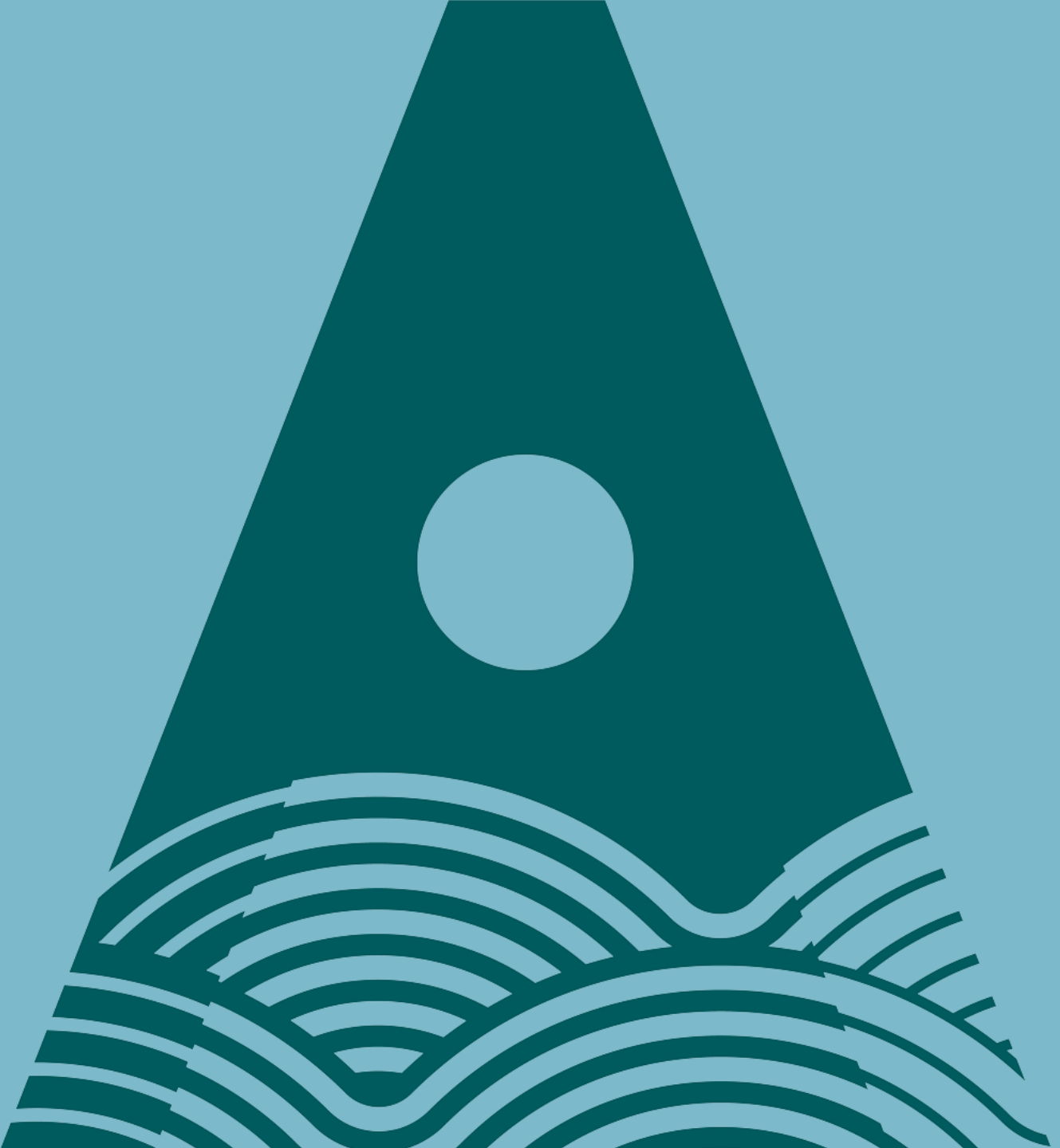

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Atlantic Technological University

Lean Sigma BIO 08025

Lecture

Descriptive Statistics II (Contd)
Graphs
Seven (Old) Quality Tools
&
Error Proofing

Dr. Stephen Daly

Seven (Old) Quality Control Tools

1. Histogram: A graphic display of the number of times (frequency) a value occurs.
2. Pareto diagram: A bar chart that organizes the data from largest to smallest to direct attention on the important items (usually the biggest contributors).
3. Cause and effect diagram: A schematic tool that resembles a fishbone that lists causes and sub-causes as they relate to a concern, also known as Fishbone diagram or Ishikawa diagram.
4. Process flow diagram: A graphical illustration of the actual process.

