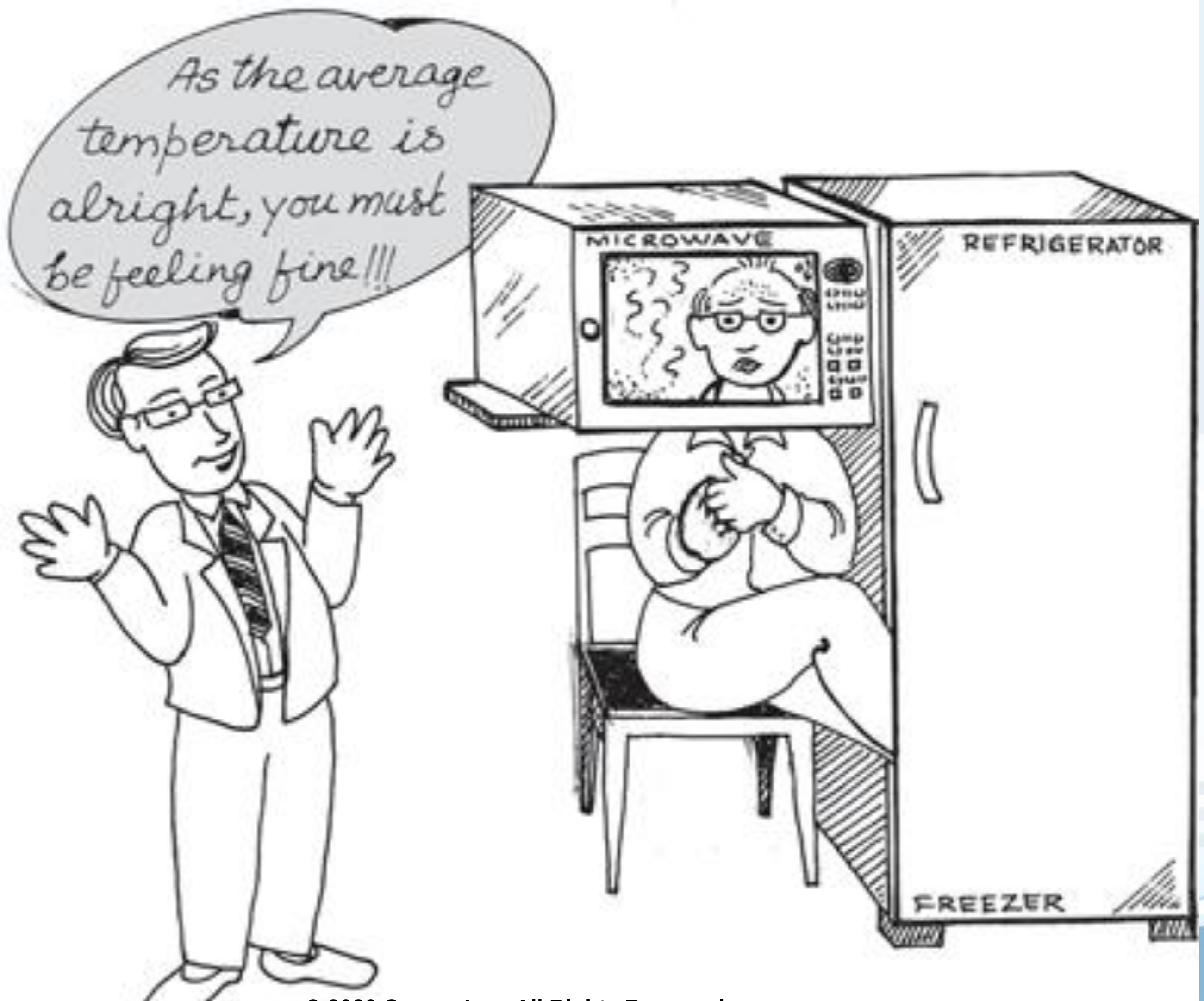
n= $\bar{X}$=

n= $\bar{X}$=

Are The 2 distributions Same ?

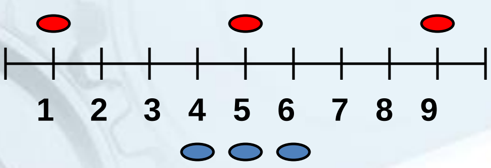
What is the Difference ?

Is Central Tendency Enough to Represent Distribution ?



Measures of Variability (Spread)

- Range “R”= Max-Min is an easy measure of Spread



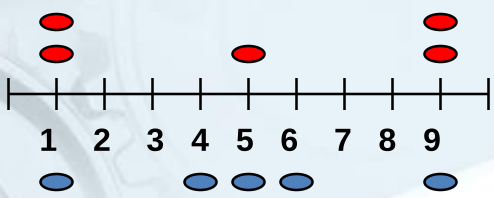
n= $\bar{X}$= R=

n= $\bar{X}$= R=

Is Range a good Measure of Variability ?

- Find the value of "n", "X" and "R" for the following 2 distributions.

Do the 2 distributions have same variability ?



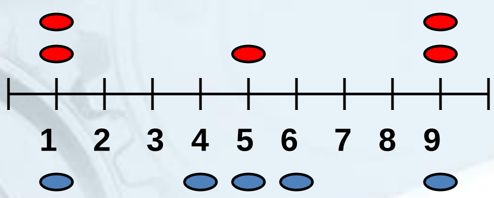
n= $\bar{X}$= R=

n= $\bar{X}$= R=

How do we measure average variability from the Center ?

Measures of Variability (Spread)

- **Calculate Standard Deviation for these 2 Distributions.**



n= $\bar{X}$= R= V= s=

n= $\bar{X}$= R= V= s=

What Does Variance Practically Mean ?

Measures of Variability

- The Range is the distance between the extreme values of a data set. (Highest - Lowest)
- The Variance ($s2$) is the Average Squared Deviation of each data point from the Mean.
- The Standard Deviation (s) is the Square Root of the Variance.
- The range is more sensitive to outliers than the variance.
- The most common and useful measure of variation is the Standard Deviation.
- The Variance for a sum or difference of two variables is found by adding both variances.

Problem target

Defines the improvement the team is seeking to accomplish

Should not presume a cause or include a solution

Has a deadline

Comprises of the focus , the target, and the deadline

- ❑ E.g Reduce the turn around time for loan approval by 20% by 20th march 2002

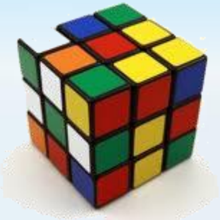
Is Actionable & sets the focus

SMART goals

Problem definition v/s Problem Goal

- **The Problem Statement describes what the Pain is**
- **The Goal Statement defines the Team's improvement objective.**

Team Breakout 2

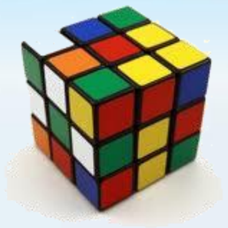


- **Plant Manager of company ABC declared in a monthly meeting that production in company ABC has decreased to low level.**
- **Objective: Read the information provided in next page and come up with a clear specific "problem statement" from following information that your team collected.**

Month	Production per day
Apr-19	405
May-19	418
Jun-19	336
Jul-19	262
Aug-19	294
Sep-19	292
Oct-19	255
Nov-19	250

Reason for breakdowns	Contribution %
Maintenance	4.1%
Planned stops	10.6%
General Cleaning	8.3%
Equipment problem	72.6%
Environment	0.6%
External problem	3.8%

More information…



- **A brainstorming was done by the team to identify major causes of lack of production quantity. There were issues related to transportation of raw materials from suppliers in last 3 months. Intermittent labour problems were occurring during last 12 months. Lots of breakdowns were reported in last 6 months in the factory. On further brainstorming on the causes related to breakdown issues, it was attributed to environmental downtime, electrical issues, panned stops, unplanned equipment downtime and other external factors.**

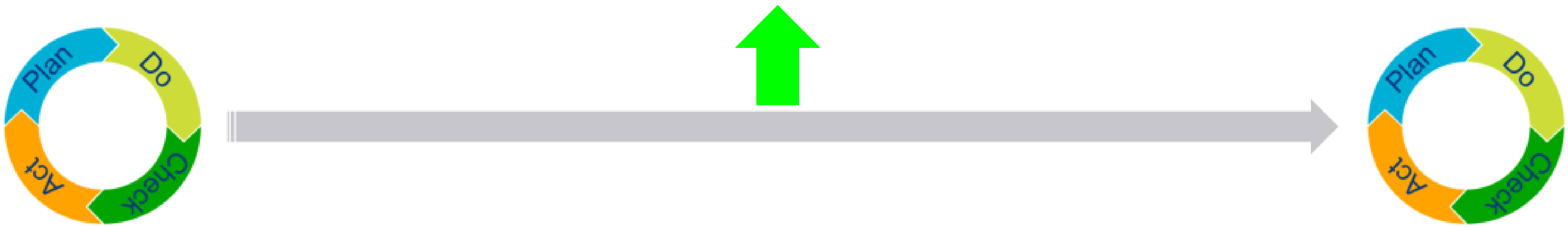
1) **Frame the Problem Statement**
2) **Represent data graphically**
3) **Frame the Goal Statement**

OMNEX
WWW.OMNEX.COM

Analyze causes

Root Cause Analysis

0	1	2	3	4	5	6	7	8
Implement immediate containment and prepare	**Form the team**	Define the Problem	Develop containment action	Identify and verify Root Cause	Identify Corrective Action	Implement Corrective Action	Define and plan Preventative action	Recognise the team



Defining Root Cause Analysis

- RCA is a systematic process for identifying “root causes” of problems or events and an approach for responding to them.
- It includes the identification of the root and contributory factors, determination of risk reduction strategies and development of action plans along with measurement strategies to evaluate the effectiveness of the plans.
- RCA is based on the basic idea that effective management requires more than merely “putting out fires” for problems that develop, but finding a way to prevent them.
- Essentially, RCA means finding the specific source(s) that created the problem so that effective action can be taken to prevent recurrence of the situation.

Why RCA is required?

Defects found at:	Own Process Step	Next Process Step	Later Process Step	Before Reaching Customer	Found By Customer
Cost:	$1	$10	$100	$1,000	$10,000
Impact:	Very Minor	Minor Delay	Rework Re-schedule of Work	Significant Rework Delay in Delivery Additional Inspection	Warranty Cost Admin. Cost Reputation Loss of Market Share

Symptom Approach vs Root Cause

Which is better?

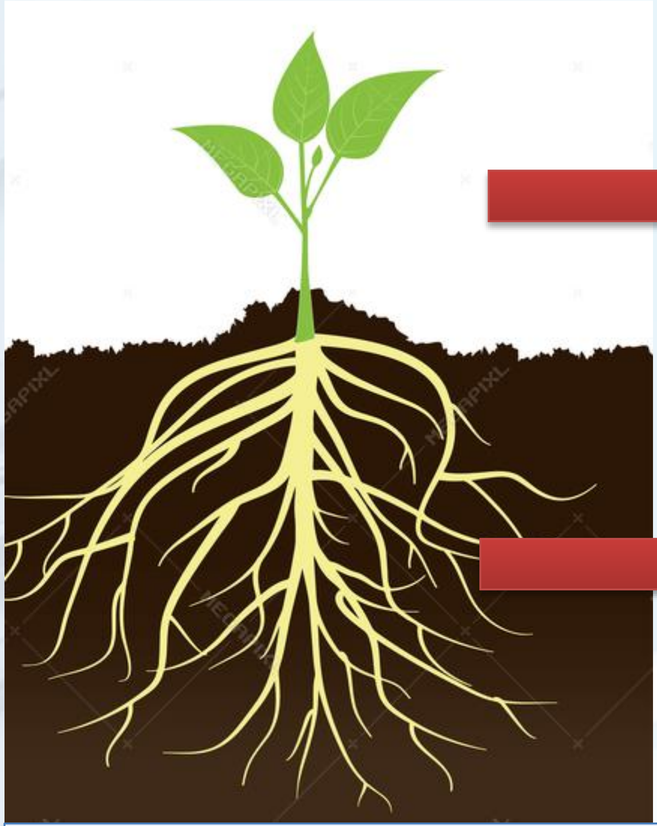
Symptom Approach

- “Errors are often a result of worker carelessness.”
- “We need to train and motivate workers to be more careful.”
- “We don’t have the time or resources to really get to the bottom of this problem.”

Root Cause

- “Errors are the result of defects in the system. People are only part of the process.”
- “We need to find out why this is
- happening, and implement mistake- proofs so it won’t happen again.”
- “This is critical. We need to fix it for good, or it will come back and burn us.”

Symptom is not the focus!



Symptom of the problem,
"The Weed"
Above the surface
(obvious)

The Underlying Causes
"The Root"
Below the surface
(not obvious)

The word "root", in root cause analysis, refers to the underlying causes, not the one cause!

Benefits of RCA thinking

- Identify barriers and the causes of problems, so that permanent solutions can be found
- Develop a logical approach to problem-solving, using data that already exists in the organization
- Identify current and future needs for organizational improvement
- Establish repeatable, step-by-step processes, in which one process can confirm the results of another

10 General Principles of RCA

1) RCA is a diagnostic and analytical tool
2) Effective RCA is a systematic process
3) Effective implementation of RCA requires a fundamental shift in attitudes and mindset
4) RCA requires supportive organizational and management cultures
5) Persistence and sustainability in the RCA effort
6) RCA is an efficient and economical process
7) Effective problem statements and event descriptions are helpful, or even required
8) RCA can help transform a reactive culture into a forward-looking culture and it also reduces the frequency of problems occurring over time within the environment
9) RCA requires a collaborative, multidisciplinary team effort
10) The focal points of RCA are corrective measures of root causes and not simply treating the symptoms of a problem or event

THE FOCUS OF INVESTIGATION AND ANALYSIS THROUGH PROBLEM IDENTIFICATION IS WHY THE EVENT OCCURRED, AND NOT WHO MADE THE ERROR i.e.

“HARD ON THE PROBLEM, SOFT ON THE PERSON”

OMNEX

WWW.OMNEX.COM

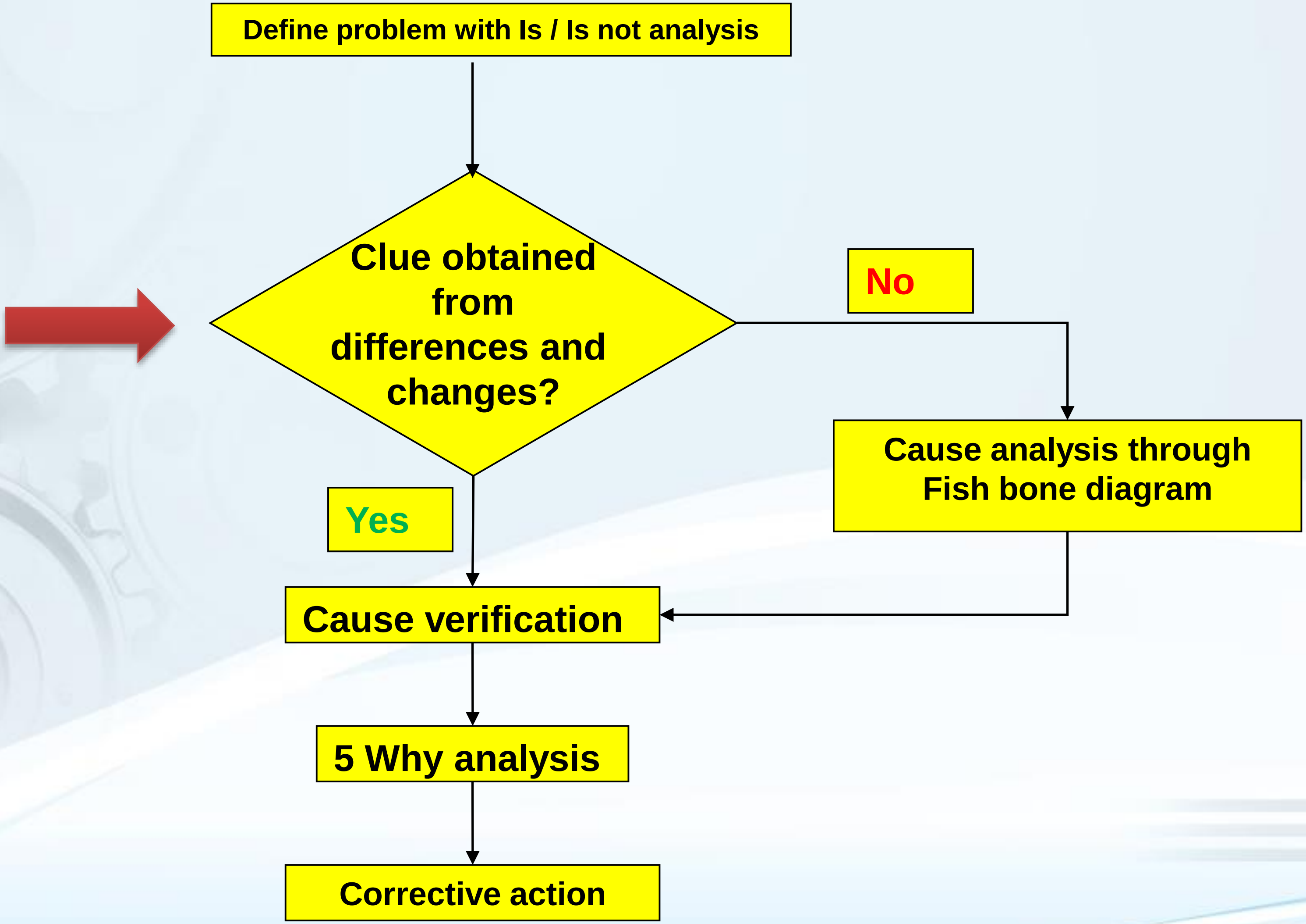
Brainstorming

- **What could cause the item to fail *in this* manner?**
- **What could cause the item to not deliver its intended function *in this* manner?**
- **What information can historic 8Ds and FMEAs provide for causes?**
- **What circumstances could cause the item to fail to perform its function?**

Brainstorming

- **Guidelines for Effective Brainstorming**
  - No evaluations, judgments or logical thinking required.
  - Relax your brain. Don’t worry about being right.
  - Quantity of ideas is most important.
  - Strive to maintain an uninterrupted stream of ideas.
  - Build on the ideas of others.
  - Reach for radical, impossible ideas.
  - Think in pictures. Use all five senses to make these pictures. Smell, feel, hear, taste, and see your ideas.
  - In each idea picture, pick “idea fragments” you like best and then add new fragments to form more ideas.

Root cause analysis flow



Identify Differences and Changes

Differences

- What is unique to, peculiar to, special to or true of the "*Is*" when compared to the "*Is Not*"?
- What new information is not already shown on the "*Is/Is Not*" list?
- Is there a "non-common denominator" between "*Is*" and "*Is Not*"?
- What is the function of comparing "*Is*" to its corresponding "*Is Not*"?

Changes

- Examine the differences
- What in, on, around, or about has changed?
- Record the date that changes took place
- Produce a Change Time Line

PROBLEM SOLVING WORKSHEET

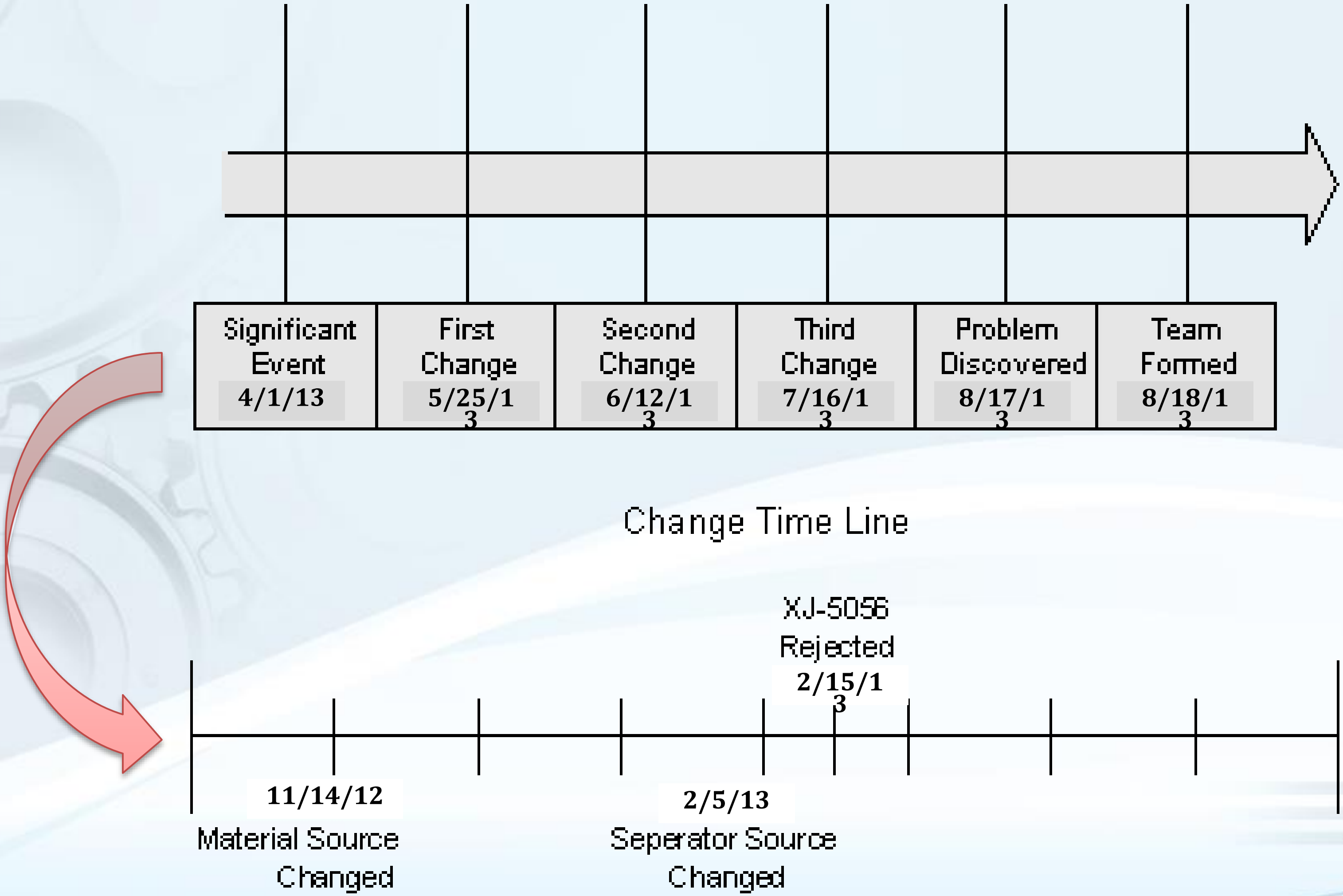
Operational Definition – What is wrong with what? Shipped Shaft XJ-5056 with rust

DESCRIPTION	IS	IS NOT	DIFFERENCES	CHANGES	POSSIBLE CAUSES
WHAT Object Deviation	**XJ-5056 shaft** **Lines of rust** **Surface rust**	**RJ-411 shaft** **Not all over part** **Not pitted**	**Material Source**	**Material Source changed on 14 Nov 92**	
WHERE On Object Geographically	**Random line on part** **In shipping** **Boxes**	**Not any particular area** **Before shipping** **In other containers**	**Heat Dispersion** **Separator**	**Packed hot due to rush on job** **Changed supplier source on 8 Feb 93**	
WHEN First Seen Subsequent Life Cycle	**15 Feb 13**	**Before and after**			
HOW MUCH Objects Problems Size	**17,290 rejected** **17/50 in sample (34%)** **One defect per object**	**Greater/less** **More than one**			

Create a Change Timeline

- Create a horizontal time line that starts before the first change and ends when the problem was discovered.
- Identify changes determined by the team on the change timeline.
- The interactions of changes become more obvious by examining the change timeline.

Example: Change Timeline



Change Analysis

Analyze what has changed

Manufacturing

- New suppliers?
- New tools?
- New operators?
- Process changes?
- Measurement system?
- Raw materials?
- Vendor supplied parts?
- Do other plants have a similar problem?

Analyze what has changed

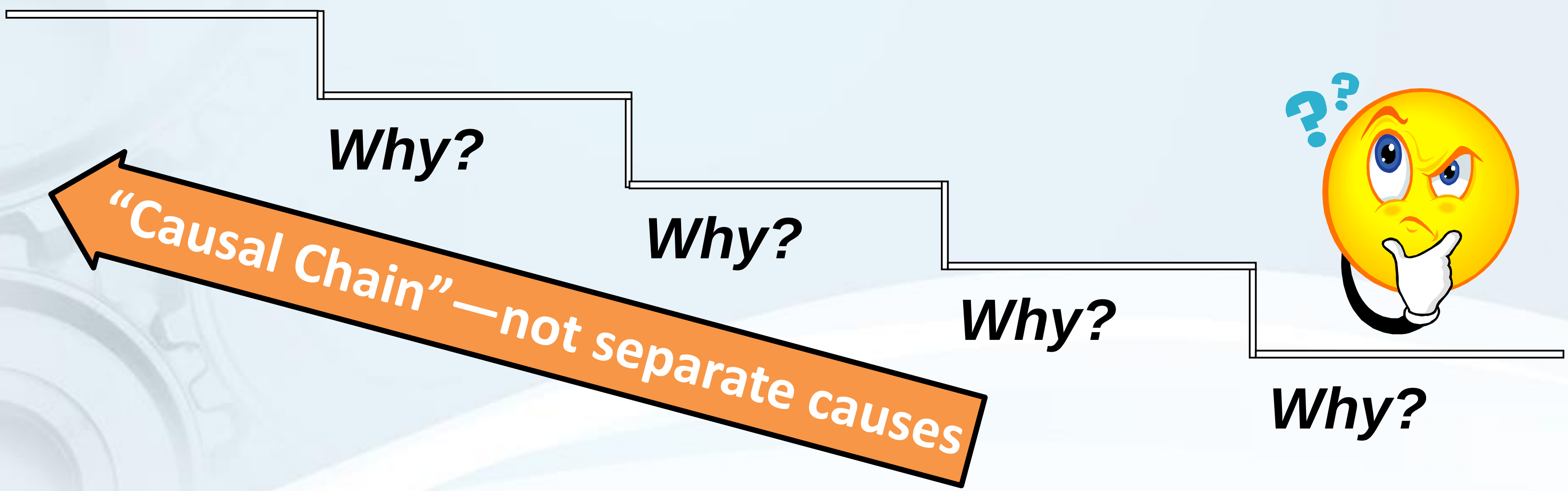
Engineering

- Any pattern to the problem?
- Geographically?
- Time of year?
- Build dates?
- Did the program exist at program sign-off?
- Was it conditionally signed off?
- Did the problem exist during pre-production prototypes, functionals?

PROBLEM SOLVING WORKSHEET					
Operational Definition – What is wrong with what?	Shipped Shaft XJ-5056 with rust				
DESCRIPTION	**IS**	**IS NOT**	**DIFFERENCES**	**CHANGES**	**POSSIBLE CAUSES**
WHAT Object Deviation	**XJ-5056 shaft** **Lines of rust** **Surface rust**	**RJ-411 shaft** **Not all over part** **Not pitted**	**Material Source**	**Material Source changed on 14 Nov 12**	**Material causes rust**
WHERE On Object Geographically	**Random line on part** **In shipping** **Boxes**	**Not any particular area** **Before shipping** **In other containers**	**Heat Dispersion** **Separator**	**Packed hot due to rush on job** **Changed supplier source on 8 Feb 13**	**Heat on part (i.e., condensation caused rust)** **Separator caused rust**
WHEN First Seen Subsequent Life Cycle	**15 Feb 13**	**Before and after**			
HOW MUCH Objects Problems Size	**17,290 rejected** **17/50 in sample (34%)** **One defect per object**	**Greater/less** **More than one**			

"5 Why" Problem Analysis

Ask "Why?" until there is
no verifiable answer



Example: 5 WHY

Problem:	**Robot stops operating suddenly**
1st Why:	Why did it stop?
	No power as the fuse melted…
2nd Why:	Why did the fuse melt?
	Current draw was too high for the fuse which overloaded…
3rd Why:	Why did it overload?
	Excessive friction through inadequate bearing lubrication…
4th Why:	Why was the lubrication inadequate?
	The oil pump was not drawing enough oil…
5th Why:	Why was the oil pump not drawing enough oil?
	The pump shaft was worn…
6th Why:	Why was the pump shaft worn?
	The oil was contaminated with abrasive particles…
7th Why:	Why was the oil contaminated?
	No oil filter on the intake pump…

HOW MANY TIMES DO YOU ASK WHY?

Until you establish the Root Cause of the problem

Getting to the Root

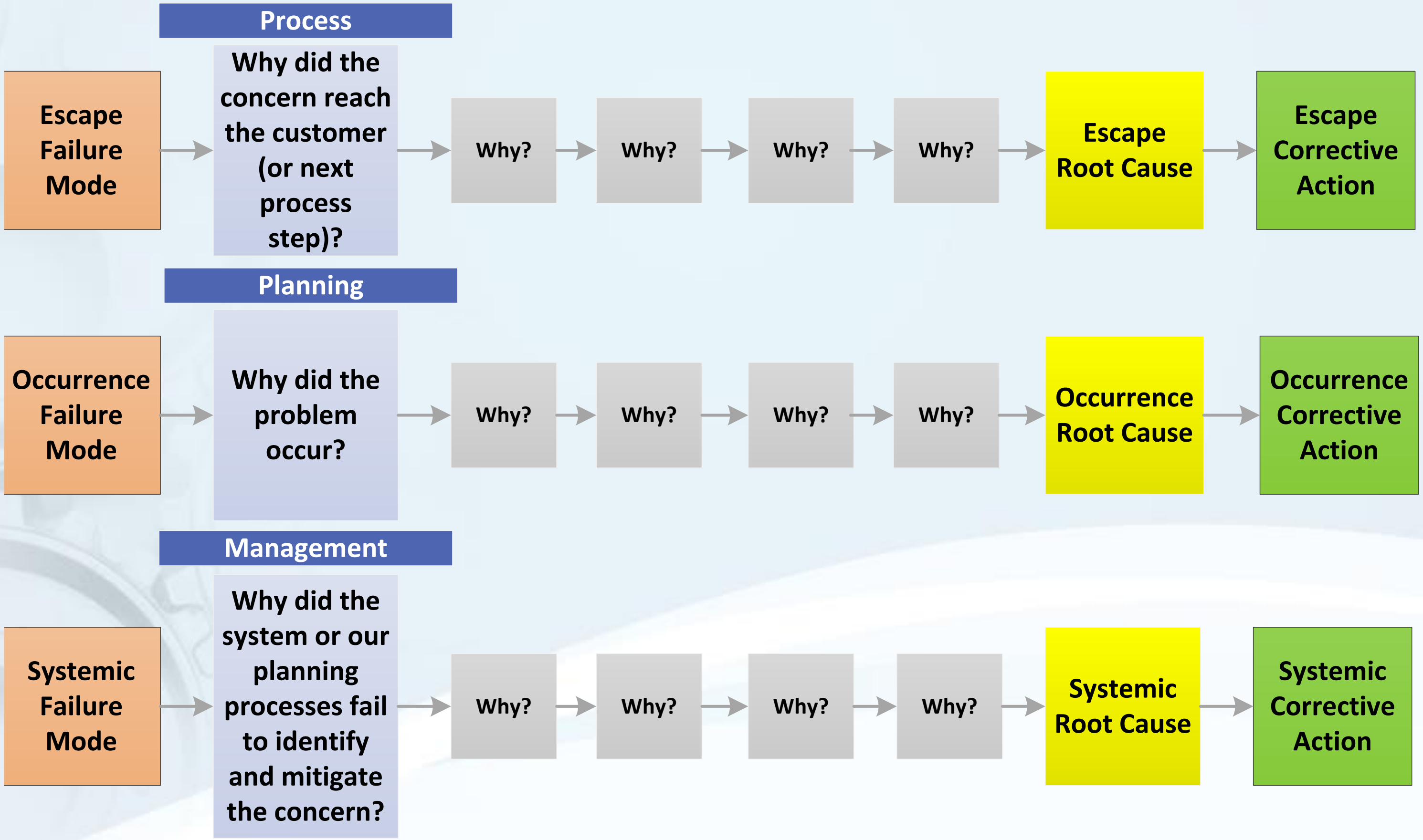
Types of Root Causes

- An *Occurrence* root cause "causes" the problem.
- A *Detection* root cause allows the problem to escape detection by the "Quality System."
- *Systemic* root causes cause both occurrence and detection root causes.

The Five Why Questions

- Classify potential root causes as *Occurrence* or *Detection*.
- For each root cause ask "Why?" repeated times and drive it down to the system root cause.

Determine Potential Root Causes



This diagram illustrates the use of "Five Why" analysis to determine potential root causes at the Escape, Occurrence and Systemic levels

Example: Rusty Shafts – 3x5 Why Analysis

Escape RC – Why did the Problem Reach the Customer (or Next Process)?

Why were parts shipped with rust? → Material in shipment rusted

Material in shipment rusted → Condition of material in shipment not checked → No procedure for assessing condition of material (E1)

Material in shipment rusted → Shipping did not notice / react to rust producing conditions → Rust producing conditions not called out on XJ5056 shipping checklist (E2)

Example: Rusty Shafts – 3x5 Why Analysis

Occurrence RC – Why Did the Problem Occur?

- **Why were parts in shipment rusted?**
  - **Moisture on parts?**
    - **Leaks in storage area? NO**
    - **Condensation?**
      - **Parts packed hot (O1)**
  - **Other contamination on parts?**
    - **Skin oil? NO**
    - **Acid residue?**
      - **Packaging? NO**
      - **Separators (new) leave acidic residue on parts (O2)**
      - **Washer pH low (O3)**

OMNEX

WWW.OMNEX.COM

Example: Rusty Shafts – 3x5 Why Analysis

Systemic RC – Why did we fail to ID the concern?

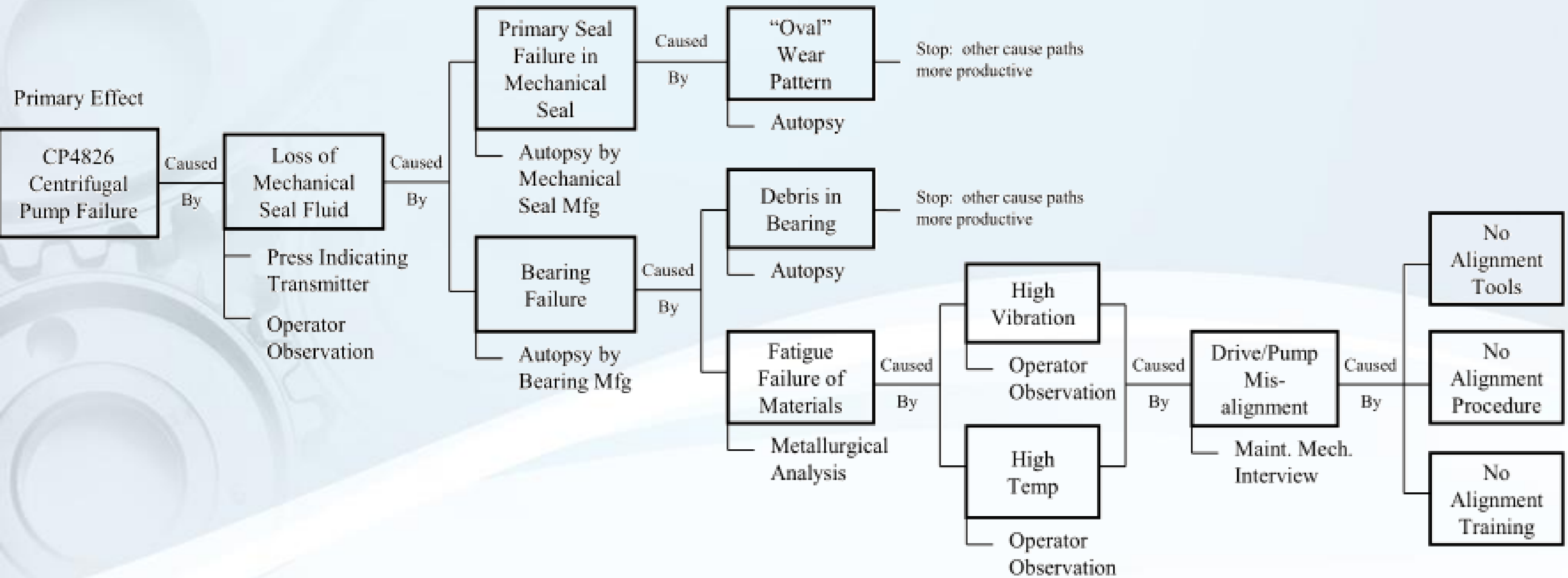
What in the planning process failed to detect this problem?

- **Different Separators** → **Source changed** → **Shipping Supv. found lower-cost source; did not evaluate effect on process** → **Packaging/ dunnage not under scope of supplier change process (S2)**
- **No instructions not to pack hot (O1)** → **Packing hot not known to cause rust** → **No evaluation of hot pack performed (S1)**
- **Washer pH low (O3)** → **No daily pH check** → **Maint. checks pH weekly per SOP** → **Manpower availability (S3)**

Another layout for Why-Why analysis – CAUSE MAP

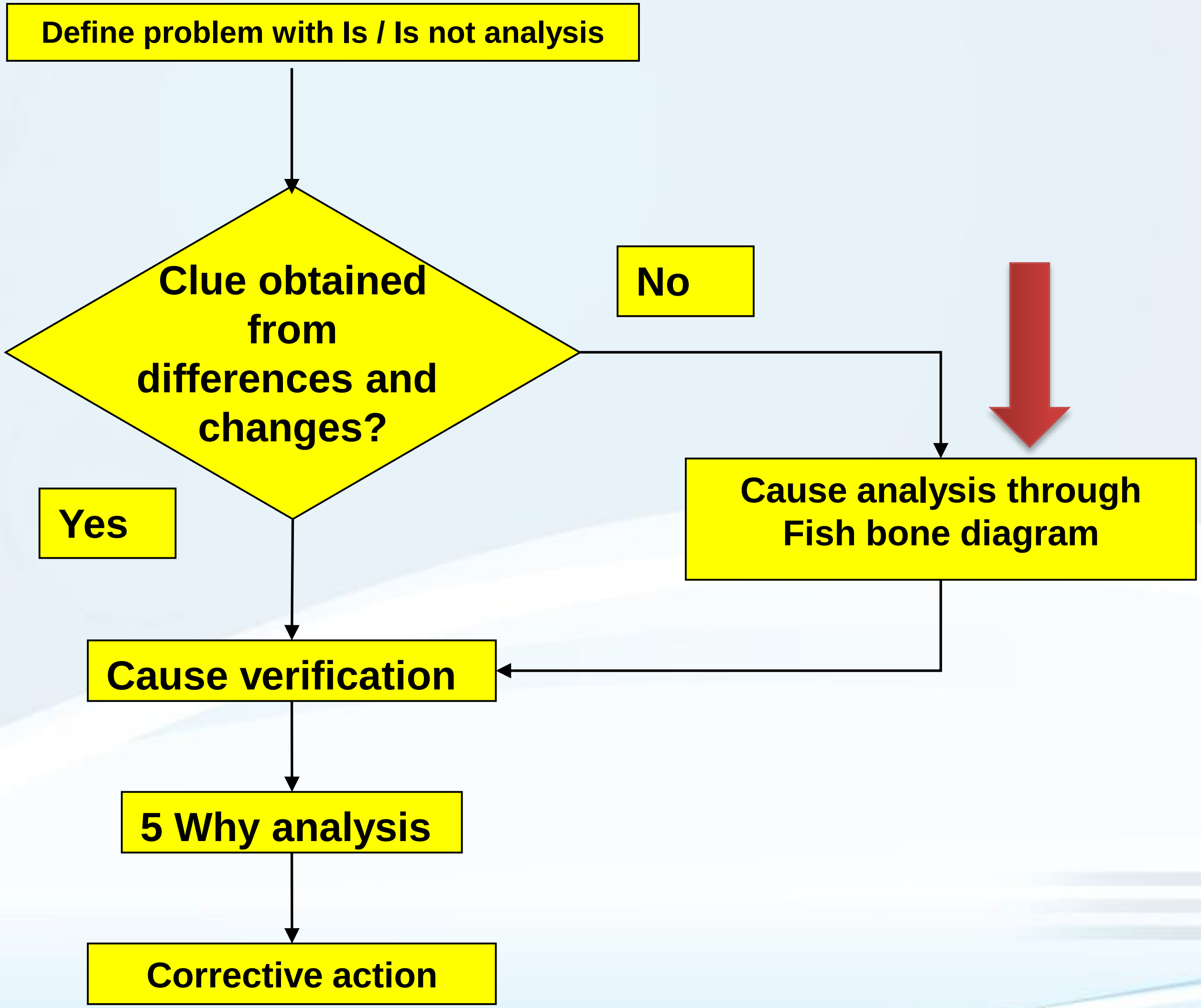
Problem Statement:

Centrifugal Pump CP4826 had to be shut down due to loss of seal fluid



Enables multiple Why-Why analysis in one layout

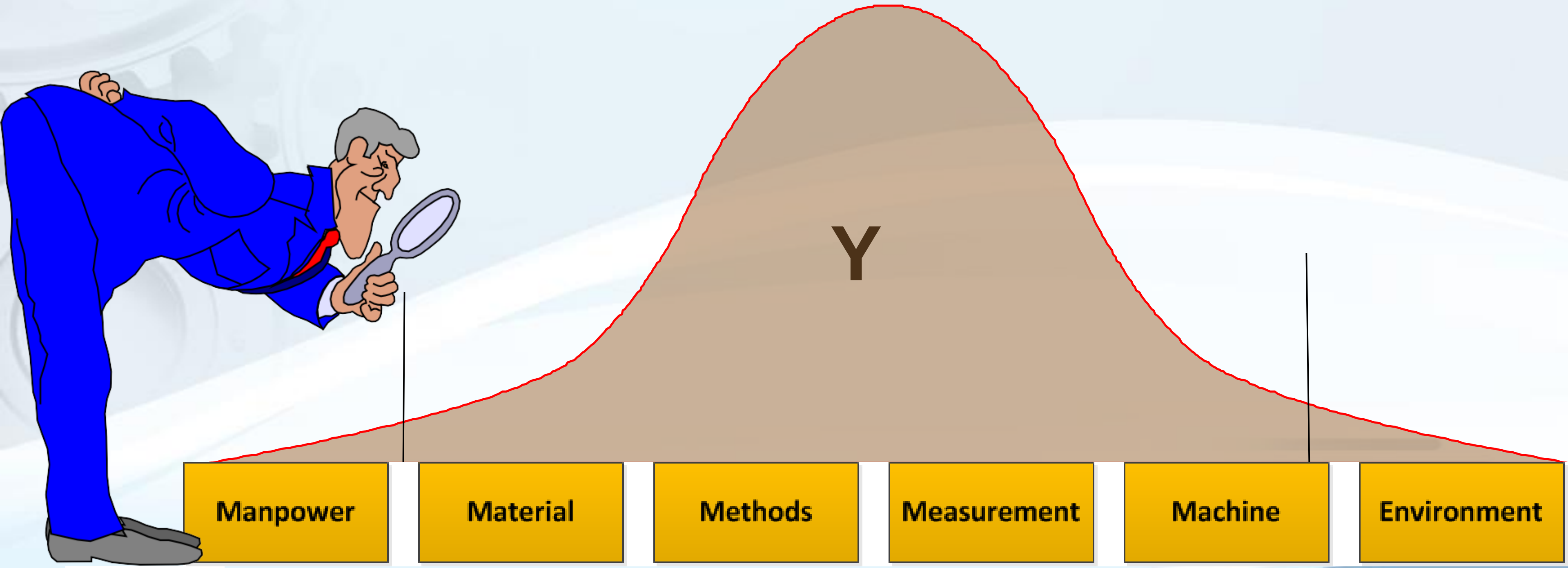
Root cause analysis flow



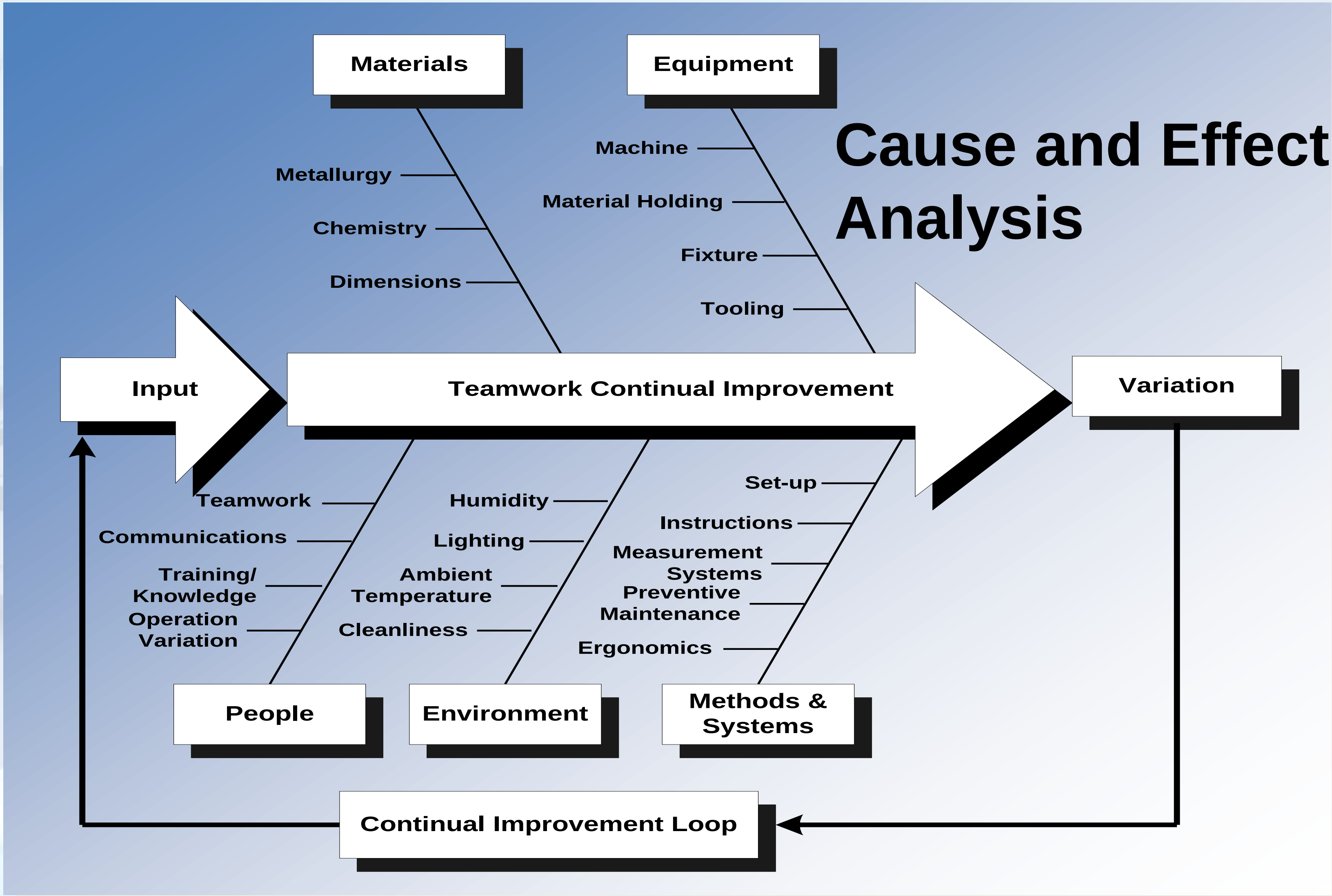
Brainstorming + C&E diagram

If the team is unable to determine the root cause by now, then they may want to brainstorm using Cause and Effect Diagrams.