5. **Check sheet:** A form used to collect, organise, and categorise data so it can be easily used for further analysis.

5. **Scatter diagram:** A graphical tool that plots one characteristic against another to understand the relationship between the two.

6. **SPC control chart:** A graph of time-ordered data that predicts how a process should behave.

Check Sheet

- A **check sheet** is one of the seven basic tools which is used to organise and display information as it is collected.
- It ensures that different people collecting data will follow the same procedures and collect the same types of information.
- Often these check sheets will be pre-printed and the format used over and over again.

Checksheet of the queries received at the reception desk of a college

Queries	Week 6					
	Monday	Tuesday	Wednesday	Thursday	Friday	**Total**
Study material availability	/			/		2
Timetable query	/				//	3
Assignment due date	///	/	//	///	///// /	15
Extension to assignment	///// //	///	/	/	///// ///// ///	25
Assignment cover sheet	///	////	//	/	///// ///// //	22
Contact number of lecturer	///	/////	///// /	////	///// ///	26
Lecturer availability	///// /	//	///	///// //	///// /	24
Problem with laboratory computers		/	///	///	///// //	14
Exam dates			/			1
Other		/	////	//	///// /	13

Check Sheet
Mobile Phone Defect Types

Defect Type	Shifts 1	2	3	4
Display Scratched	√ √ √	√ √ √ √	√	√ √ √
Damaged	√ √	√ √ √		
Button Stuck		√ √ √ √		√ √ √
Battery Dead		√ √	√	

Check Sheet

COMPONENTS REPLACED BY LAB
TIME PERIOD: 22 Feb to 27 Feb 2009
REPAIR TECHNICIAN: Bob

TV SET MODEL 1013

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

Scatter Diagrams

- A Scatter Diagram is a graphical representation of the relationship (i.e. Correlation) of a pair of qualitative or quantitative variables, where the data is plotted as ‘dots’.