Caution: this is not "open" brainstorming; test each potential cause against the problem description and test data before considering.



Cause & Effect Analysis



Cause and Effect Diagram

PURPOSE and USAGE

- To provide a pictorial display of a list in which you identify and organize *possible* causes of problems, or factors needed to ensure success of some effort.
- It is an effective tool that allows people to easily see the relationship between factors to study processes, situations, and for planning.

Cause and Effect Diagram

Historical Background

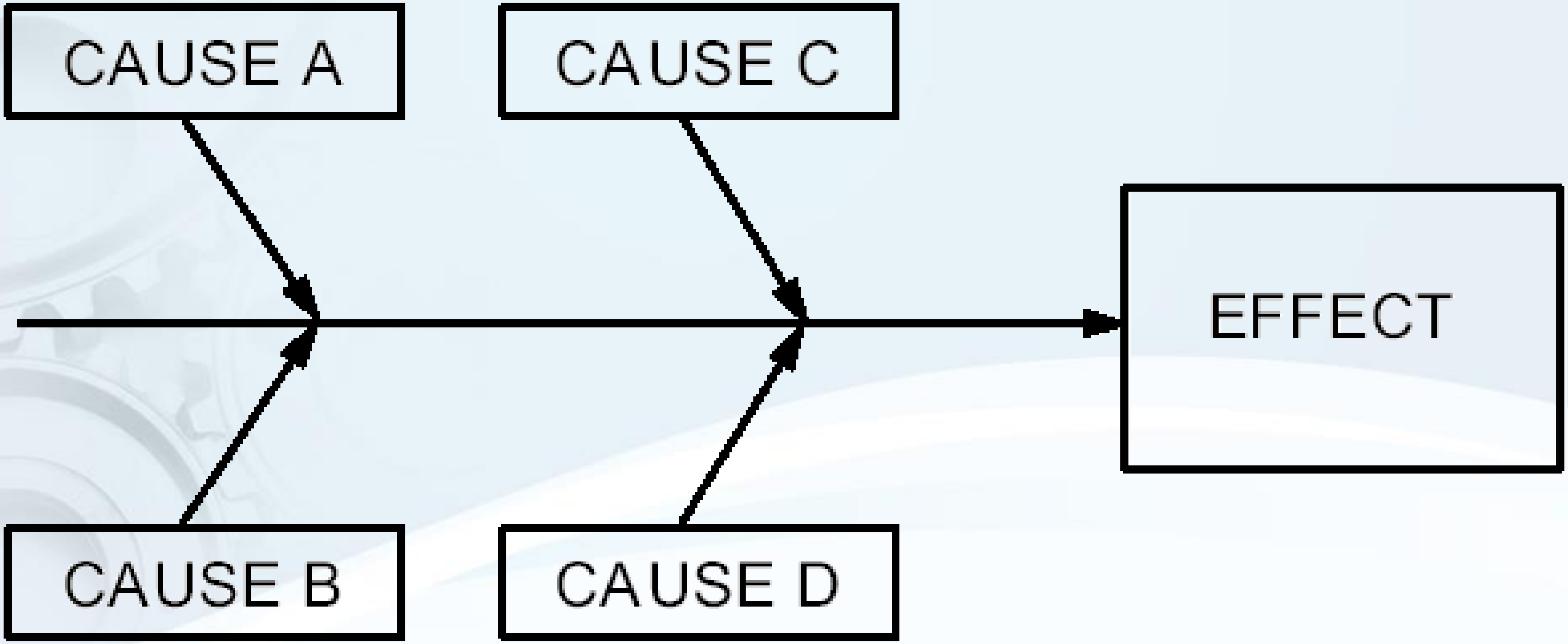
- The cause-and-effect diagram is also called the Ishikawa diagram (after its creator, Kaoru Ishikawa of Japan), or the fishbone diagram (due to its shape).
- It was created so that all possible causes of a result could be listed in such a way as to allow a user to graphically show these possible causes. From this diagram, the user can define the most likely causes of a result.
- This diagram was adopted by Dr. W. Edwards Deming as a helpful tool in improving quality. Dr. Deming helped develop statistical tools to be used for the census and taught the Industry and the military his methods of quality management. He also introduced Total Quality Management in Japan in the 1950's and revitalize TQM in the Western industries in the 1980's.

Benefits of Using a Cause-and-Effect Diagram

- Helps determine root causes
- Encourages group participation
- Uses an orderly, easy-to-read format
- Indicates possible causes of variation
- Increases process knowledge
- Identifies areas for collecting data

Cause and Effect Diagram

Basic Layout of Cause-and-Effect Diagrams



Step 1 - Identify and Define the Effect

- Decide on the effect to examine
- Use Operational Definitions of y
- Phrase effect as

>positive (an objective) or

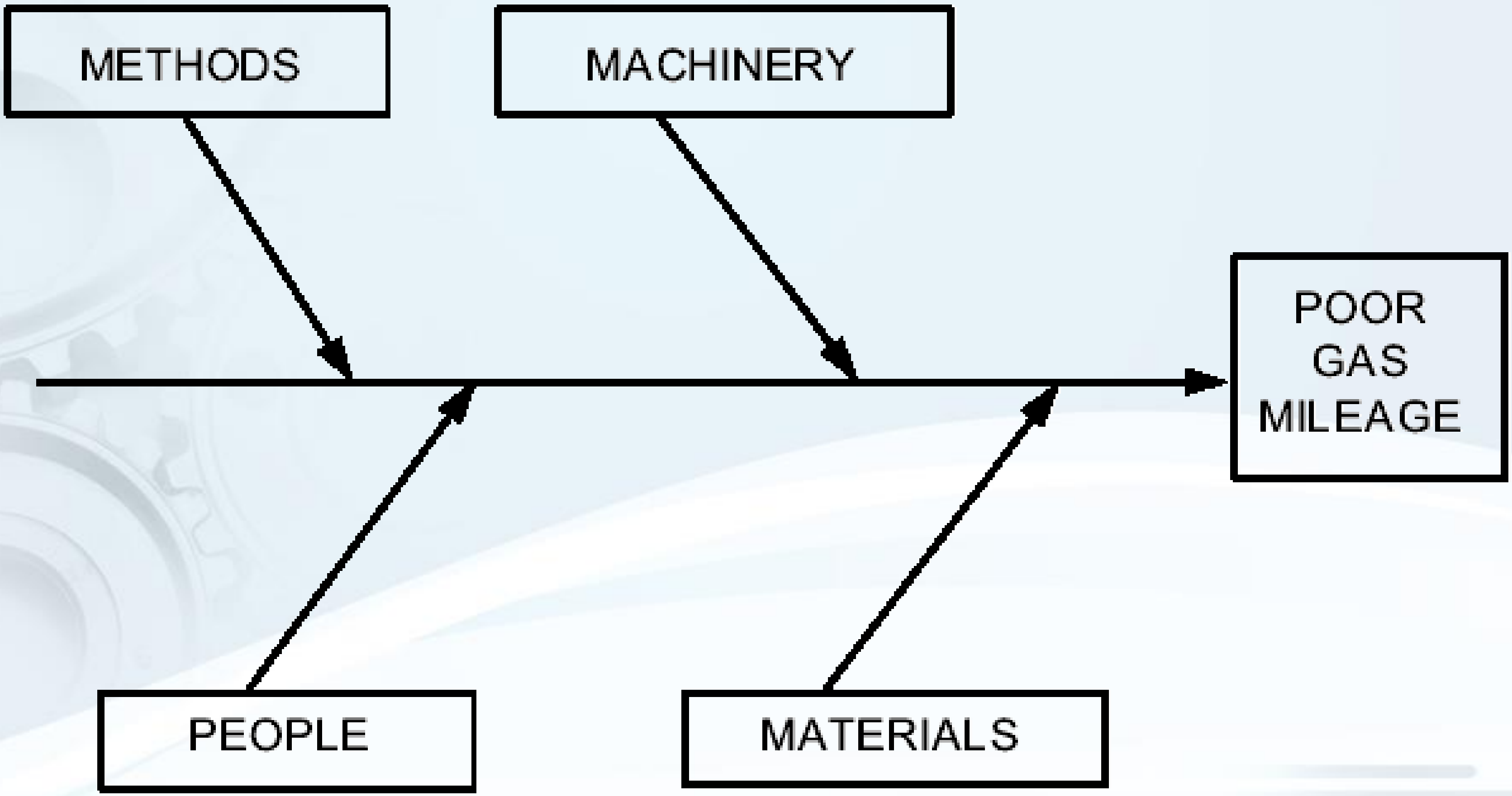
>negative (a problem)

Cause and Effect Diagram

Step 2 - Fill in the Effect Box and Draw the Spine

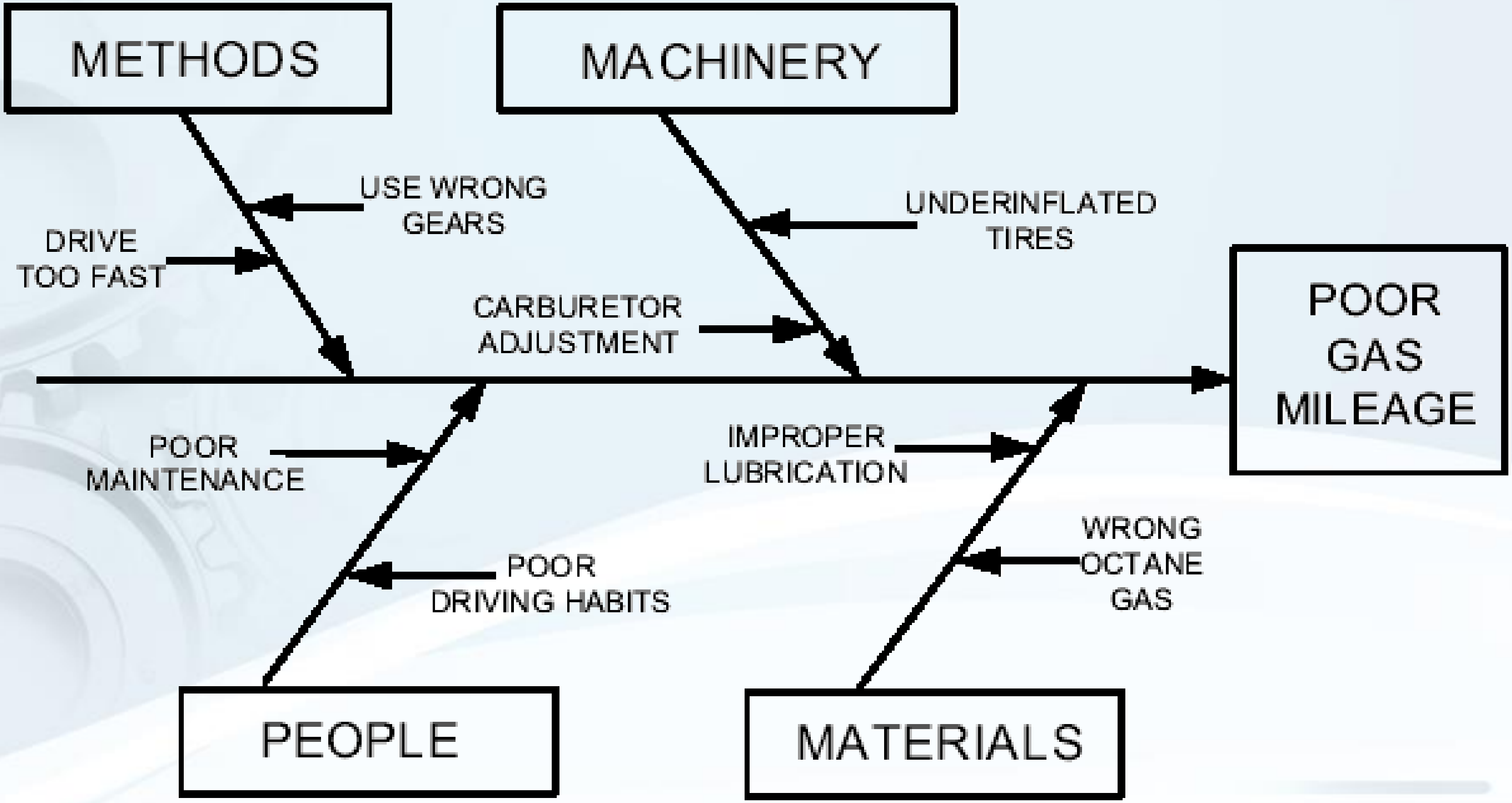
Cause and Effect Diagram

Step 3 - Identify Main Categories



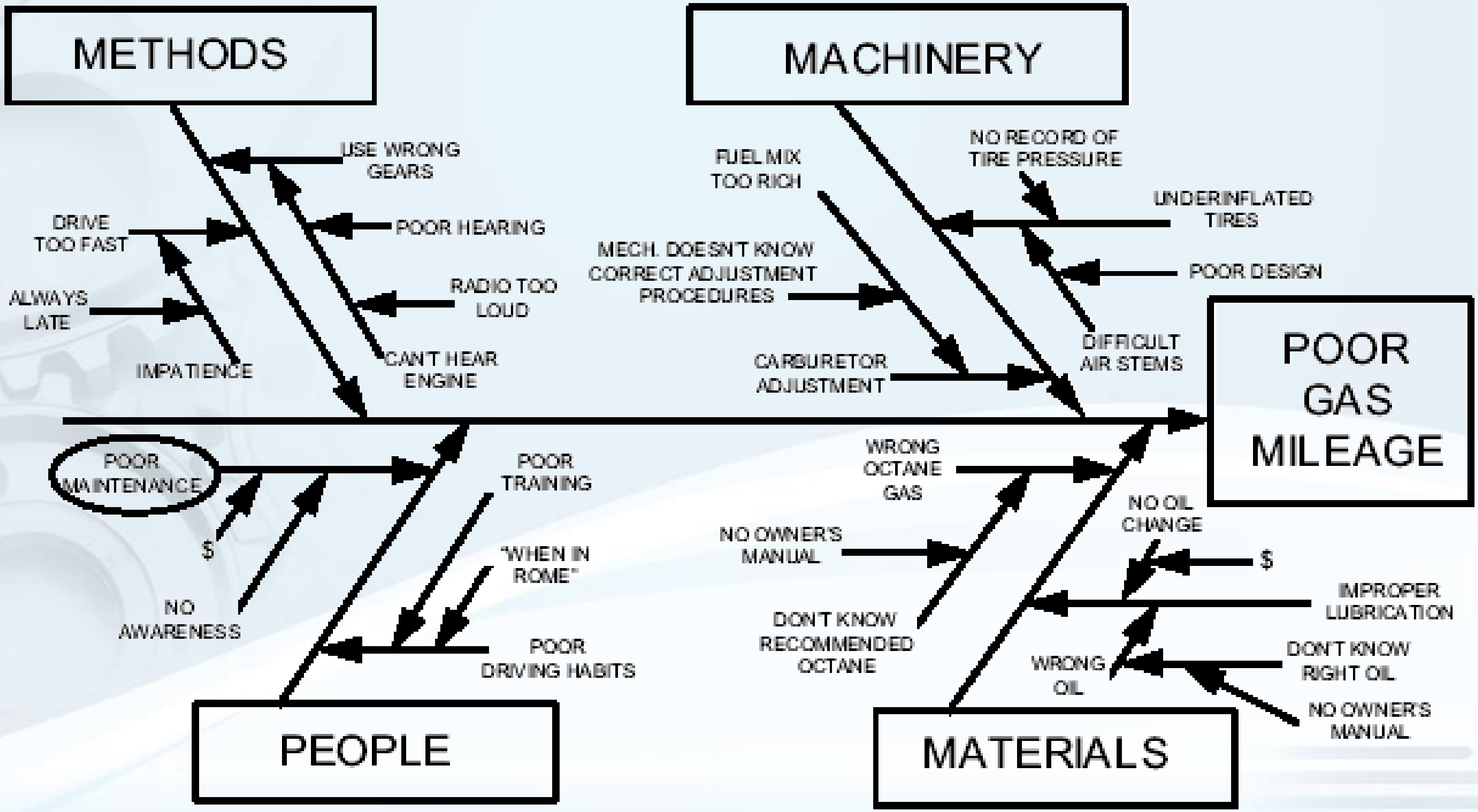
Cause and Effect Diagram

Step 4 - Identify Causes Influencing the Effect



Cause and Effect Diagram

Step 5 - Add Detailed Levels



OMNEX

WWW.OMNEX.COM

Cause and Effect Diagram

Step 6 - Analyze the Diagram

Analysis helps you identify causes that warrant further investigation. Since Cause-and-Effect Diagrams identify only possible causes, you may want to use a Pareto Chart to help your team determine the cause to focus on first.

Look at the "balance" of your diagram, checking for comparable levels of detail for most of the categories.

- *A thick cluster of items in one area may indicate a need for further study.*
- *A main category having only a few specific causes may indicate a need for further identification of causes.*
- *If several major branches have only a few sub branches, you may need to combine them under a single category.*

Look for causes that appear repeatedly. These *may* represent root causes.

Look for what you can measure in each cause so you can quantify the effects of any changes you make.

Most importantly, identify and circle the causes that *you can take action on.*

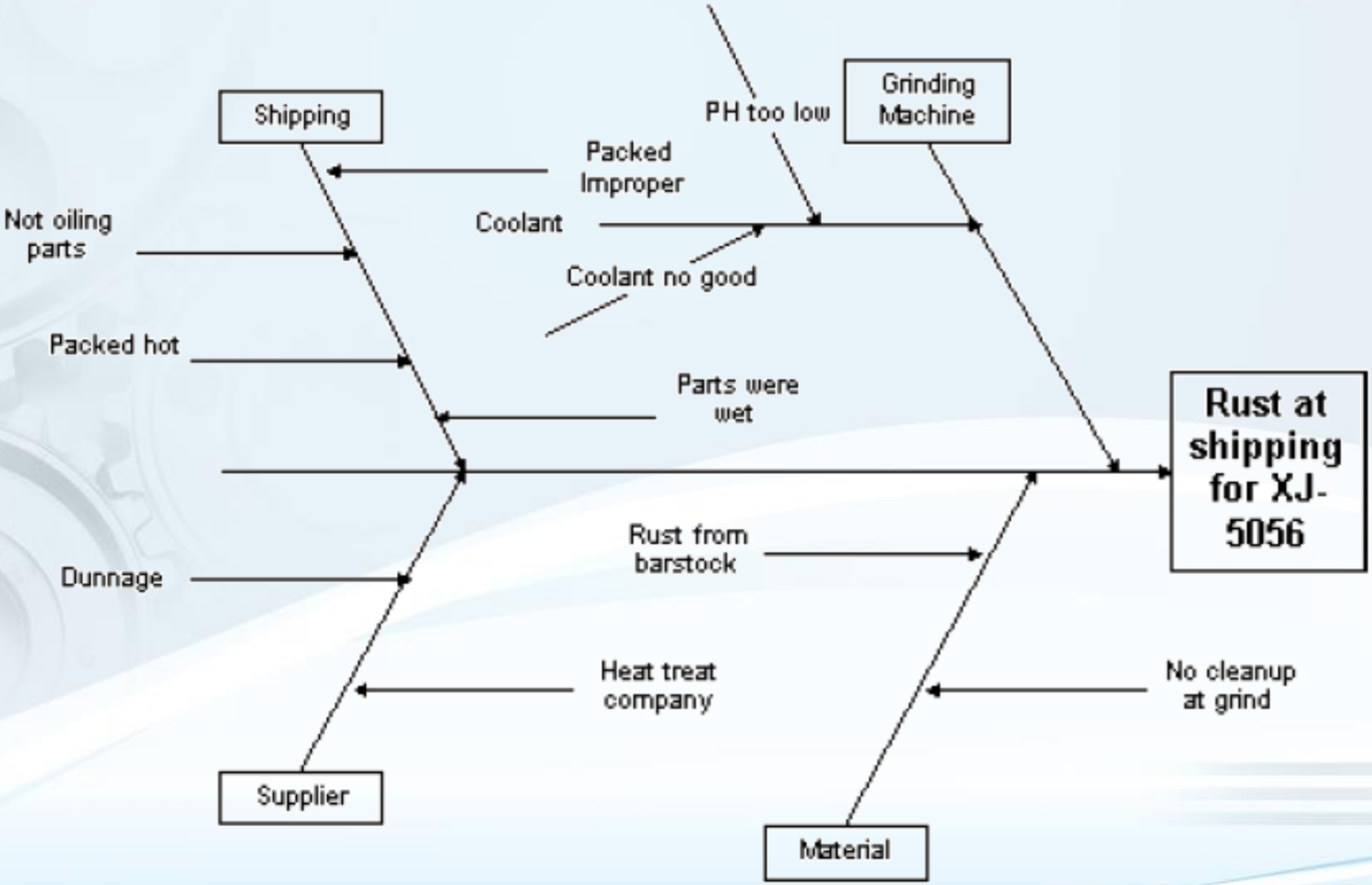
Cause and Effect Diagram

Step 6 - Analyze the Diagram

From this list pick out the causes you want to investigate further
(Use the funneling of Xs as discussed further)

E.g. *Poor Maintenance* appears to be a cause for which you could develop measurements. Moreover, *Poor Maintenance* appears to be a cause that you can take action on. It is circled in the <u>Diagram</u> earmark it for further investigation.

Example: Cause & Effect Diagram



Applicability of RCA Tools

- **5 WHY Analysis**
  - **When looking at one major cause and needs drill down to arrive at one root cause**
- **Fishbone Diagram**
  - **When looking at numerous major causes and needs drill down probing to arrive at numerous cause(s) based on their cause & effect relationships**

Generate multiple Potential Root Causes

Repeat 5 WHY until you can not find any more causes!

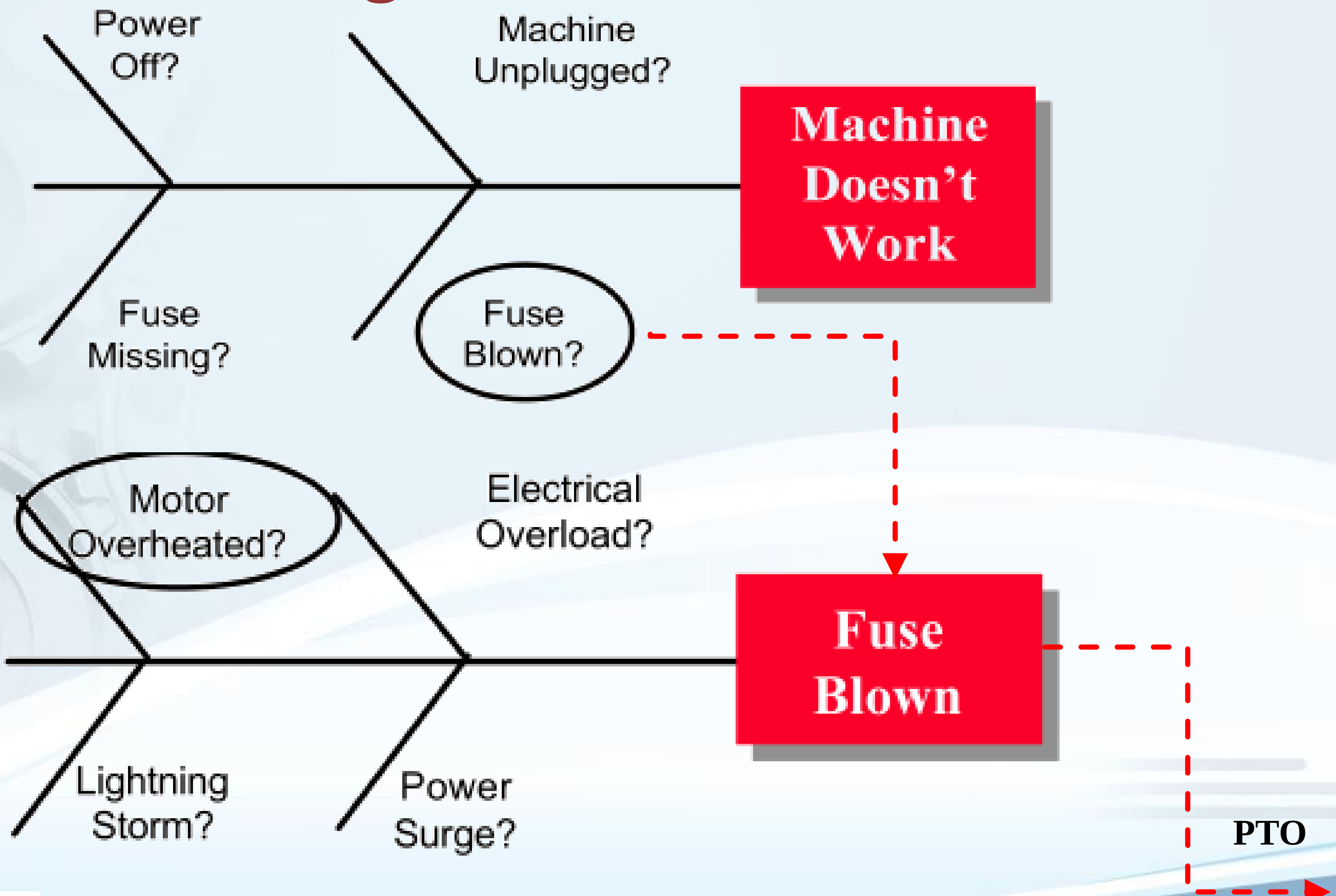
Examine Changes

- How could this change possibly cause the problem?
- Be creative, yet realistic.
- Could a change have multiple effects?

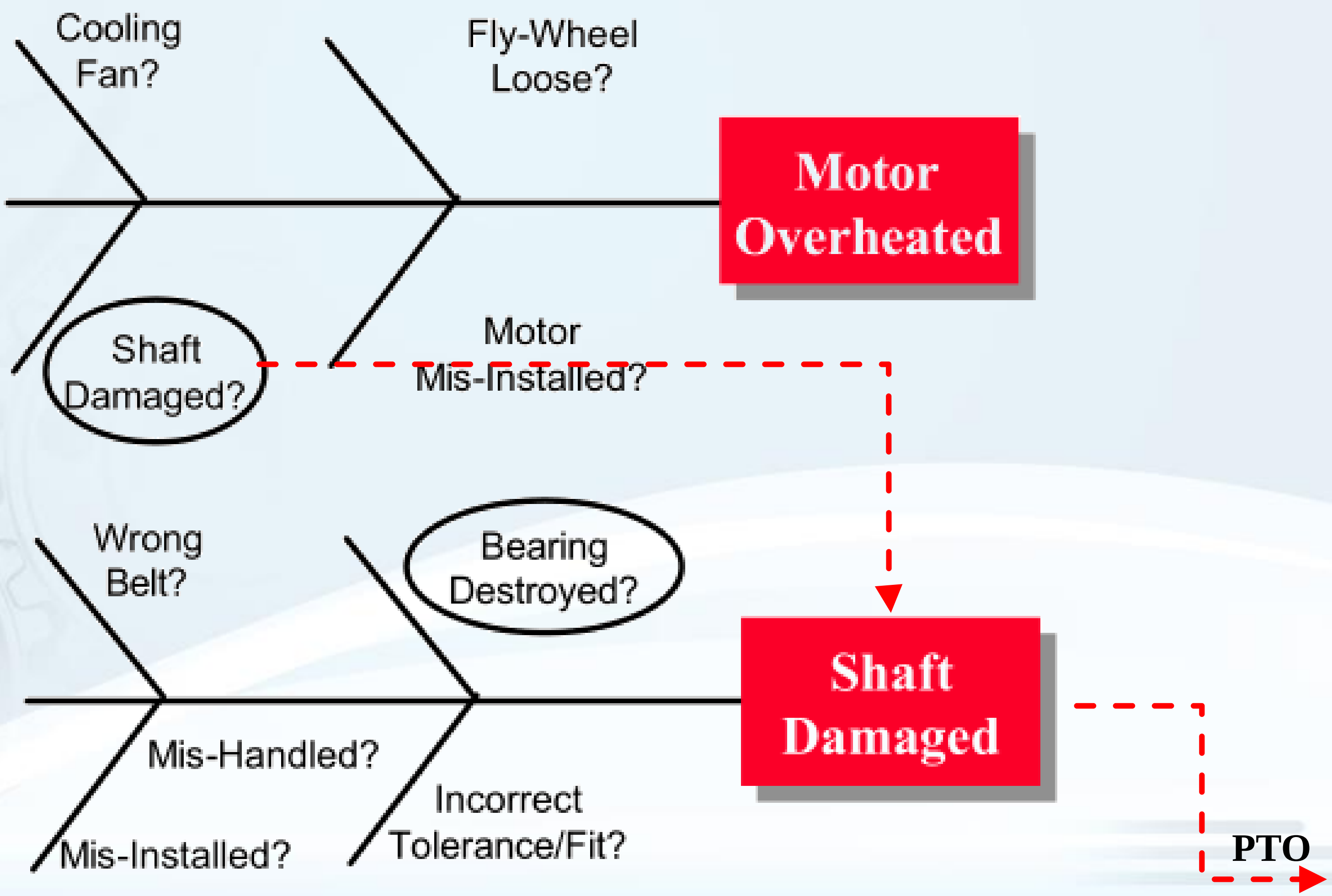
Brainstorm Using Cause and Effect Diagrams

- Revisit the 5 Why and investigate linkages to cause and effect diagram.

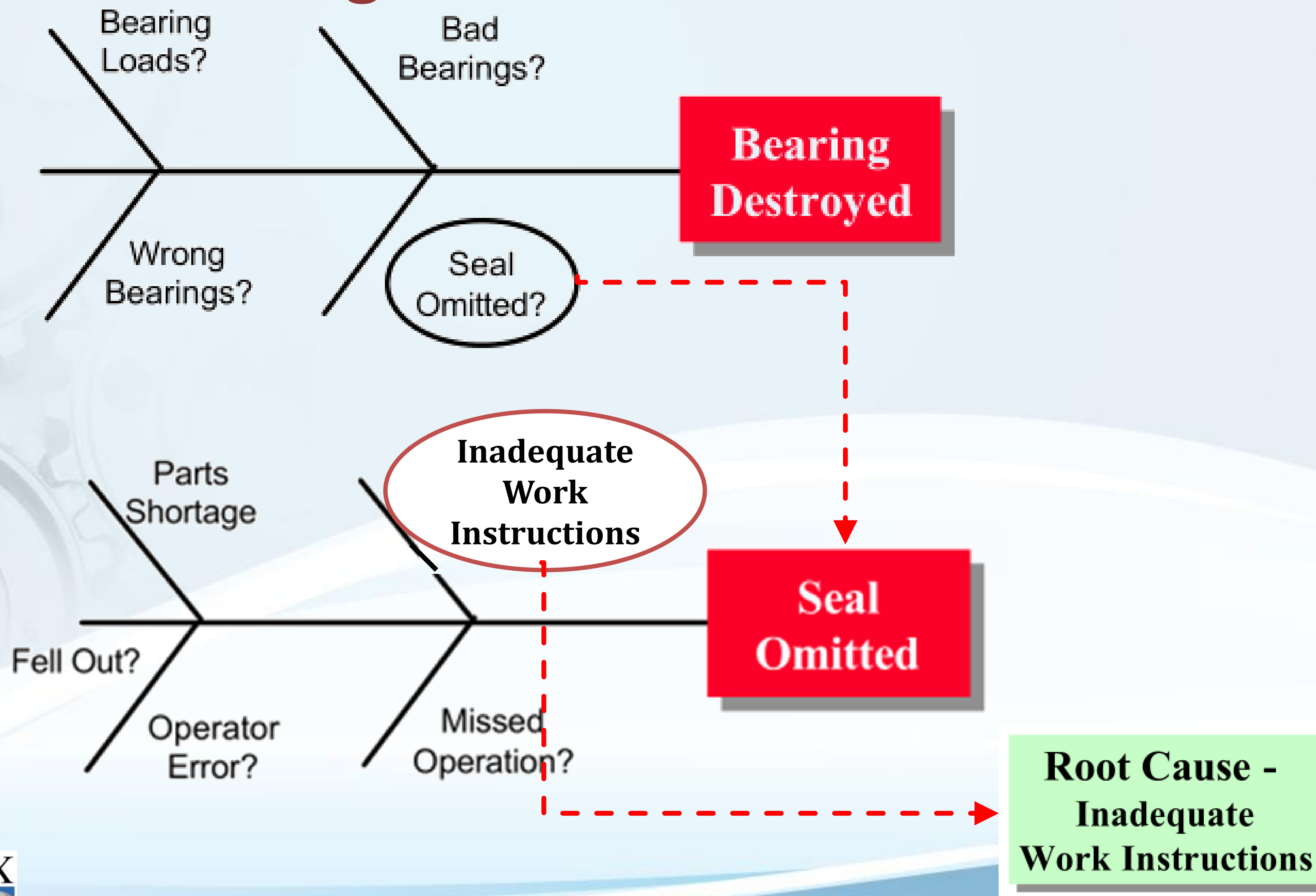
Example: Cause & Effect diagrams using 5 WHY thinking



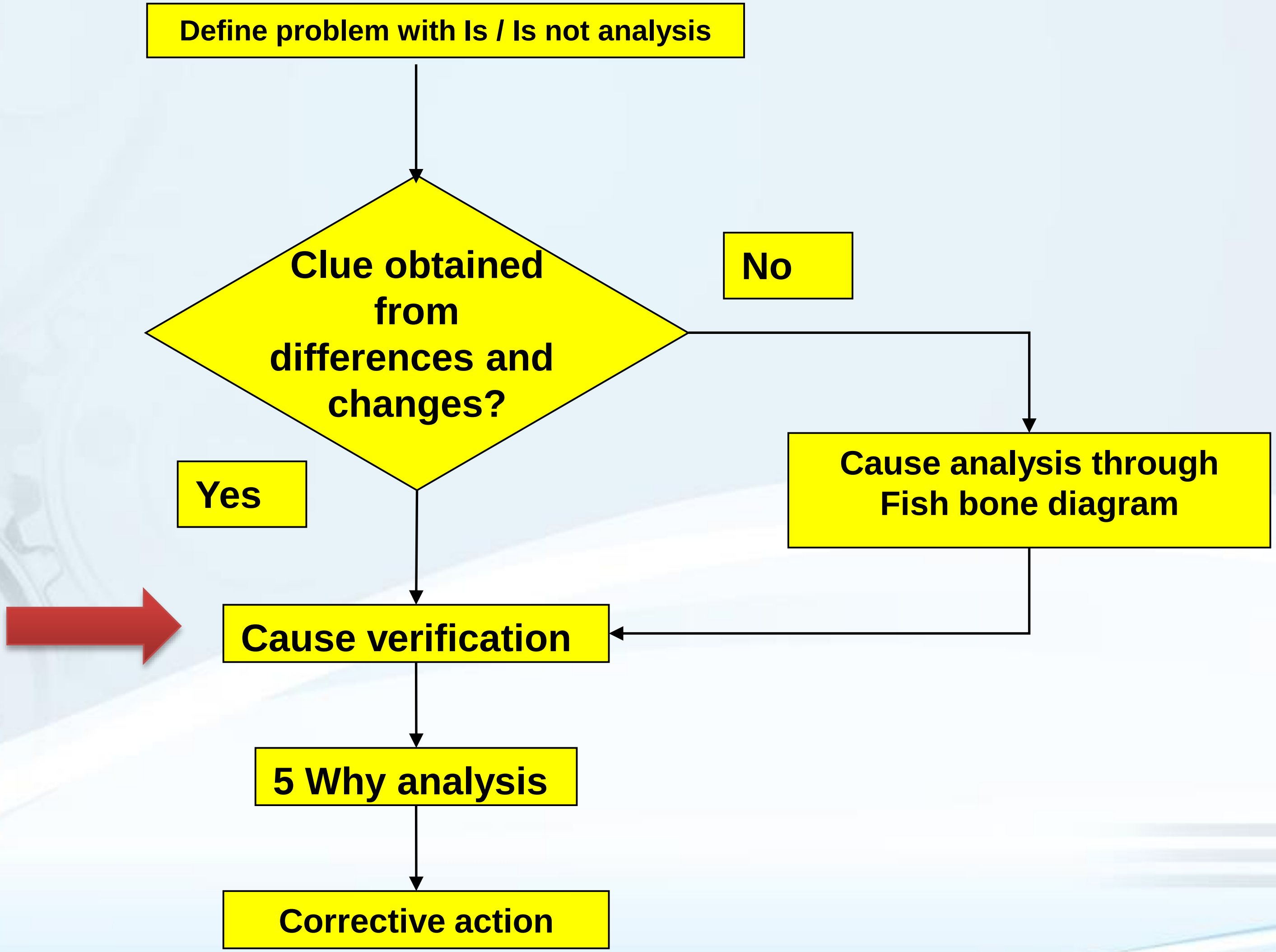
Example: Cause & Effect diagrams using 5 WHY thinking



Example: Cause & Effect diagrams using 5 WHY thinking



Root cause analysis flow



WWW.OMNEX.COM

Verifying Root Causes – Test cause analysis

- **Ask the Key Question**
  - A root cause must produce an affirmative answer to the Key Question:
  - Does this cause explain all that is known about what the problem is and all that is known about what the problem is not?
  - The Test Cause Worksheet can be used
  - If no cause passes the Key Question test, additional potential causes may have to be generated by combining causes.

Confirm Root Causes

- **Does this cause explain all that is known about what:**
  - The problem is?
  - What the problem is not?

Test Cause Worksheet

Concern Number: 2012-008
Concern Title: **Rusty Shafts**

IS/IS NOT CRITERIA	Coolant No Good	pH Too Low in Washer	Rust From Bar Stock	Packed Hot	Heat Treat	Separator
	POSSIBLE CAUSES					
XJ5056 Shaft	-	+	+	+	+	+
Line of Rust	-	-	-	-	-	+
Surface Rust	+	+	-	+	+	+
Random	-	-	-	+	-	+
In Shipping	-	+	-	+	-	+
Boxes	-	+	-	+	-	+
7/28/2012	-	+	-	+	-	-
#=17290	+	+	+	+	+	+
One Defect	+	+	+	+	+	+

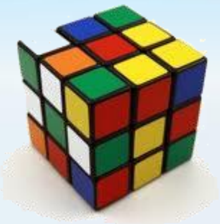
A + indicates that a Is/Is Not criterion produces an affirmative answer to the Key Question.
A - indicates that a Is/Is Not criterion produces a negative answer to the Key Question.
A ? Indicates that a Is/Is Not criterion requires investigation.

Key Question: Does this cause explain all that is known about what the problem is and all that is known about what the problem is not?

RCA Tool Selection Matrix

RCA Tools	1. Define the Problem *(Identify Improvement Area)*	2. Understand the Problem *(Evaluate Improvement Area)*	2. Understand the Problem *(Collect Data)*	2. Understand the Problem *(Data Analysis)*	3. Immediate Action *(Develop Action Plan)*	4. Corrective Action *(Implement Action Plan)*	5. Confirm the Solution *(Monitor Action Plan)*
Activity Sampling		•	•	•			
Brain Storming (NGT)	•	•			•		
Cause and Effect Dgrms		•			•	•	
Check Sheets			•			•	
Gemba Gembutsu - 5whys		•	•				
Histograms				•			
Pareto Analysis	•			•			•
Performance Measurem't	•	•				•	•
Process Mapping	•	•	•				
Quality Planning					•		•
Risk Assessment (FMEA)	•	•			•		
Root Cause Analysis	•	•	•	•	•	•	•
Sampling			•				
Scatter Diagrams				•			
Six Sigma	•	•	•	•	•	•	•
SMART	•						
Statistical Quality Control	•	•	•	•			•

Team Breakout 3



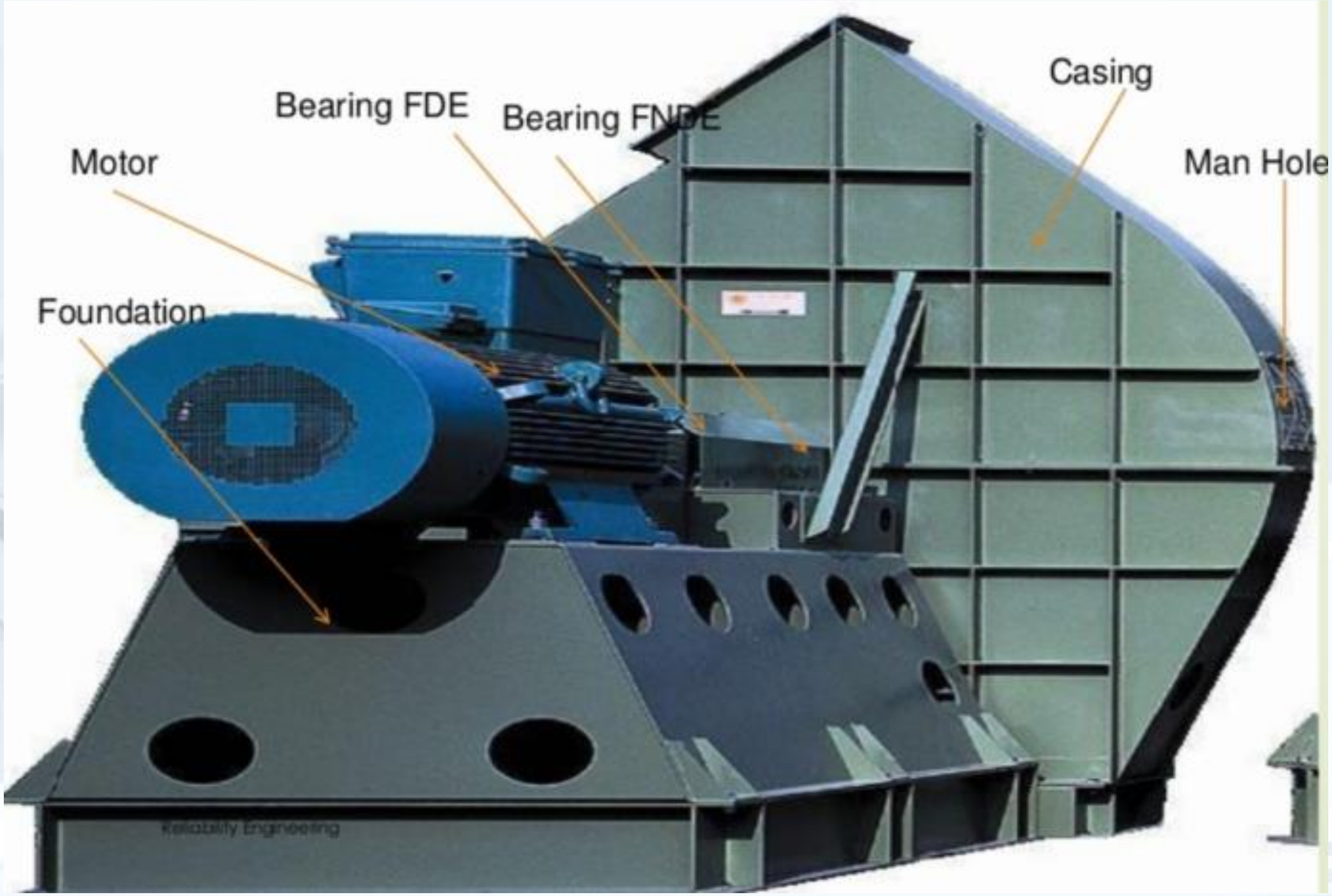
- From your findings from Breakout exercise 2, drill down further to identify the potential root causes. More information given below:
- Draw a fishbone diagram for Machine breakdown and identify which machines are the top contributors.
- Downtime data for 10 machines in the line are listed in below table.