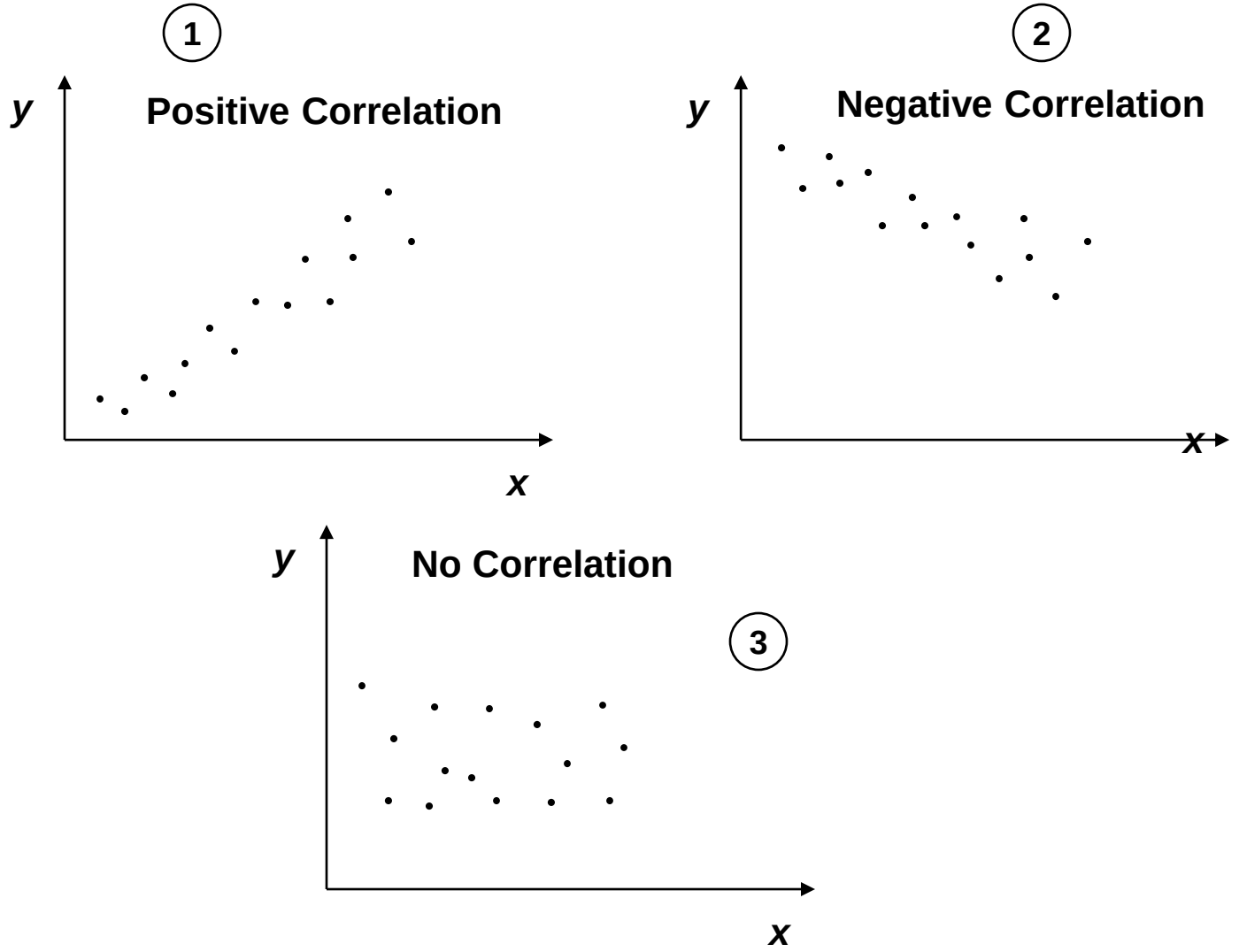
Overview

- A very useful tool for studying the Correlation between two variables without mathematics.
- Often the first step in a many quality investigations or data analyses.
- The Correlation can be either positive, negative or there may be no correlation.
- Positive Correlation - Variable *y* increases as *x* increases.
- Negative Correlation - Variable *y* decrease as *x* increases.
- No Correlation - No relationship between *x* and *y*.
- Can be used to predict the value of variable *y* based on a value of *x*.

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.