Team Breakout 3

Equip Code	Critical equipment	MTTR (hours)	Downtime Frequency
1	Centrifugal Fan	3.2	5
2	Pump station 2 Motor	3	2
3	Granulator Drum	2	2
4	Feed Belt Conveyor	1.5	2
5	Recycle Belt Conveyor	2.5	1
6	Bag Filter	2.5	1
7	Burner	1	1
8	Belt Conveyor	0.5	1
9	Belt Conveyor	0.2	1
10	Bucket Elevator	0	0

MTTR :-
Mean Time to Repair
It represents the average time required to repair a failed component or device.
Formula:-
MTTR = Total downtime / number of stops

Team Breakout 4



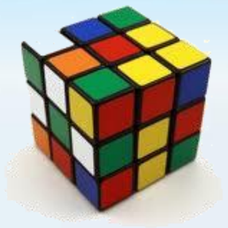
MACHINE 1: Centrifugal Fan

OMNEX
WWW.OMNEX.COM

Team Breakout 4

The CFT team discussed in a brainstorming session about why Machine 1 failed. Machine getting unplugged, Electric failure of motor, Power off and machine overload were some of the possible causes identified. After cause verification, it was found out that Machine Overload was the major cause. But why did this happen?

Was it due to process problem? Other causes identified were mechanical vibration problem in machine, cleaning problem and electrical problem. One of the production engineers mentioned that mechanical vibration issues happened recently on Machine 1 and needs to be checked on priority. Upon, validation and ruling out other causes, the team proceeded to find the root cause for Vibration Problem using Cause & Effect clubbed with 5 WHY thinking.

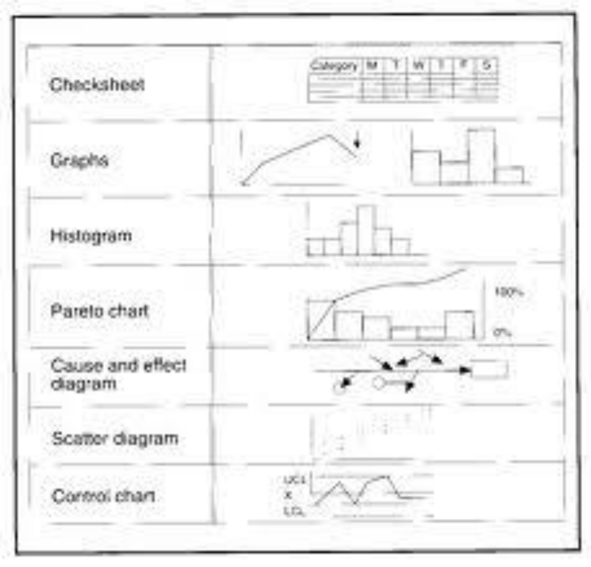


Team Breakout 4

While brainstorming for vibration problem, numerous causes came to picture such as Bad maintenance, Bent shaft, Misalignment, Bearing failure, Bad fixation with base and Unbalance. On further validation, it was found that Unbalance was the root cause. But the team felt this could be further drilled down. So they did another 5 Why analysis on the Unbalance issue. Three causes identified were Rotor problem, Bad Balancing and Scale/Dust accumulated. On drilling down finally on Dust accumulation problem, it was found that Sandblasting efficiency was poor, incorrect balancing, design on hopper was poor and cleaning issues. Out of the four causes, only the first mentioned cause was prevalent.

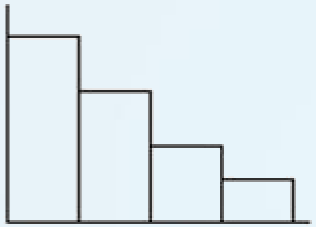
1) **Which RCA tools would you use to visualize the brainstorming outcomes mentioned above?**
2) **Please draw the tools and identify the Final Root Cause**

Simple RCA tools - Data Handling



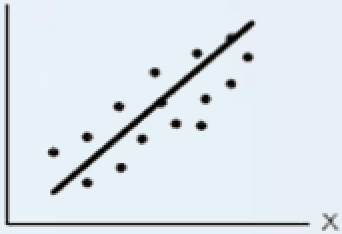
FOREMOST RCA TOOLS & TECHNIQUES

Brainstorming

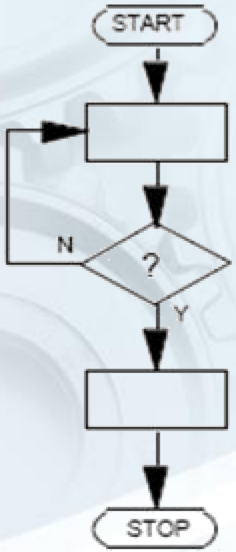


Pareto Chart

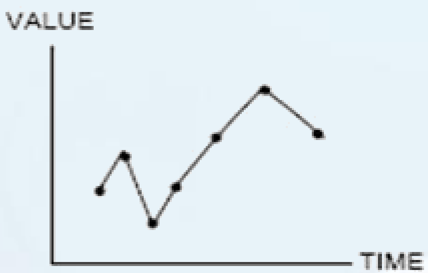
Fishbone Diagram



Scatter Diagram

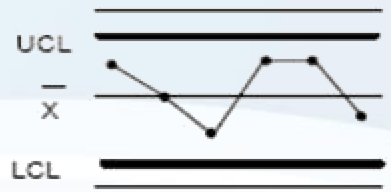


Flowchart

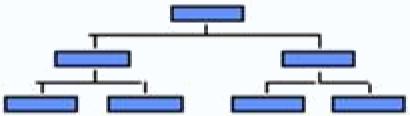


Run Chart

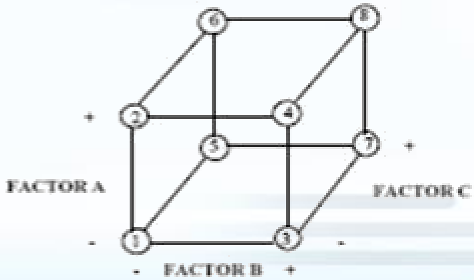
Histogram



Control Charts



Tree Diagram

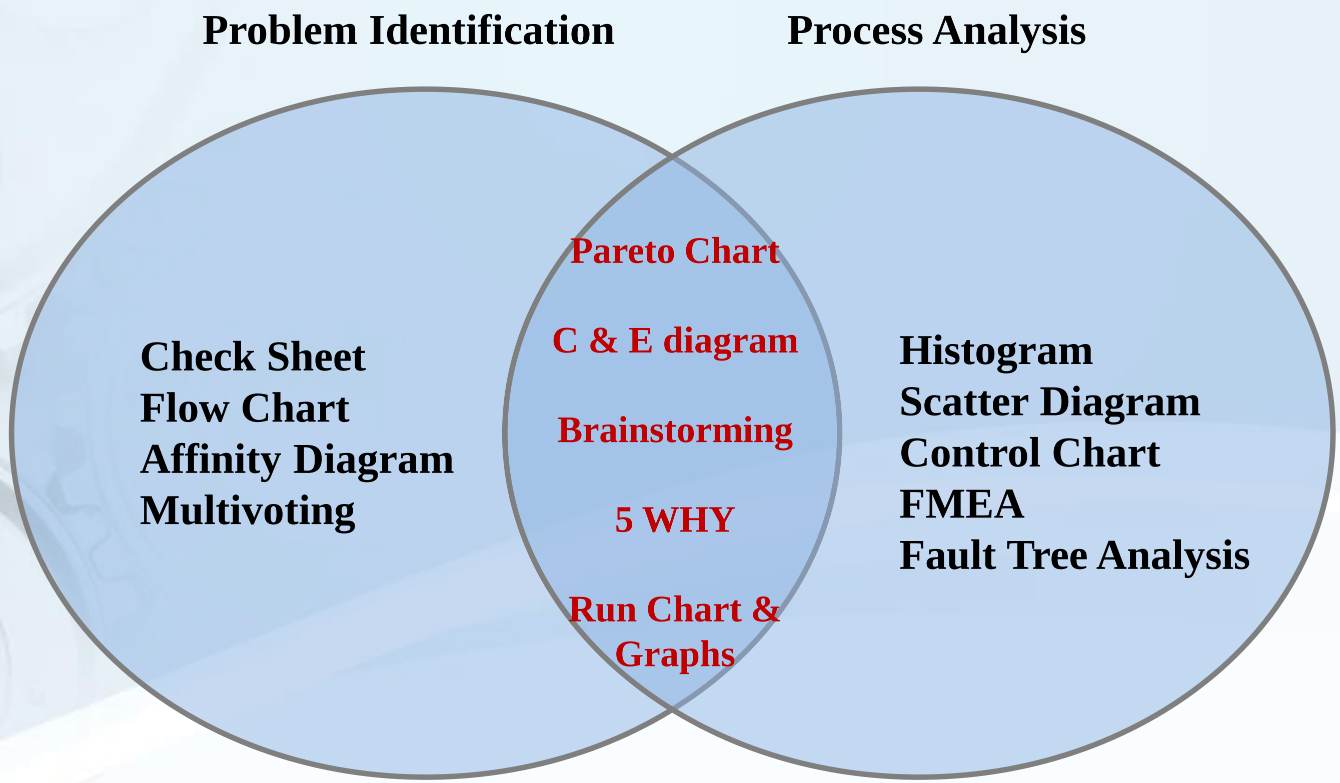


Design of Experiments

WWW.OMNEX.COM

Purpose of RCA Tools

CONTINUOUS IMPROVEMENT



INTRODUCTION

The Guide to Quality Control and The Statistical Quality Control Handbook, written by a Japanese quality consultant named Kaoru Ishikawa are useful in providing an understanding on how to use and interpret the 7 basic QC tools. Ishikawa believed that there was no end to quality improvement and in 1985 suggested that seven base tools be used for collection and analysis of quality data.

CHECK SHEET

CHECKSHEET

- Check Sheet and Pareto
  - Used for Collecting data and prioritizing the area that needs to be improved or corrected
  - Check sheet is a must before we do Pareto
- Making Check sheet
  - Identify the Data that needs to be collected (Rejection, Machine downtime, Delivery compliance etc..)
  - Identify the Problem codes that needs to be assigned whenever a problem is encountered
  - Identify the Cause Code that needs to be assigned, to assign a cause associated with the problem. When the Cause is not known, should be coded as unknown
  - Start Collecting Data for doing Pareto

CHECK SHEET

COMPONENTS REPLACED BY LAB
TIME PERIOD: 22 Feb to 27 Feb 1998
REPAIR TECHNICIAN: Bob

TV SET MODEL 1013

Integrated Circuits ||||
Capacitors |||| |||| |||| |||| |||| ||
Resistors ||
Transformers ||||
Commands
CRT |

FLOW CHART

FLOW CHART

HISTORY AND BACKGROUND

As a whole, flow charting has been around for a very long time. In fact, flow charts have been used for so long that no one individual is specified as the "father of the flow chart". The reason for this is obvious. A flow chart can be customized to fit any need or purpose. For this reason, flow charts can be recognized as a very unique Quality improvement method.

FLOW CHART

Step-by-Step Instruction of how to develop a flow chart.

- **Gather information of how the process flows: use**
  - **a) conservation,**
  - **b) experience, or**
  - **c) product development codes.**
- **Trial process flow.**
- **Allow other more familiar personnel to check for accuracy.**
- **Make changes if necessary.**
- **Compare final actual flow with best possible flow.**

Note: Process should follow the flow of Step1, Step 2, ..., Step N.

Step N= End of Process

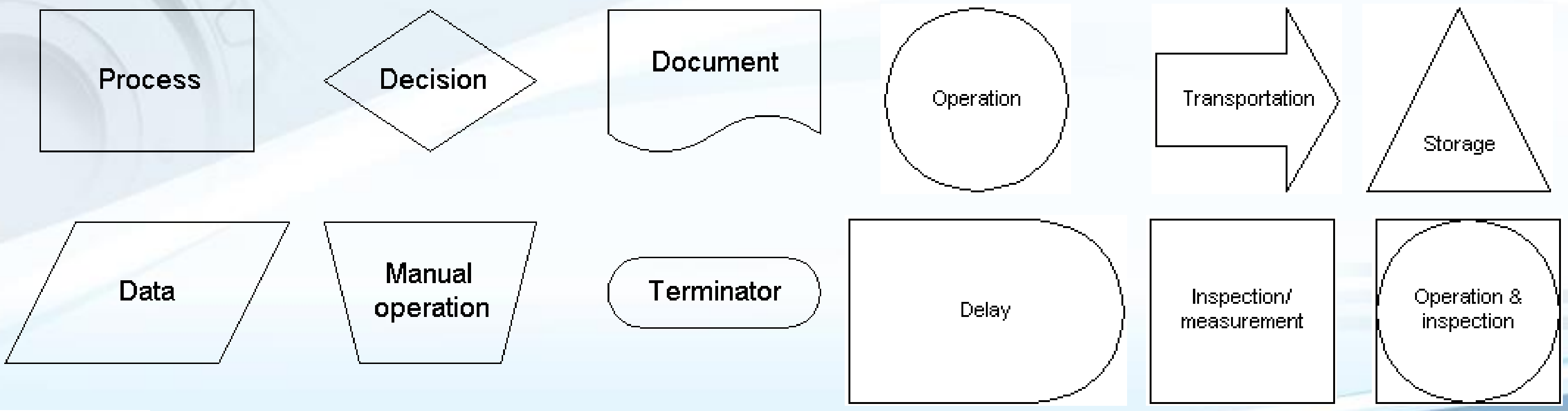
OMNEX

WWW.OMNEX.COM

FLOW CHART

CONSTRUCTION

- **Define the boundaries of the process clearly.**
- **Use the simplest symbols possible.**
- **Make sure every feedback loop has an escape.**
- **There is usually only one output arrow out of a process box. Otherwise, it may require a decision diamond.**

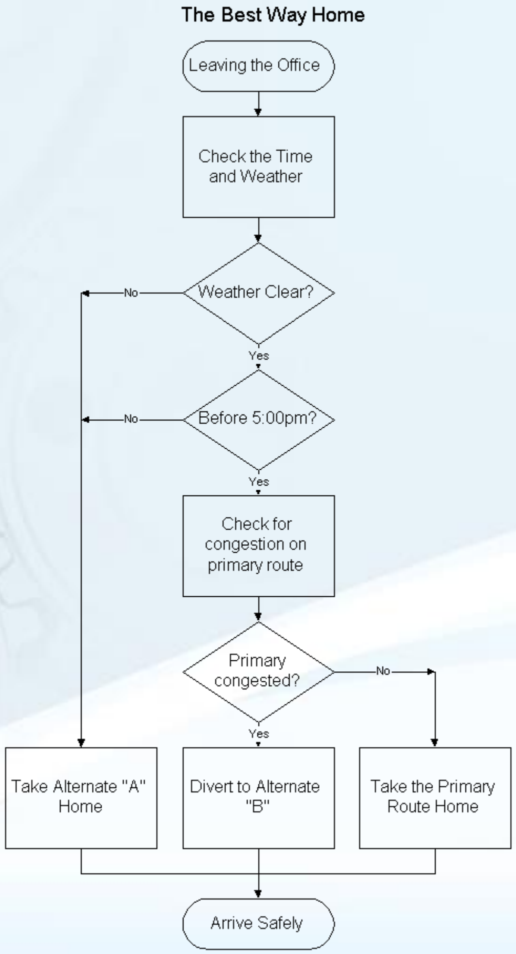


FLOW CHART

INTERPRETATION

1. **Analyze flow chart of actual process.**
2. **Analyze flow chart of best process.**
3. **Compare both charts, looking for areas where they are different. Most of the time, the stages where differences occur is considered to be the problem area or process.**
4. **Take appropriate in-house steps to correct the differences between the two separate flows.**

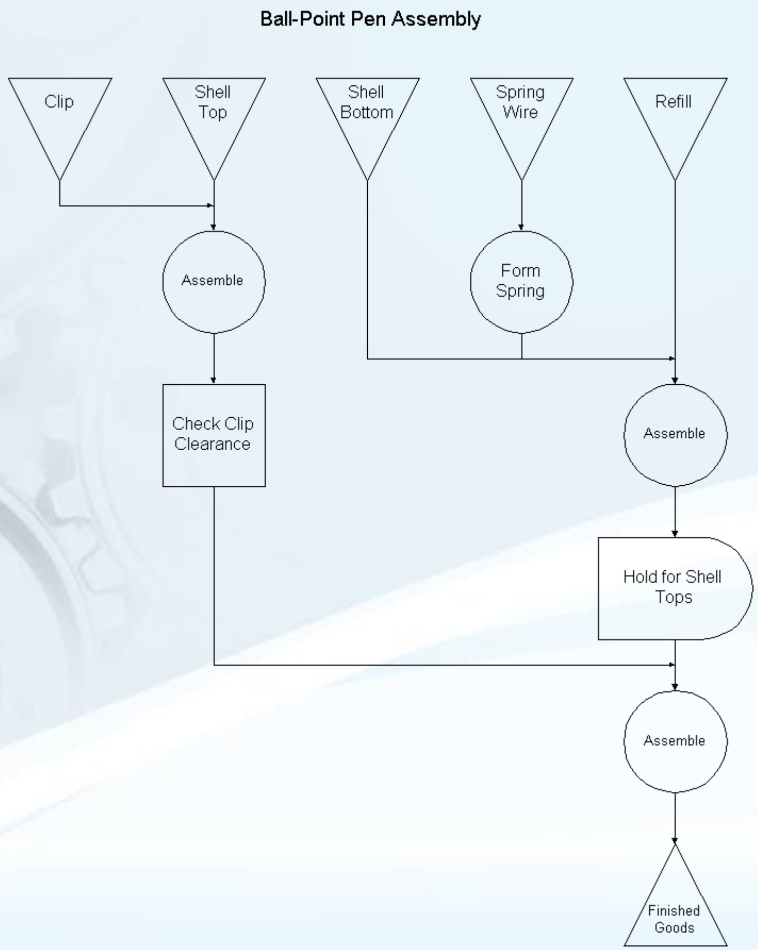
FLOW CHART EXAMPLE



Process Flow Chart- Finding the best way home

This is a simple case of processes and decisions in finding the best route home at the end of the working day.

FLOW CHART EXAMPLE



Process Flow Chart- How a process works (Assembling a ballpoint pen)

AFFINITY DIAGRAM

AFFINITY DIAGRAM

- Definition: An affinity diagram is an organizational tool most often used at the beginning of a team's work to organize large volumes of ideas or issues into major categories.
- The ideas may have come from the group's initial brainstorming session.
- "Affinity" means close relationship or connection, or similarity of structure
- When developing an Affinity Diagram, it is most important to determine the primary issue and major related subgroups in order to grasp the appropriate relationships, links, or connections.

AFFINITY DIAGRAM

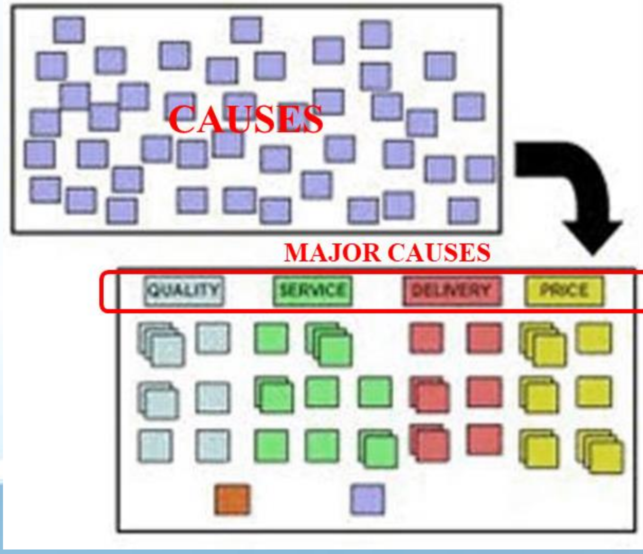
Steps

- Define the primary issue, using neutral, broad language;
- Brainstorm - use cards or adhesive notes which can be moved and sorted;
- Display in random fashion all ideas for the team (on a wall or table)

AFFINITY DIAGRAM

Steps

- Each team member participates in sorting the ideas into major groupings -- in silence and quickly, without discussion and without time for contemplation -- until team consensus is reached;
- Discuss the major groupings and create a concise title for each grouping
- Draw the affinity diagram, based on major groupings, linking all ideas related to each grouping.



Example: Affinity Diagram

Display the generated ideas

Problem: There are lot of issues in implementing continuous process improvement

- Data collection process needs
- Pressure for success
- Lack of follow-up by management
- Which comes first, composing the team or stating the problem?
- Want to solve problem before clearly defined
- Lack of training at all levels
- What are the rewards for using tools
- Unrealistic allotment of time
- Everybody needs to change but me
- Need new data collection system
- Lack of management understanding of need for it
- Developing product without developing process
- Not using collected data
- Too busy to learn
- Don't know what customer wants
- Some people will never change
- Lack of trust in the process
- Behavior modifications may take longer than time available
- Short-term planning mentality
- Competition versus cooperation
- Need to be creative
- Too many projects at once

OMNEX

WWW.OMNEX.COM

Example: Affinity Diagram

Sort ideas into related Groups

Problem: There are lot of issues in implementing continuous process improvement

Some people will never change	Developing product without developing process	Lack of follow-up by management	Competition versus cooperation	Data collection process needs
Everybody needs to change but me	Which comes first, composing the team or stating the problem?	Lack of training at all levels	Pressure for success	Need new data collection system
Need to be creative	Don't know what customer wants	Too busy to learn	What are the rewards for using tools	Unrealistic allotment of time
Behavior modifications may take longer than time available	Want to solve problem before clearly defined		Short-term planning mentality	Not using collected data
Lack of trust in the process			Lack of management understanding of need for it	Too many projects at once

Example: Affinity Diagram

Create Header Cards and add to groups

Problem: There are lot of issues in implementing continuous process improvement

Breaking through old way "Dinosaur" thinking	Lack of planning	Organizational issues	Old management culture	Lack of TQL knowledge
Some people will never change	Developing product without developing process	Lack of follow-up by management	Competition versus cooperation	Data collection process needs
Everybody needs to change but me	Which comes first, composing the team or stating the problem?	Lack of training at all levels	Pressure for success	Need new data collection system
Need to be creative	Don't know what customer wants	Too busy to learn	What are the rewards for using tools	Unrealistic allotment of time
Behavior modifications may take longer than time available	Want to solve problem before clearly defined		Short-term planning mentality	Not using collected data
Lack of trust in the process			Lack of management understanding of need for it	Too many projects at once

MULTIVOTING

MULTIVOTING

- **A repetitive process used by a team to select the most important or popular items from a large list of items generated by the team**

- **<u>Benefits of Multi-voting</u>**
  - ✓ **Reduces a larger list of items.**
  - ✓ **Prioritizes team issues.**
  - ✓ **Identifies important items.**

MULTIVOTING

- Step 1 - Work from a large list
- Step 2 - Assign a letter to each item
- Step 3 - Tally the votes
- Step 5 - Repeat the process

EXAMPLE: MULTIVOTING

First Vote Tally

Problem: Lack of team meetings' productivity

Tally	Item	Tally	Item
|	A. No agenda	|	I. Problems not mentioned
||||	B. No clear objectives	||||	J. Interrupted by phone calls
||	C. Going off on tangents	||	K. Few meaningful metrics
|	D. Extraneous topics	||||	L. Interrupted by visitors
||	E. Too many "sea stories"	|||	M. No administrative support
|||| |	F. Vital members missing from meeting	||||	N. Meetings extended beyond allotted time
||||	G. Not enough preparation for meetings	||||	O. Members distracted by pressing operations

OMNEX
WWW.OMNEX.COM

EXAMPLE: MULTIVOTING

Second Vote Tally

Problem: Lack of team meetings' productivity

- I 卌 — B. No clear objectives
- 卌 — F. Vital members missing from meeting
- IIII — G. Not enough preparation for meetings
- III — J. Interrupted by phone calls
- IIII — L. Interrupted by visitors
- II — N. Meetings extended beyond allotted time
- I — O. Members distracted by pressing operation

PARETO CHART

PARETO CHART

What Is a Pareto Chart?