Examples

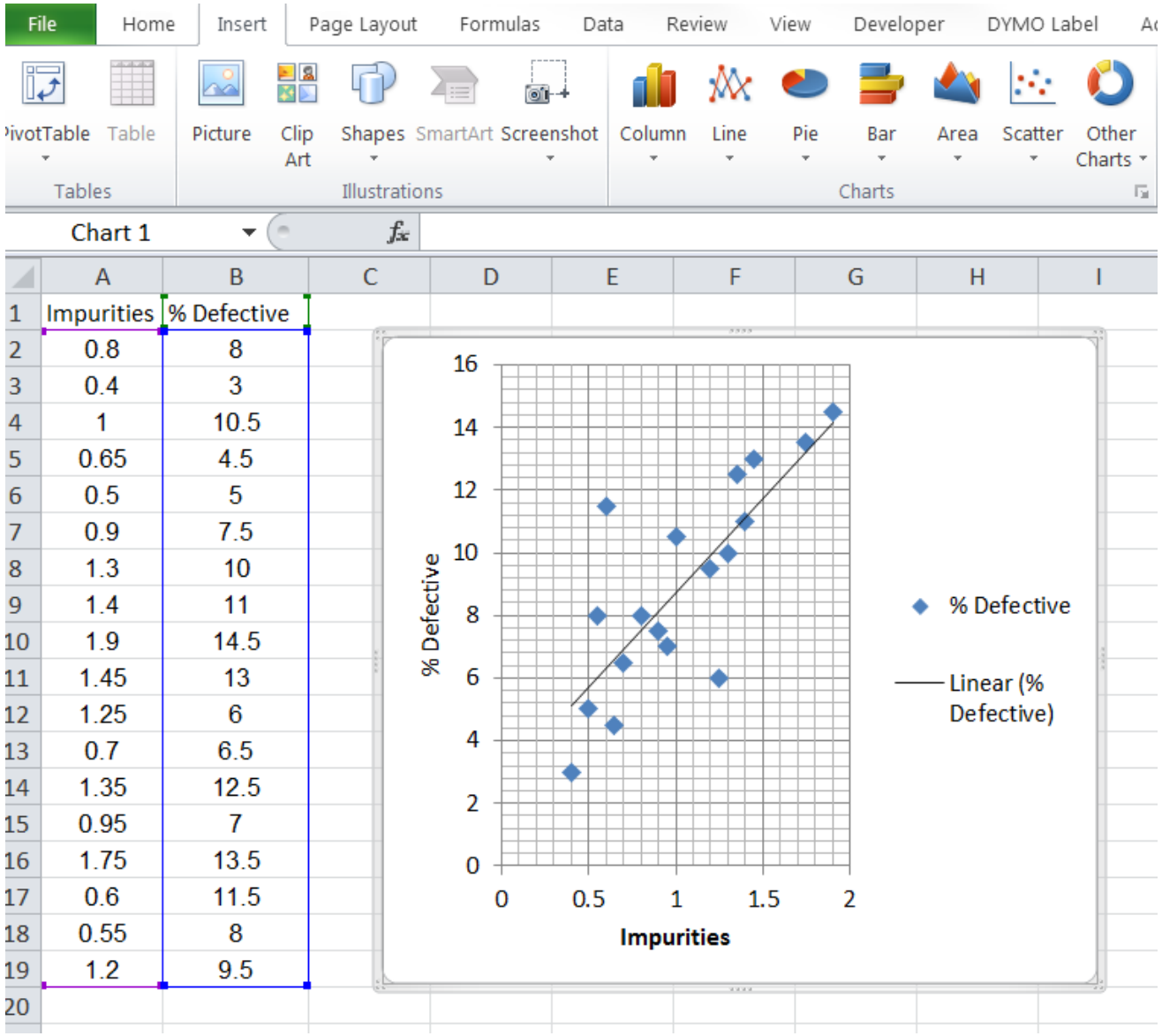


Example - Scatter Diagram

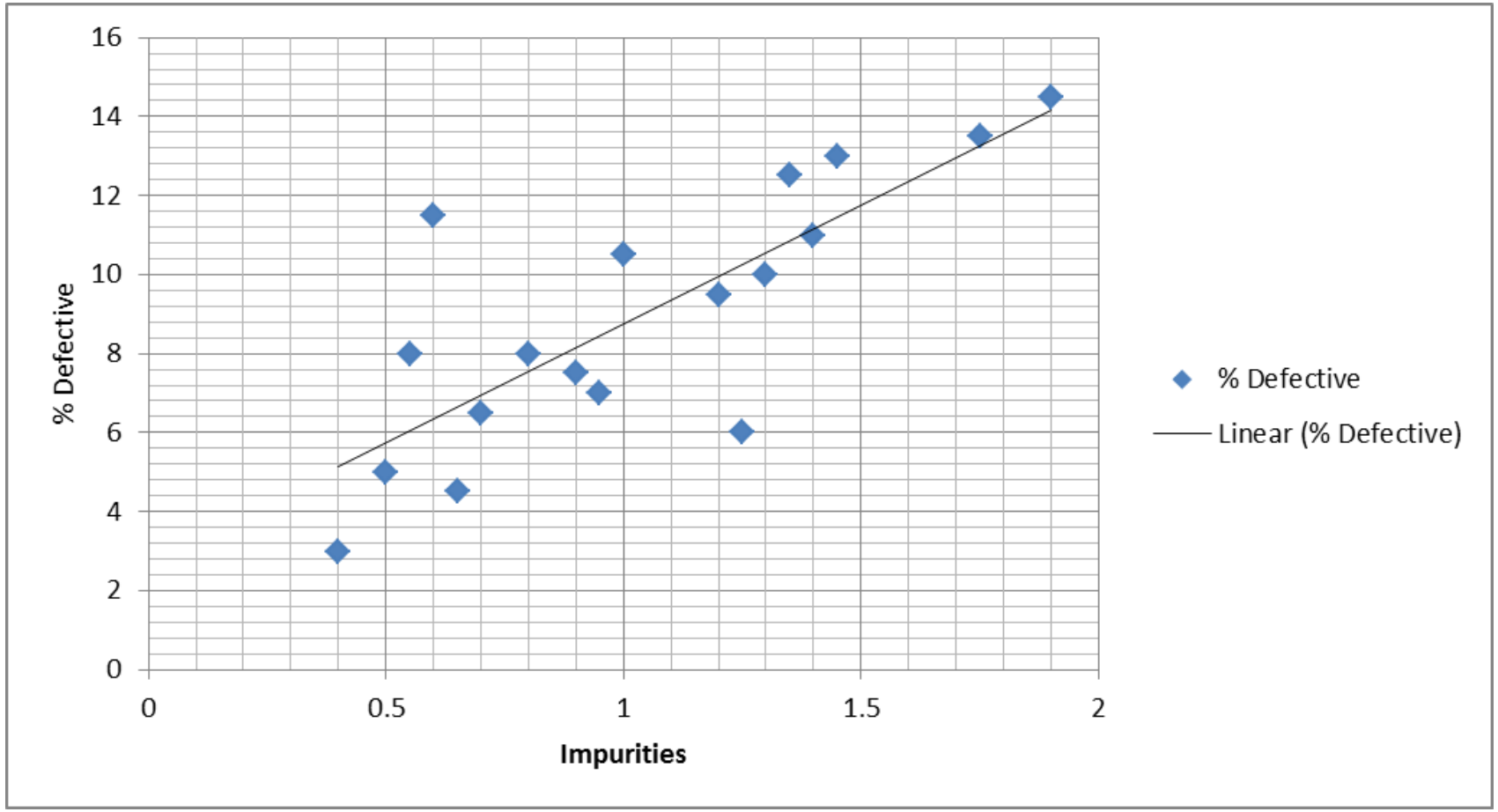
Is there a relationship between the the amount (%) of impurities in a raw material and the percentage defective product produced.

Impurities	% defective	Impurities	% defective
0.80	8.0	1.45	13.0
0.40	3.0	1.25	6.0
1.00	10.5	0.70	6.5
0.65	4.5	1.35	12.5
0.50	5.0	0.95	7.0
0.90	7.5	1.75	13.5
1.30	10.0	0.60	11.5
1.40	11.0	0.55	8.0
1.90	14.5	1.20	9.5

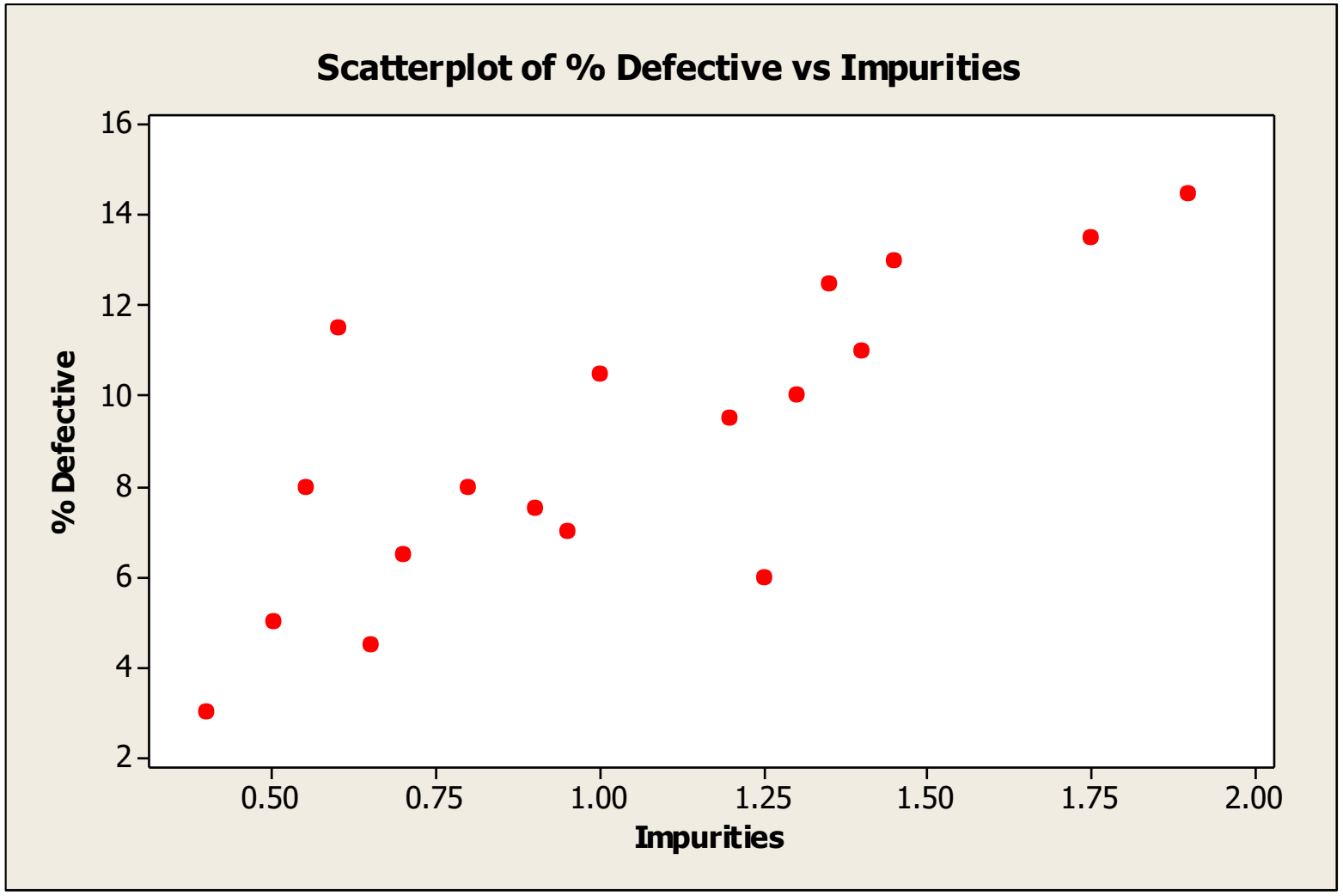
Excel Scatterplot of % Defective vs Impurities