- **Bar chart arranged in descending order of height from left to right**
- **Bars on left relatively more important than those on right**
- **Separates the "vital few" from the "trivial many" (Pareto Principle)**

Why Use a Pareto Chart?

- **Breaks big problem into smaller pieces**
- **Identifies most significant factors**
- **Shows where to focus efforts**
- **Allows better use of limited resources**

PARETO CHART

Constructing a Pareto Chart

Step 1 - Record the data

Step 2 - Order the data

Step 3 - Label the vertical axis

Step 4 - Label the horizontal axis

Step 5 - Plot the bars

Step 6 - Add up the counts

Step 7 - Add a cumulative line

Step 8 - Add title, legend, and date

Step 9 - Analyze the diagram

PARETO CHART EXAMPLE

Problem Scenario

You recently inherited $10,000 and would like to apply it to some of your outstanding bills. Here is what you owe:

Home improvement loan balance	**$1,956**
Visa	**$2,007**
Mastercard	**$1,983**
Church building fund pledge (monthly installments of $83.33 for two years)	**$2,000**
Balance of car loan	**$1,971**
School tuition (monthly installments Of $169.17 for one year)	**$2,030**

OMNEX

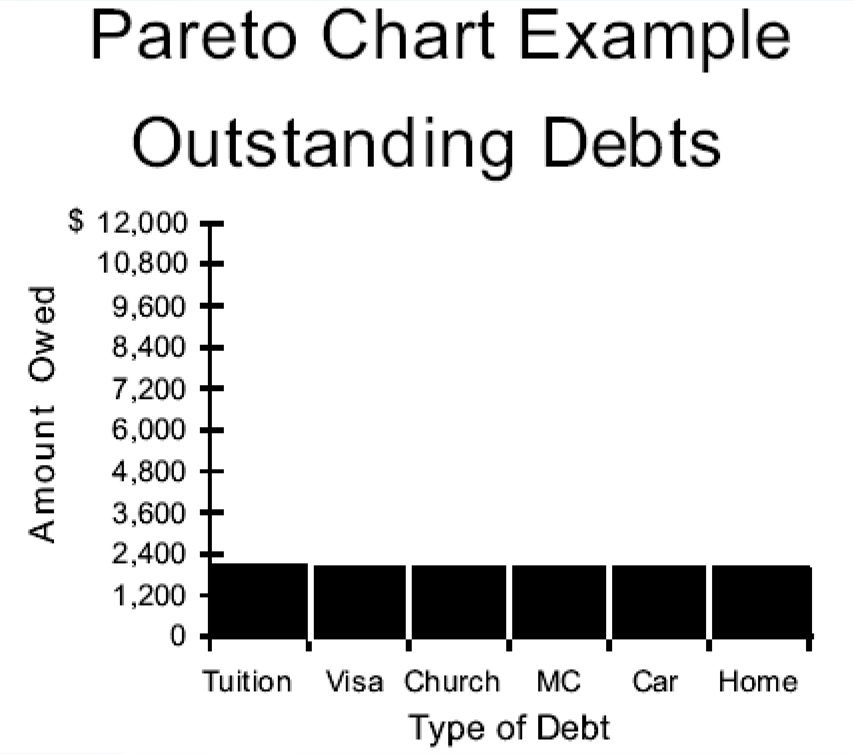
WWW.OMNEX.COM

PARETO CHART EXAMPLE

Analysis Sheet Outstanding Debts

Category	Amount ($)
School tuition (monthly Installments)	2,030
Visa	2,007
Church pledge(monthlyinstallments)	2,000
MasterCard	1,983
Balance of car loan	1,971
Home improvement loan balance	1,956
Total	11,947

PARETO CHART EXAMPLE



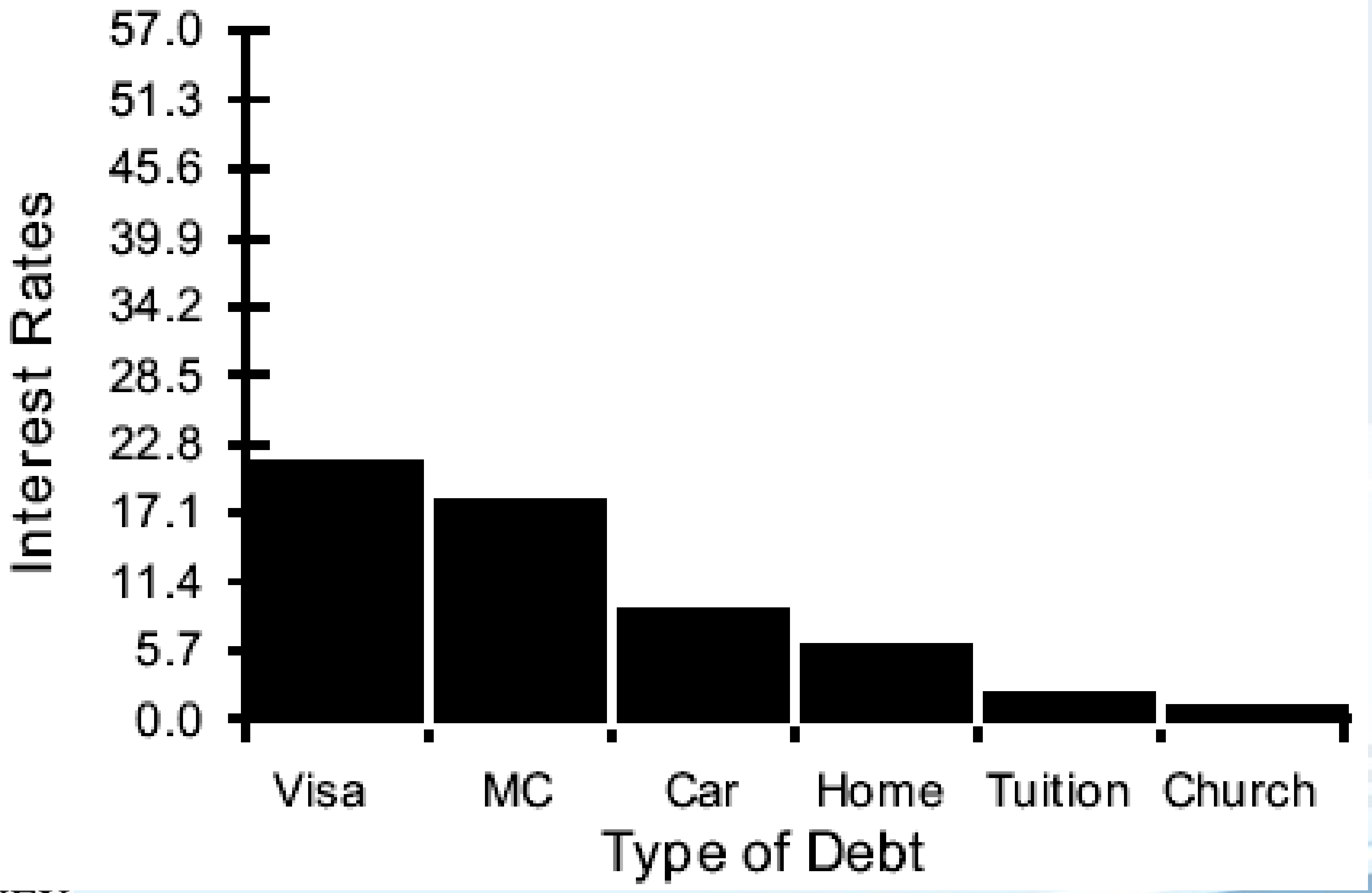
You probably noticed that no single bar is dramatically different from the others. Looking at your outstanding debts in this way isn't much help. Is there a different way the data could be categorized to make it more meaningful? What if you were to consider the interest rates on your outstanding debts?

PARETO CHART

Analysis Sheet
Interest Rates on Outstanding Debts

Category	Int. Rate (%)
Visa	21
Mastercard	18
Home improvement loan balance	9
School tuition (monthly installments)	6
Balance of car loan	2
Church pledge (monthly installments)	1

PARETO CHART



PARETO CHART

How do we interpret a Pareto Chart?

When you look at a Pareto Chart, you can see break points in the heights of the bars which indicate the most important categories. This information is useful when you are establishing priorities.

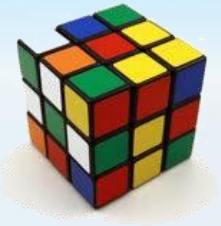
As you can see in the example we've just looked at, you can detect two big breaks in the heights of the bars when you categorize the data in a different way:

- **The first break point is between the second and third bars. The difference between these two bars is much more noticeable than the other differences. This shows the relative importance of the first two bars in relation to the others.**
- **The other break point occurs after the fourth bar. Addressing the third and fourth bars will give a higher payoff than addressing the last bar.**

Team Breakout 5: Pareto Chart

Equip Code	Critical equipment	MTTR	Downtime Frequency
1	Centrifugal Fan	3.2	5
2	Pump station 2 Motor	3	2
3	Granulator Drum	2	2
4	Feed Belt Conveyor	1.5	2
5	Recycle Belt Conveyor	2.5	1
6	Bag Filter	2.5	1
7	Burner	1	1
8	Belt Conveyor	0.5	1
9	Belt Conveyor	0.2	1
10	Bucket Elevator	0	0

Team Breakout 5: Objective



- **In the previous slide, you can find the downtime data for 10 machines. Which machines are the top contributors in this scenario?**
- **Plot a Pareto Chart for Downtime (hours)**

RUN CHART

RUN CHARTS/TIME PLOT/TREND CHART

PURPOSE

In-depth view into Run Charts-a quality improvement technique;
How Run charts are used to monitor processes;
How using Run charts can lead to improved process quality

USAGE

Run charts are used to analyze processes according to time or order.
Run charts are useful in discovering patterns that occur over time.

OMNEX
WWW.OMNEX.COM

RUN CHARTS/TIME PLOT/TREND CHART

KEY TERMS

Trends: Trends are patterns or shifts according to time. An upward trend, for instance, would contain a section of data points that increased as time passed.

Population: A population is the entire data set of the process. If a process produces one thousand parts a day, the population would be the one thousand items.

Sample: A sample is a subgroup or small portion of the population that is examined when the entire population can not be evaluated. For instance, if the process does produce one thousand items a day, the sample size could be perhaps three hundred.

OMNEX

RUN CHARTS/TIME PLOT/TREND CHART

HISTORY

Run charts originated from control charts, which were initially designed by Walter Shewhart. Walter Shewhart was a statistician at Bell Telephone Laboratories in New York. Shewhart developed a system for bringing processes into statistical control by developing ideas which would allow for a system to be controlled using control charts. Run charts evolved from the development of these control charts, but run charts focus more on time patterns while a control chart focuses more on acceptable limits of the process. Shewhart's discoveries are the basis of what as known as SQC or Statistical Quality Control.

RUN CHARTS/TIME PLOT/TREND CHART

INSTRUCTIONS FOR CREATING A CHART

Step 1 : Gathering Data

Step 2 : Organizing Data

Step 3 : Charting Data

Step 4 : Interpreting Data

Step 1 : Gathering Data

To begin any run chart, some type of process or operation must be available to take measurements for analysis. Measurements must be taken over a period of time. The data must be collected in a chronological or sequential form. You may start at any point and end at any point. For best results, at least 25 or more samples must be taken in order to get an accurate run chart.

OMNEX

WWW.OMNEX.COM

RUN CHARTS/TIME PLOT/TREND CHART

Step 2 : Organizing Data

Once the data has been placed in chronological or sequential form, it must be divided into two sets of values x and y. The values for x represent time and the values for y represent the measurements taken from the manufacturing process or operation.

Step 3 : Charting Data

Plot the y values versus the x values by hand or by computer, using an appropriate scale that will make the points on the graph visible. Next, draw vertical lines for the x values to separate time intervals such as weeks. Draw horizontal lines to show where trends in the process or operation occur or will occur.

RUN CHARTS/TIME PLOT/TREND CHART

Step 4 : Interpreting Data

After drawing the horizontal and vertical lines to segment data, interpret the data and draw any conclusions that will be beneficial to the process or operation. Some possible outcomes are:

- **Trends in the chart**
- **Cyclical patterns in the data**
- **Observations from each time interval are consistent**

RUN CHART EXAMPLE

Problem Scenario

You have just moved into a new area that you are not familiar with. Your desire is to arrive at work on time, but you have noticed over your first couple of weeks on the job that it doesn't take the same amount of time each day of the week. You decide to monitor the amount of time it takes to get to work over the next four weeks and construct a run chart.

Step 1: Gathering Data

Collect measurements each day over the next four weeks. Organize and record the data in chronological or sequential form.

	M	T	W	TH	F
WEEK 1	33	28	26.5	28	26
WEEK 2	35	30.5	28	26	25.5
WEEK 3	34.5	29	28	26	25
WEEK 4	34	29.5	27	27	25.5

RUN CHART EXAMPLE

Step 2: Organizing Data

Determine what the values for the x (time, day of week) and y (data, minutes to work) axis will be.

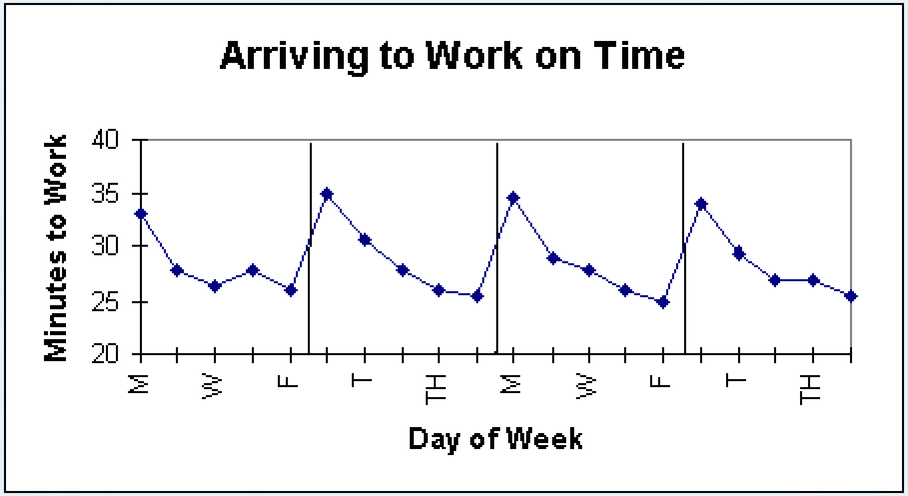
	Day	Travel Time	
WEEK 1	M	33	
	T	28	
	W	26.5	
	TH	28	
	F	26	
WEEK 2	M	35	
	T	30.5	
	W	28	
	TH	26	
	F	25.5	
WEEK 3	M	34.5	
	T	29	
	W	28	
	TH	26	
	F	25	
WEEK 4	M	34	
	T	29.5	
	W	27	
	TH	27	
	F	25.5	

Step 3: Charting Data

Plot the y values versus the x values by hand or by computer using the appropriate scale. Draw horizontal or vertical lines on the graph where trends or inconsistencies occur.

OMNEX
WWW.OMNEX.COM

RUN CHART EXAMPLE



Step 4: Interpreting Data

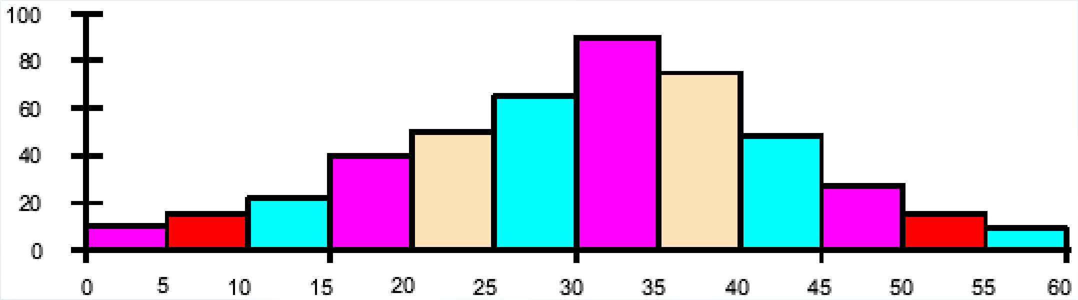
Interpret results and draw any conclusions that are important. An overall decreasing trend occurs each week with Mondays taking the most amount of time and Fridays generally taking the least amount of time. Therefore you accordingly allow yourself more time on Mondays to arrive to work on time.

HISTOGRAM

HISTOGRAM

What is a Histogram?

A Histogram is a vertical bar chart that depicts the distribution of a set of data. Unlike Run Charts or Control Charts, which are discussed in other modules, a Histogram does not reflect process performance over time. It's helpful to think of a Histogram as being like a snapshot, while a Run Chart or Control Chart is more like a movie.

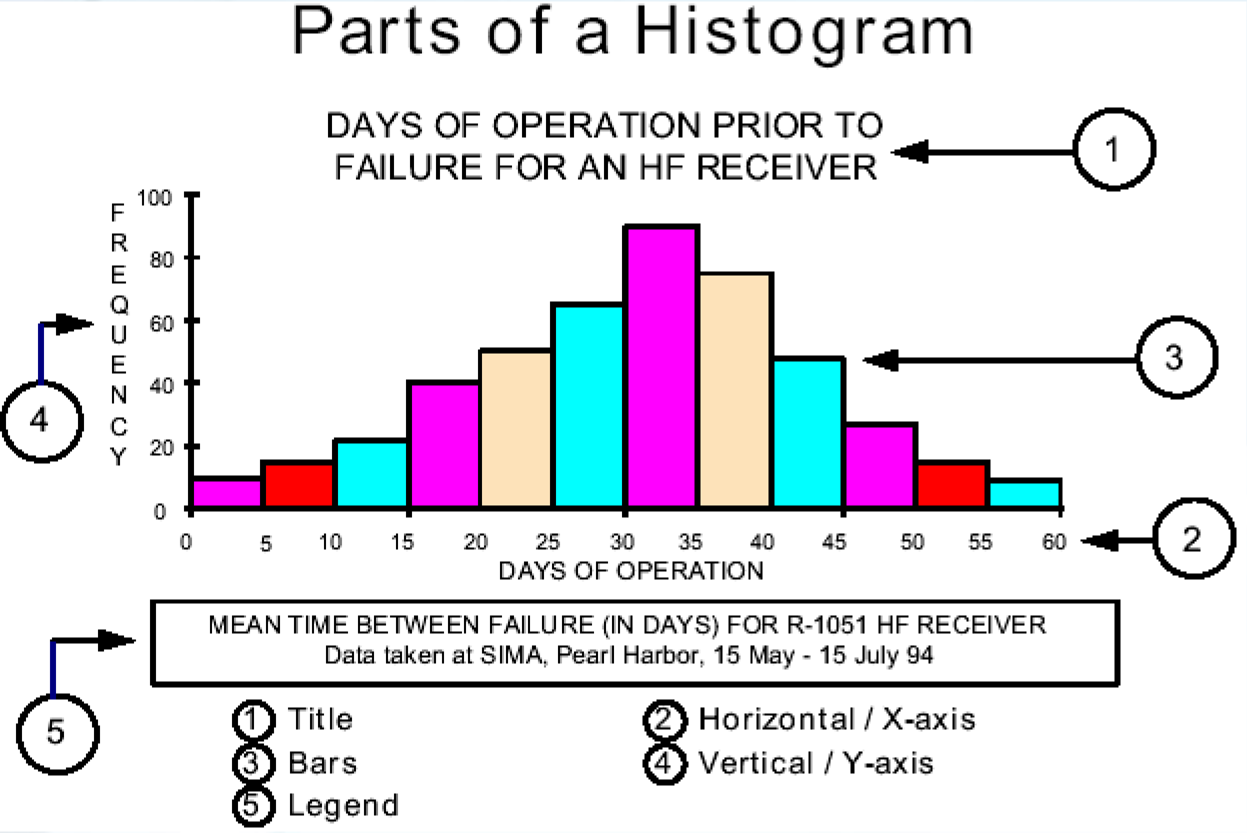


HISTOGRAM

When Are Histograms Used?

- **Summarize large data sets graphically**
- **Compare measurements to specifications**
- **Communicate information to the team**
- **Assist in decision making**

HISTOGRAM



Parts of a Histogram
DAYS OF OPERATION PRIOR TO
FAILURE FOR AN HF RECEIVER
1
FREQUENCY
100
80
60
40
20
0
4
3
0
5
10
15
20
25
30
35
40
45
50
55
60
2
DAYS OF OPERATION
MEAN TIME BETWEEN FAILURE (IN DAYS) FOR R-1051 HF RECEIVER
Data taken at SIMA, Pearl Harbor, 15 May - 15 July 94
5
1 Title
2 Horizontal / X-axis
3 Bars
4 Vertical / Y-axis
5 Legend

CONSTRUCTING A HISTOGRAM

<u>Constructing a Histogram</u>

Step 1 - Count number of data points
Step 2 - Summarize on a tally sheet
Step 3 - Compute the range
Step 4 - Determine number of intervals
Step 5 - Compute interval width
Step 6 - Determine interval starting points
Step 7 - Count number of points in each interval
Step 8 - Plot the data
Step 9 - Add title and legend

CONSTRUCTING A HISTOGRAM

How to Construct a Histogram

Step 1 - Count the total number of data points

Number of yards long (+ data) and yards short (- data) that a gun crew missed its target.

-180	30	190	380	330	140	160	270	10	- 90
- 10	30	60	230	90	120	10	50	250	180
-130	220	170	130	- 50	- 80	180	100	110	200
260	190	-100	150	210	140	-130	130	150	370
160	180	240	260	- 20	- 80	30	80	240	130
210	40	70	- 70	250	360	120	- 60	- 30	200
50	20	30	280	410	70	- 10	20	130	170
140	220	- 40	290	90	100	- 30	340	20	80
210	130	350	250	- 20	230	180	130	- 30	210
-30	80	270	320	30	240	120	100	20	70
300	260	20	40	- 20	250	310	40	200	190
110	-30	50	240	180	50	130	200	280	60
260	70	100	140	80	190	100	270	140	80
110	130	120	30	70					

TOTAL = 135

CONSTRUCTING A HISTOGRAM

How to Construct a Histogram

Step 2 - Summarize the data on a tally sheet

DATA	TALLY	DATA	TALLY	DATA	TALLY	DATA	TALLY	DATA	TALLY
- 180	1	- 20	3	90	2	190	4	290	1
- 130	2	- 10	2	100	5	200	4	300	1
- 100	1	10	2	110	3	210	4	310	1
- 90	1	20	5	120	4	220	2	320	1
- 80	2	30	6	130	8	230	2	330	1
- 70	1	40	3	140	5	240	4	340	1
- 60	1	50	4	150	2	250	4	350	1
- 50	1	60	2	160	2	260	4	360	1
- 40	1	70	5	170	2	270	3	370	1
- 30	5	80	5	180	5	280	2	380	1
								410	1

CONSTRUCTING A HISTOGRAM

Step 3 - Compute the range for the data set

Largest value = + 410 yards past target

Smallest value = - 180 yards short of target

Range of values = 590 yards

Calculation: **+ 410 - (- 180) = 410 + 180 = 590**

Step 4 - Determine the number of intervals required

IF YOU HAVE THIS MANY DATA POINTS	***USE THIS NUMBER OF INTERVALS:***
Less than 50	**5 to 7 intervals**
50 to 99	**6 to 10 intervals**
100 to 250	**7 to 12 intervals**
More than 250	**10 to 20 intervals**

OMNEX

WWW.OMNEX.COM

CONSTRUCTING A HISTOGRAM

Step 5 - Compute the interval width

$$\text{Interval Width} = \frac{\text{Range}}{\text{Number of Intervals}} = \frac{590}{10} = 59$$

Use 10 for the number of intervals

Round up to 60

CONSTRUCTING A HISTOGRAM

Step 6 - Determine the starting point of each interval

Step 7 - Count the number of points in each interval

INTERVAL NUMBER	STARTING VALUE	INTERVAL WIDTH	ENDING VALUE	NUMBER OF COUNTS
1	-180	60	-120	3
2	-120	60	-060	5
3	-060	60	000	13
4	000	60	060	20
5	060	60	120	22
6	120	60	180	24
7	180	60	240	20
8	240	60	300	18
9	300	60	360	6
10	360	60	420	4

Equal to or greater than the STARTING VALUE

But less than the ENDING VALUE

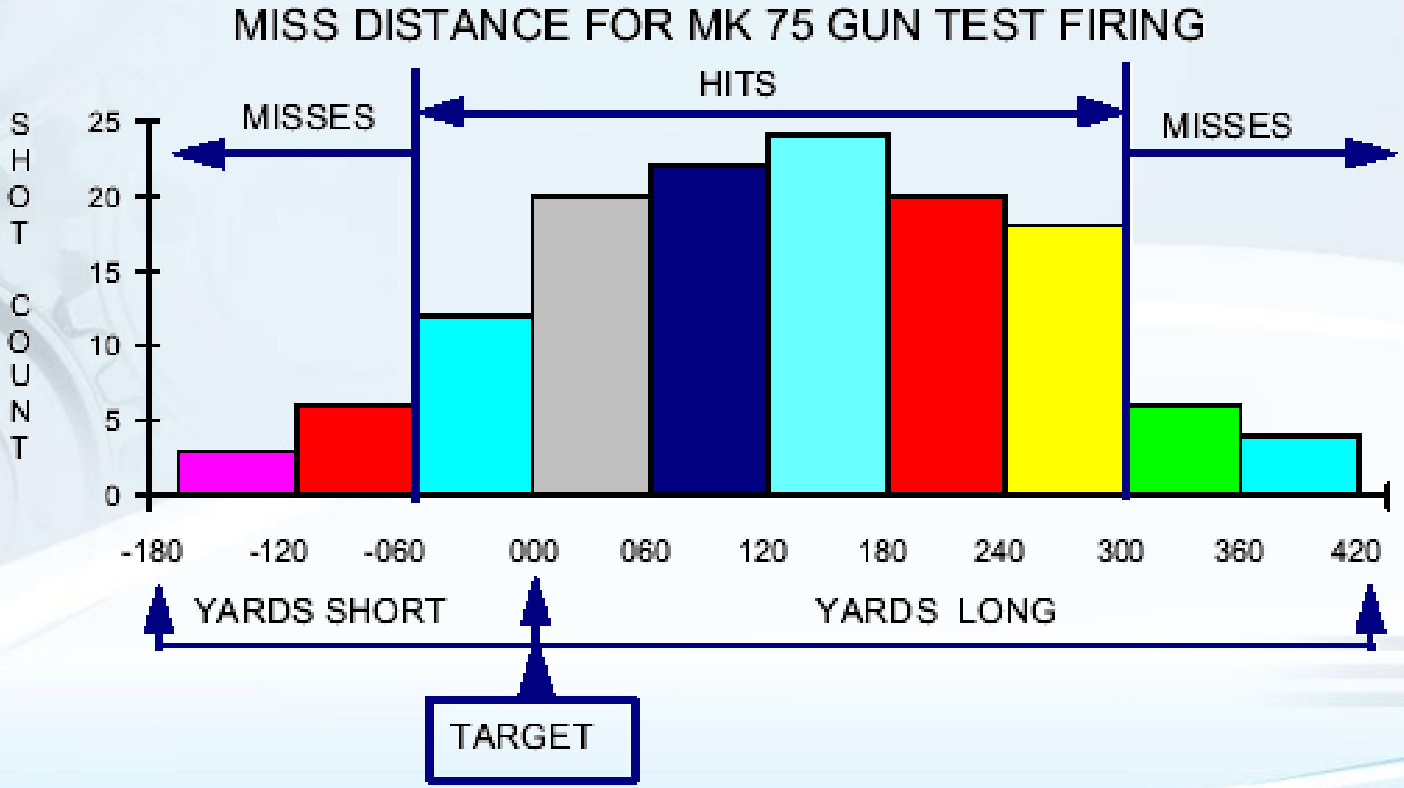
OMNEX

WWW.OMNEX.COM

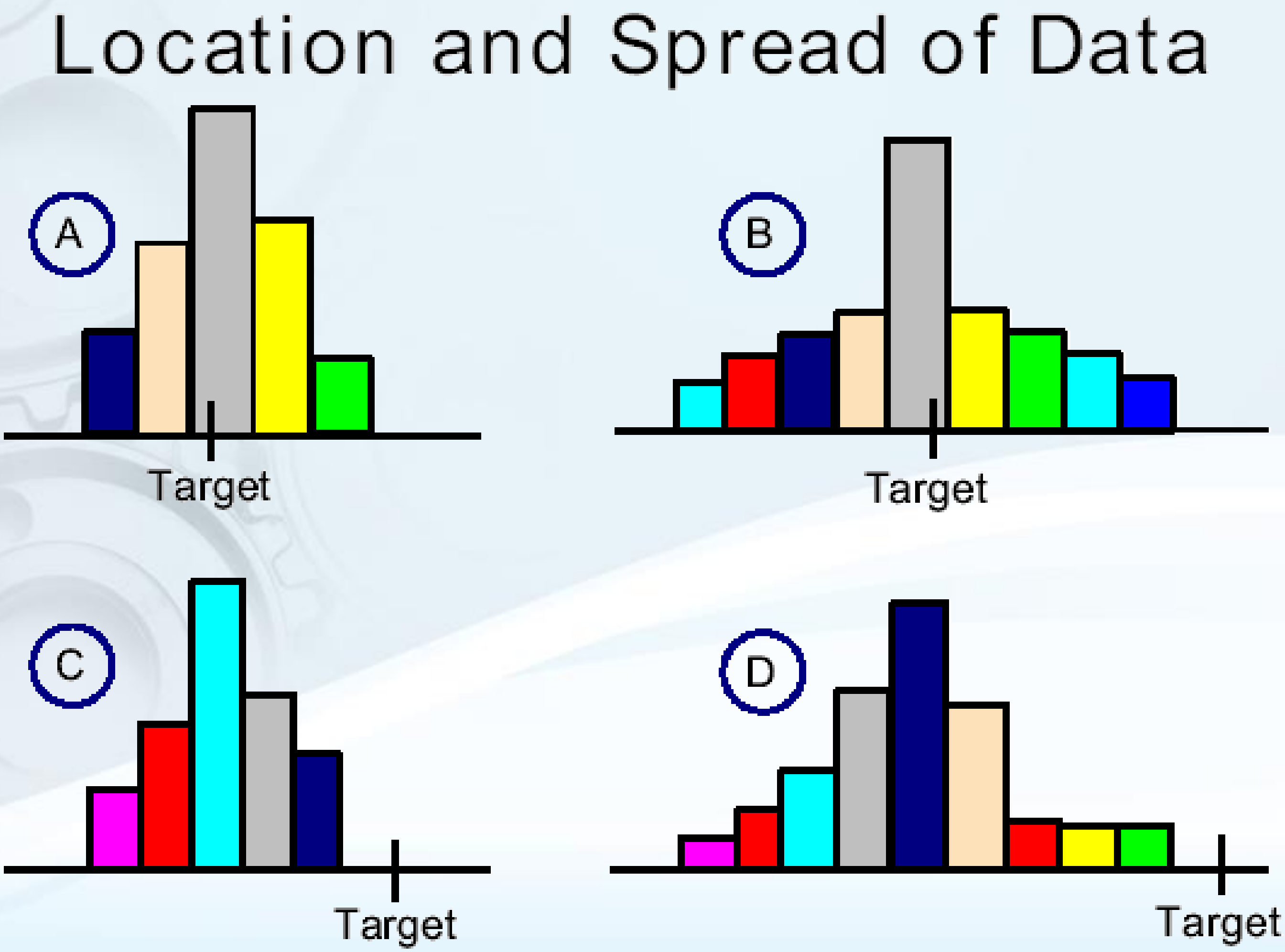
CONSTRUCTING A HISTOGRAM

Step 8 - Plot the data

Step 9 - Add the title and legend



INTERPRETING A HISTOGRAM



Most of the data were on target, with very little variation from it, as in A

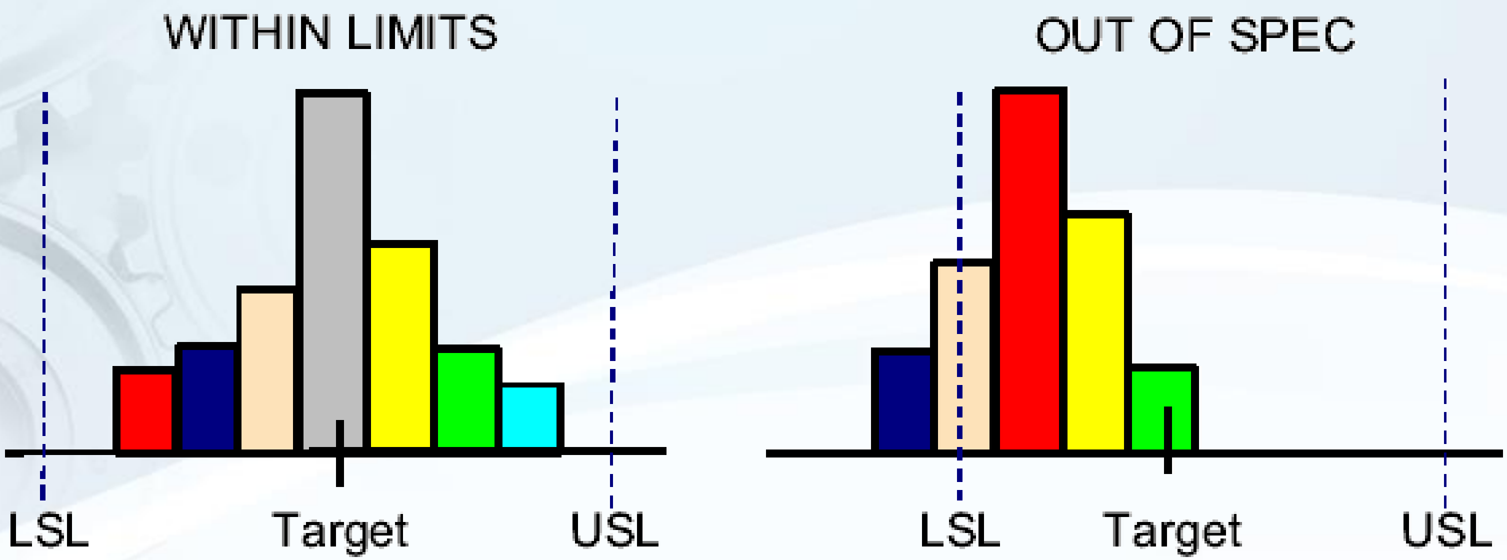
Although some data were on target, many others were dispersed away from the target, as in B

Even when most of the data were close together, they were located off the target by a significant amount, as in C

The data were off target and widely dispersed, as in D

INTERPRETING A HISTOGRAM

Is Process Within Specification Limits?



LSL = Lower specification limit

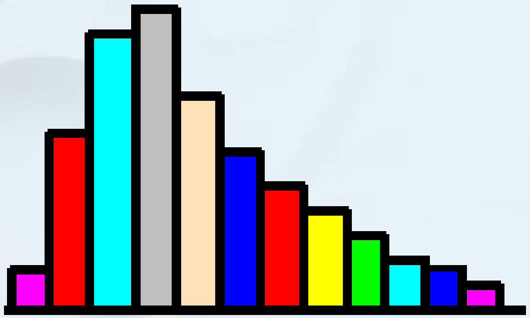
USL = Upper specification limit

WWW.OMNEX.COM

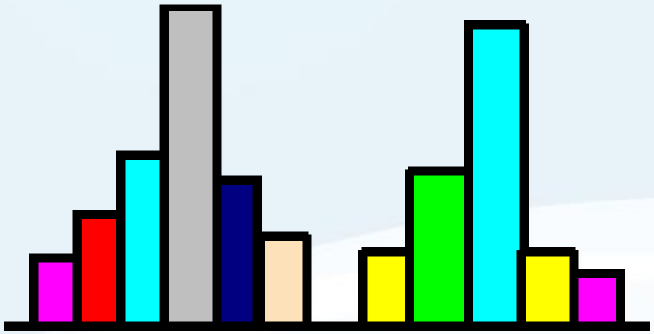
INTERPRETING A HISTOGRAM

WWW.OMNEX.COM

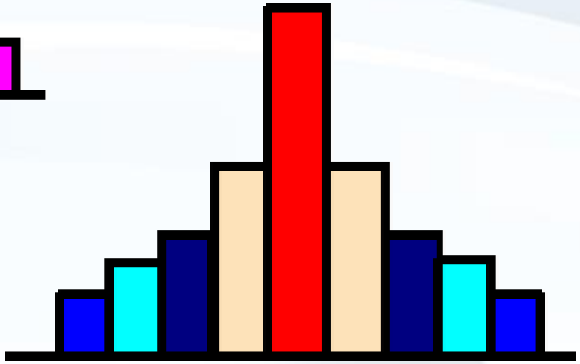
INTERPRETING A HISTOGRAM
Common Histogram Shapes



Skewed
(not symmetrical)



Discontinued



Symmetrical
(mirror imaged)

SCATTER DIAGRAM

SCATTER DIAGRAM

Commonly, while a cause-effect diagram has been used to describe the relationship between two variables, the histogram was used to visualize the structure of the data. However, a means of observing the kinds of relationships between variables was needed. Using the theory of linear regression which originated from studies performed by Sir Francis Galton (1822-1911), the scatter diagram was developed so that intuitive and qualitative conclusions could be drawn about the paired data, or variables. The concept of correlation was employed to decide whether a significant relationship existed between the paired data. Furthermore, regression analysis was used to identify the exact nature of the relationship.

SCATTER DIAGRAM

Scatter diagrams are used to study possible relationships between two variables. Although these diagrams cannot prove that one variable causes the other, they do indicate the existence of a relationship, as well as the strength of that relationship.

A scatter diagram is composed of a horizontal axis containing the measured values of one variable and a vertical axis representing the measurements of the other variable.

The purpose of the scatter diagram is to display what happens to one variables when another variable is changed. The diagram is used to test a theory that the two variables are related. The type of relationship that exists is indicated by the slope of the diagram.

SCATTER DIAGRAM

Key Terms

Variable - a quality characteristic that can be measured and expressed as a number on some continuous scale of measurement.

Relationship - Relationships between variables exist when one variable depends on the other and changing one variable will effect the other.

Data Sheet - contains the measurements that were collected for plotting the diagram.

Correlation - an analysis method used to decide whether there is a statistically significant relationship between two variables.

Regression - an analysis method used to identify the exact nature of the relationship between two variables.

CONSTRUCTION OF SCATTER DIAGRAM

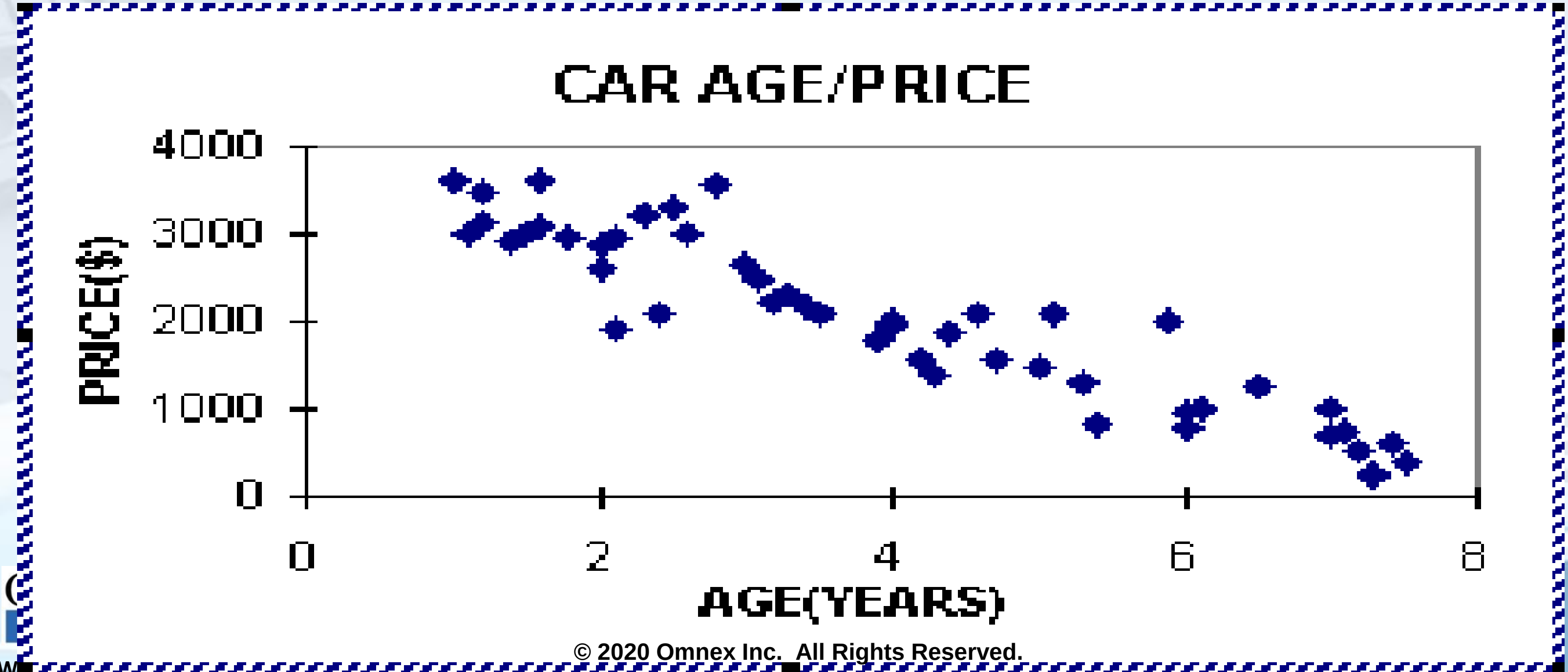
Collect and construct a data sheet of 50 to 100 paired samples of data, that you suspect to be related. Construct your data sheet as follows:

Car	Age (In Years)	Price (In Dollars)
1	2	4000
2	4	2500
3	1	5000
4	5	1250
:	:	:
:	:	:
100	7	1000

CONSTRUCTION OF SCATTER DIAGRAM

Draw the axes of the diagram. The first variable (the independent variable) is usually located on the horizontal axis and its values should increase as you move to the right. The vertical axis usually contains the second variable (the dependent variable) and its values should increase as you move up the axis.

Plot the data on the diagram. The resulting scatter diagram may look as follows:



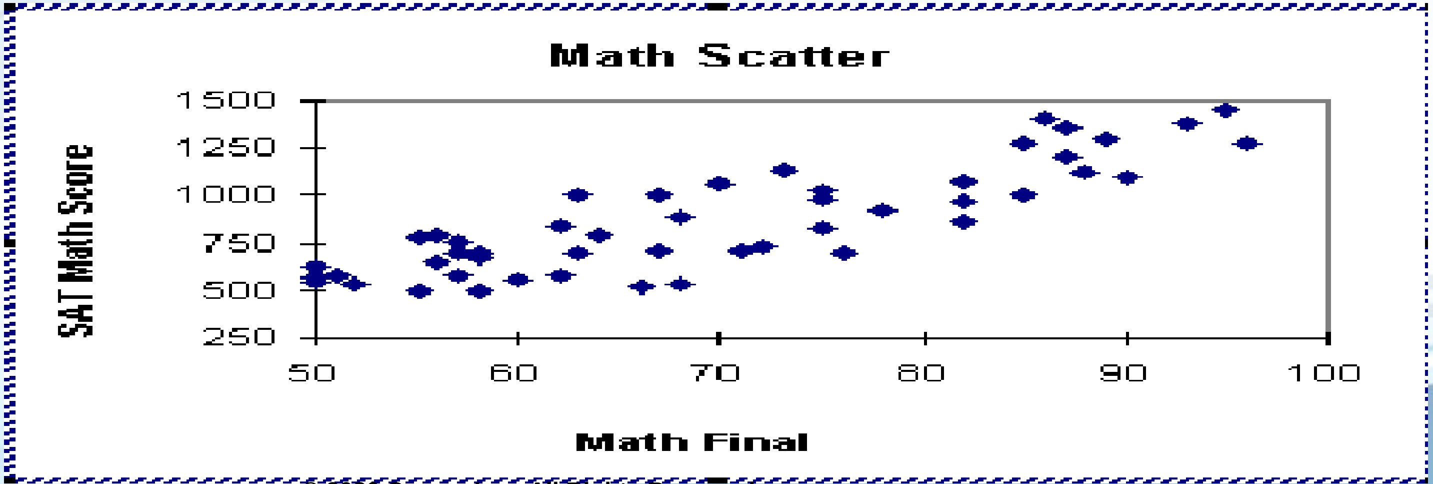
INTERPRETATION OF SCATTER DIAGRAM

The scatter diagram is a useful tool for identifying a potential relationship between two variables. The shape of the scatter diagram presents valuable information about the graph. It shows the type of relationship which may be occurring between the two variables. There are several different patterns (meanings) that scatter diagrams can have. The following slides describe five of the most common scenarios.

1. Positive correlation
2. Possible Positive correlation
3. No correlation
4. Possible Negative correlation
5. Negative correlation

INTERPRETATION OF SCATTER DIAGRAM

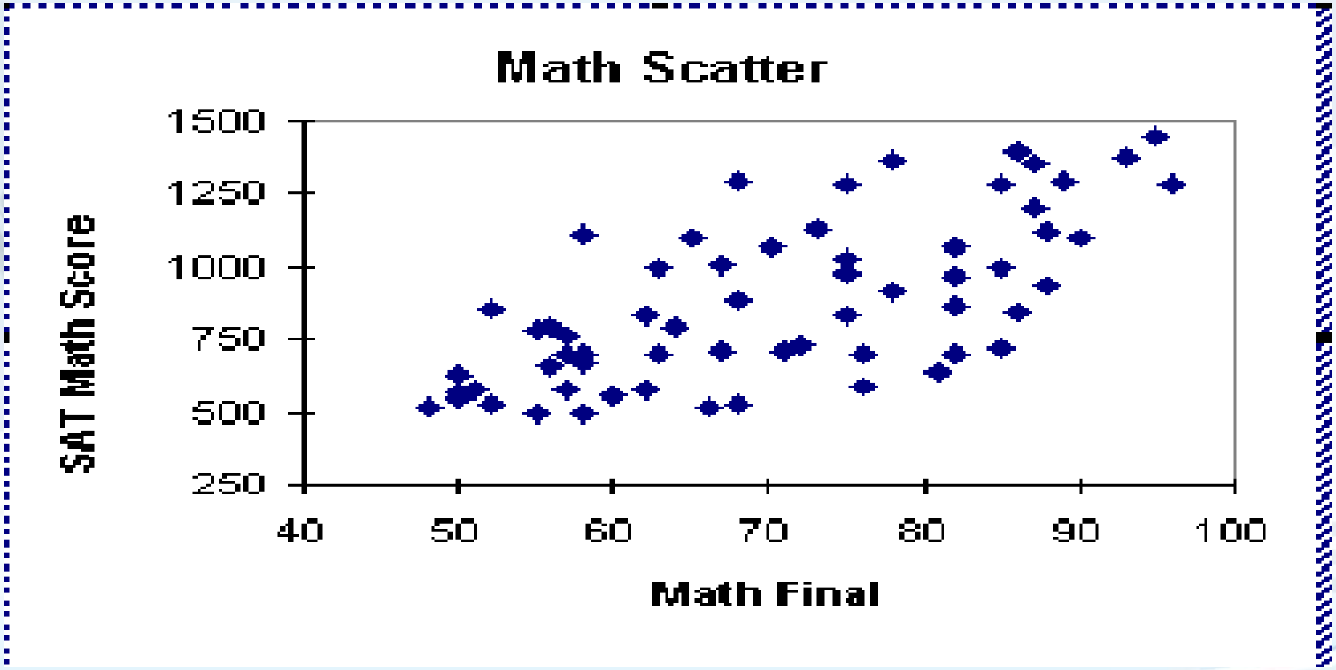
The first pattern is positive correlation, that is, as the amount of variable x increases, the variable y also increases. It is tempting to think this is a cause/effect relationship. This is an incorrect thinking pattern, because correlation does not necessarily mean causality. This simple relationship could be caused by something totally different. For instance, the two variables could be related to a third, such as curing time or stamping temperature. Theoretically, if x is controlled, we have a chance of controlling y.



OMNEX
WWW.OMNEX.COM

INTERPRETATION OF SCATTER DIAGRAM

Secondly, we have possible positive correlation, that is, if x increases, y will increase somewhat, but y seems to be caused by something other than x. Designed experiments must be utilized to verify causality.

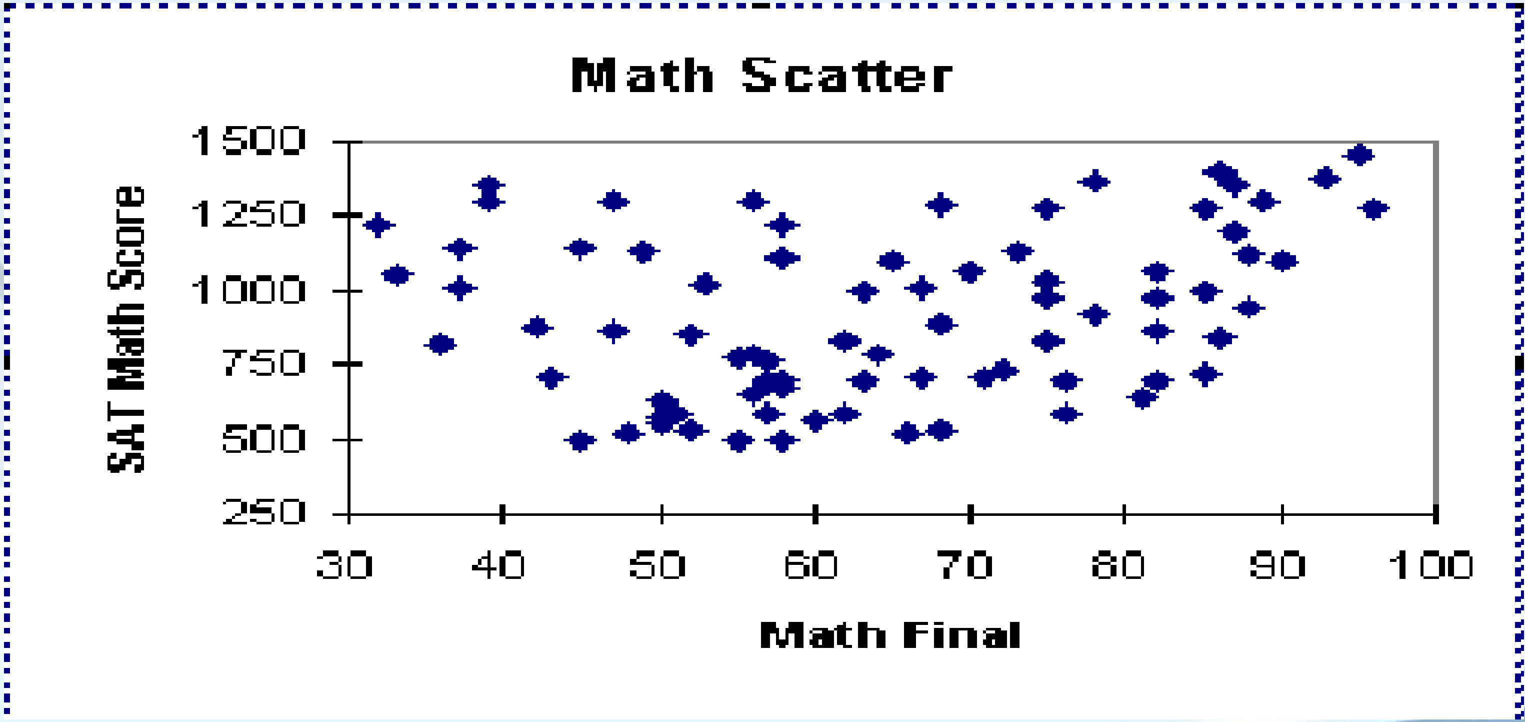


OMNEX

WWW.OMNEX.COM

INTERPRETATION OF SCATTER DIAGRAM

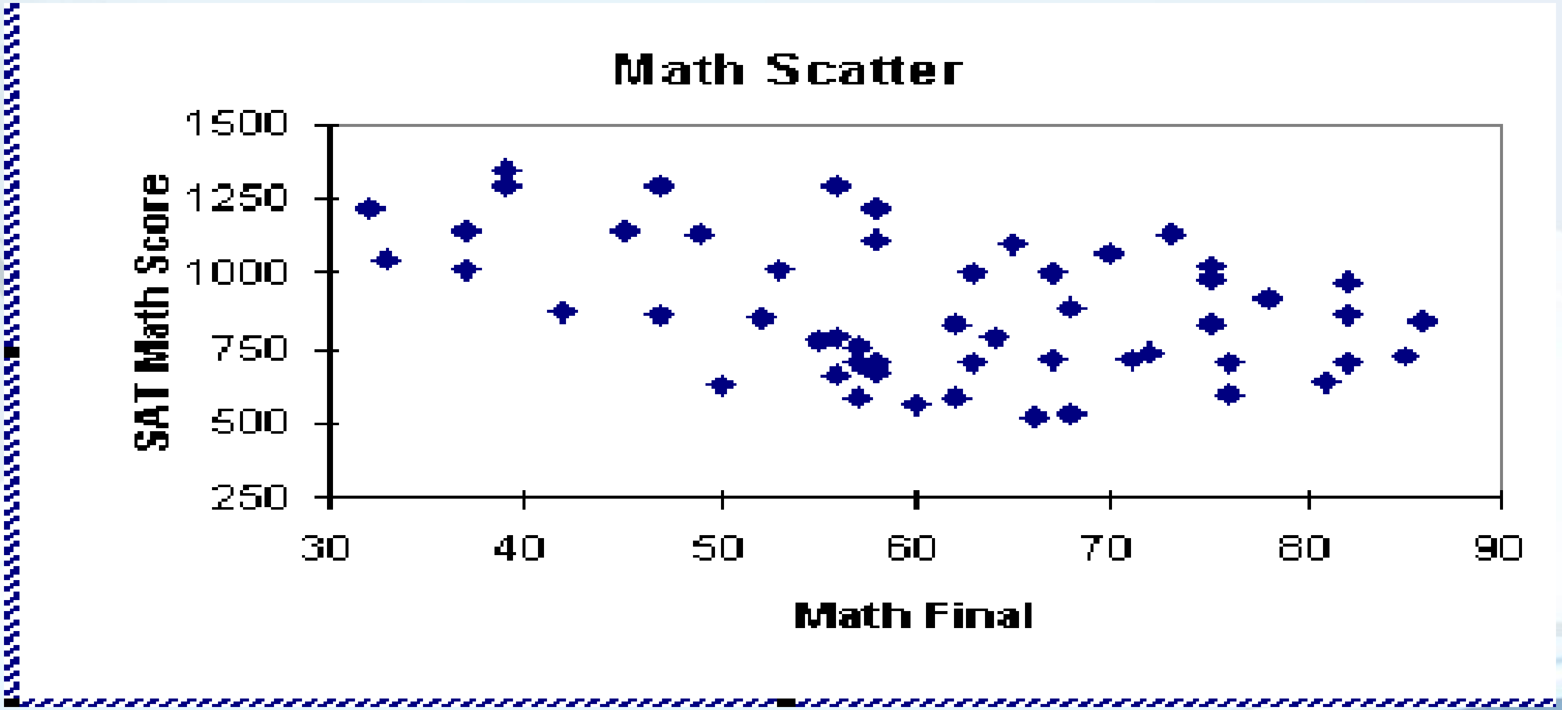
We also have the no correlation category. The diagram is so random that there is no apparent correlation between the two variables.



OMNEX
WWW.OMNEX.COM

INTERPRETATION OF SCATTER DIAGRAM

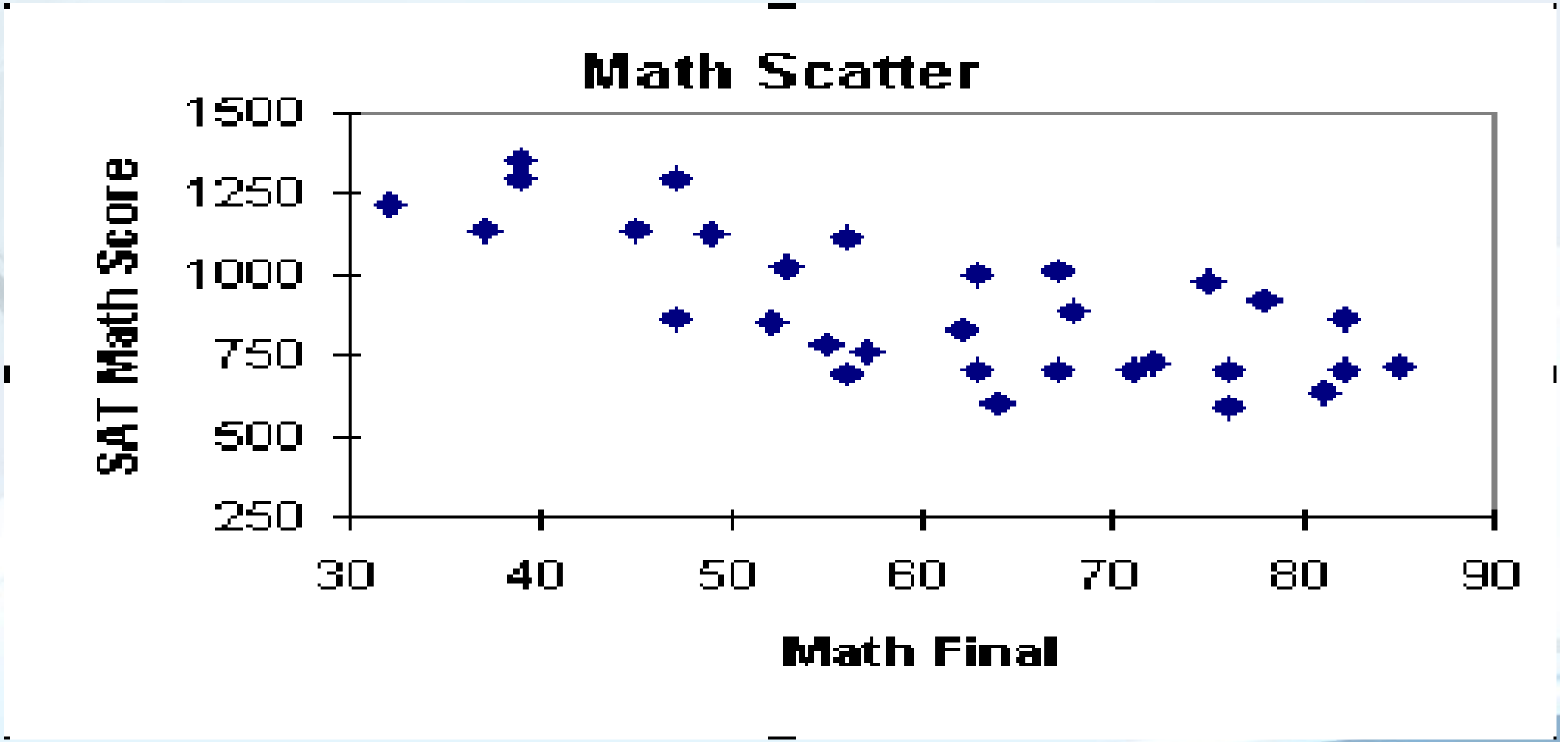
There is also possible negative correlation, that is, an increase in x will cause a tendency for a decrease in y, but y seems to have causes other than x.



OMNEX
WWW.OMNEX.COM

INTERPRETATION OF SCATTER DIAGRAM

Finally, we have the negative correlation category. An increase in x will cause a decrease in y. Therefore, if y is controlled, we have a good chance of controlling x.



KEY OBSERVATIONS

- A strong relationship between the two variables is observed when most of the points fall along an imaginary straight line with either a positive or negative slope.

- No relationship between the two variables is observed when the points are randomly scattered about the graph.

CONTROL CHART

HISTORY OF CONTROL CHART

- **Control charting is one of the tools of *Statistical Quality Control*(SQC) It is the most technically sophisticated tool of SQC. It was developed in the 1920s by Dr. Walter A. Shewhart of the Bell Telephone Labs.**
- **Dr. Shewhart developed the control charts as an statistical approach to the study of manufacturing process variation for the purpose of improving the economic effectiveness of the process. These methods are based on continuous monitoring of process variation.**

USES OF CONTROL CHART

Control chart is a device for describing in a precise manner what is meant by statistical control. Its uses are:

1. It is a proven technique for improving productivity.
2. It is effective in defect prevention.
3. It prevents unnecessary process adjustments.
4. It provides diagnostic information.
5. It provides information about process capability.

TYPES OF CONTROL CHART

- Control charts for Attributes.
    1. *p* chart
    2. *c* chart
    3. *u* chart

- Control charts for Variables.
    1. X bar chart
    2. R chart

A control chart may indicate an out-of-control condition either when one or more points fall beyond the control limits, or when the plotted points exhibit some nonrandom pattern of behavior.

CRITERIA TO IDENTIFY OUT OF CONTROL PROCESS

1. One or more points outside of the control limits. This pattern may indicate:
   - A special cause of variance from a material, equipment, method, or measurement system change.
   - Mismeasurement of a part or parts.
   - Miscalculated or misplotted data points.
   - Miscalculated or misplotted control limits.
2. A run of eight points on one side of the center line. This pattern indicates a shift in the process output from changes in the equipment, methods, or materials or a shift in the measurement system.
3. Two of three consecutive points outside the 2-sigma warning limits but still inside the control limits. This may be the result of a large shift in the process in the equipment, methods, materials, or operator or a shift in the measurement system.

CRITERIA TO IDENTIFY OUT OF CONTROL PROCESS

4. Four of five consecutive points beyond the 1-sigma limits.
5. An unusual or nonrandom pattern in the data.
   - A trend of seven points in a row upward or downward. This may show
     - Gradual deterioration or wear in equipment.
     - Improvement or deterioration in technique.
   - Cycling of data can indicate
     - Temperature or other recurring changes in the environment.
     - Differences between operators or operator techniques.
     - Regular rotation of machines.
     - Differences in measuring or testing devices that are being used in order.
6. Several points near a warning or control limit.

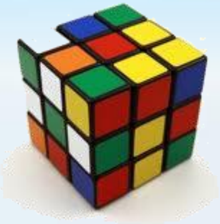
CAPABILITY & CONTROL

CAPABILITY	CONTROL	
	Process is in control (Stable)	**Process is out of control (Unstable)**
Process is capable of meeting specification	**CASE A** Healthy situation	**CASE C** Situation is OK now, but not stable. Be alert until process can be stabilized.
Process is not capable of meeting specification	**CASE B** Evaluate product requirements against the need for new process approach.	**CASE D** Major process improvement is required.

OMNEX
WWW.OMNEX.COM

Team Breakout 6

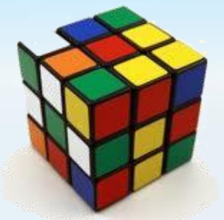
Problem Definition



"The problem investigated in this case study is about the rejections of lathe beds, because of the defects that occurred after the heat treatment process using flame hardening, which was used to provide the required hardness"

Team Breakout 6

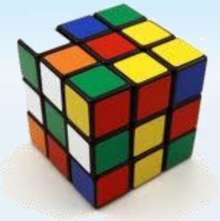
Flame Hardening Process Description



The lathe bed being a heavy component remains stationary and is heat treated using a movable equipment which provides the heating using a gas torch. The flame coming out of the jet is traversed across the whole length to heat treat the surface of the bed. An overhead guide carries a traveling head which moves parallel to the surface of the bed and the length of travel is pre-set based on the length of the bed. The traveling head moves along a guide rail powered by an electric motor with a variable speed drive. A torch and a nozzle are fixed to the traveling head to provide a flame and a water jet respectively. Using oxy-acetylene gas the torch produces a flame and starts heating the top surface of the bed. The water jet following the torch provides rapid quenching and both move along the guide rail with the same speed. The intensity of the flame as well the water jet are predetermined based on prior experimental runs. A forward and return movement of the traveling head is considered as one cycle. The height at which the traveling head is fixed above the bed decides the gap between the flame tip and the surface of the plate. This height is also preset by the operator and no adjustments are supposed to be made during the process. Once the hardening process is completed the hardness is measured and recorded.

Team Breakout 6

Criteria for Acceptance



The hardened bed is expected to possess a certain hardness as specified by the design department and any bed not having the hardness in that range is rejected.

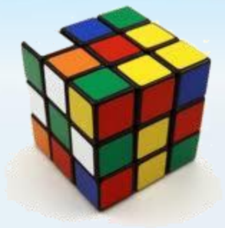
The flame hardening process which imparts a hardness of about 42 (Lower Specification Limit, LSL) to 48 (Upper Specification Limit, USL) HRC is considered satisfactory. A bed with hardness higher than 48 HRC is rejected.

<u>Note:</u>

HRC refers to the hardness value as measured along the Rockwell C scale. The Rockwell scale is a hardness scale based on indentation hardness of a material and the result is a dimensionless number noted as HRA, HRB, HRC, etc., where the last letter is the respective Rockwell scale

Team Breakout 6

Data Collection

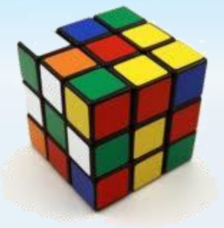


In order to ascertain the quality of the lathe bed, the hardness data was collected on 32 beds that were hardened in a certain sequence and the reading of the hardness inspection are given in the Table 1.

No.	Hardness	No.	Hardness	No.	Hardness	No.	Hardness
1	44	9	45	17	45	25	45
2	50	10	51	18	45	26	47
3	49	11	48	19	47	27	48
4	44	12	45	20	51	28	48
5	47	13	45	21	44	29	43
6	44	14	42	22	50	30	45
7	49	15	45	23	48	31	45
8	45	16	43	24	47	32	43

Table 1 : Hardness values (in HRC) of 32 beds

Team Breakout 6

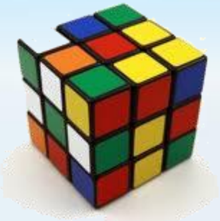


Questions

1) Plot a Run Chart and document the trend of the hardness data. Also write down your findings about the data.
2) Plot a Histogram and share your analysis points related to hardness Skewness, mean, median and specification limits proximity.
3) Calculate the standard deviation to understand the noise factor in the process. Share your findings relating to Histogram output.

Team Breakout 6

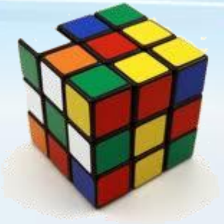
Brainstorming results



- Heating cycle too long.
- Flame heads too close to work.
- Oversize flame nozzles.
- Non-uniform heating.
- Time interval between heating and quenching too short.
- Quenching medium not agitated enough.
- Surface decarburized.
- Severity of quench, too low.
- Delay before quenching too long.
- Part not thoroughly quenched.
- Delay before quenching too long.
- Metallurgically unsuitable prior structure.
- Heating cycle too long.
- Excessive rate of gas flow.
- Flame velocity too high.
- Short heating cycle too low.
- Severity of quench too low.
- Low flow rate of gas.
- Excess of fuel gas in flame.
- Flame velocity too low.
- Rates of gas flow, too low.
- Flame velocity too low.
- Improper arrangement of flame heads.

OMNEX

Team Breakout 6



Questions

Overheating	Uneven Hardness	Insufficient Hardness
Distortion	Shallow Depth of Hardening	Excessive Depth of Hardening

4) Group the brainstormed causes into the above six headers which are the major causes. First, draw an affinity diagram and then convert it into a Cause & Effect diagram

5) Draw a control chart with 8 subgroups and share your findings about the process performance.

OMNEX
WWW.OMNEX.COM

THANK YOU

Info-in@Omnex.com

Are there any Questions?