Excel Scatterplot of % Defective vs Impurities



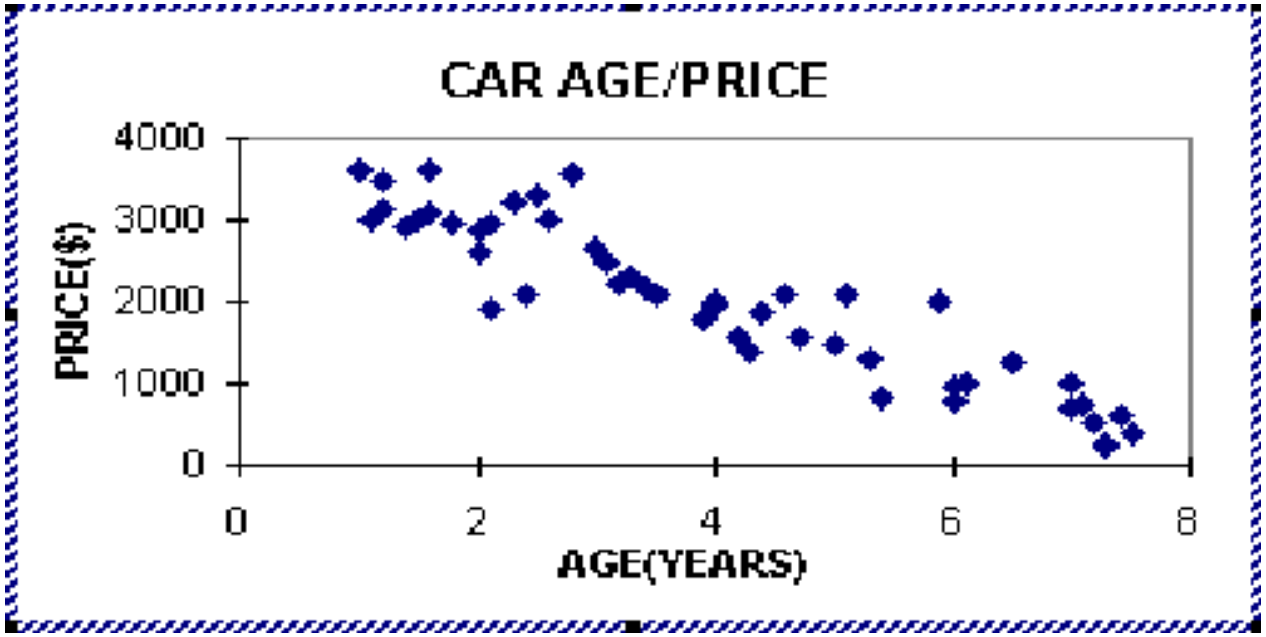
Minitab Graph



Construction of Scatter Diagrams

- 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) Vs Price. 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:



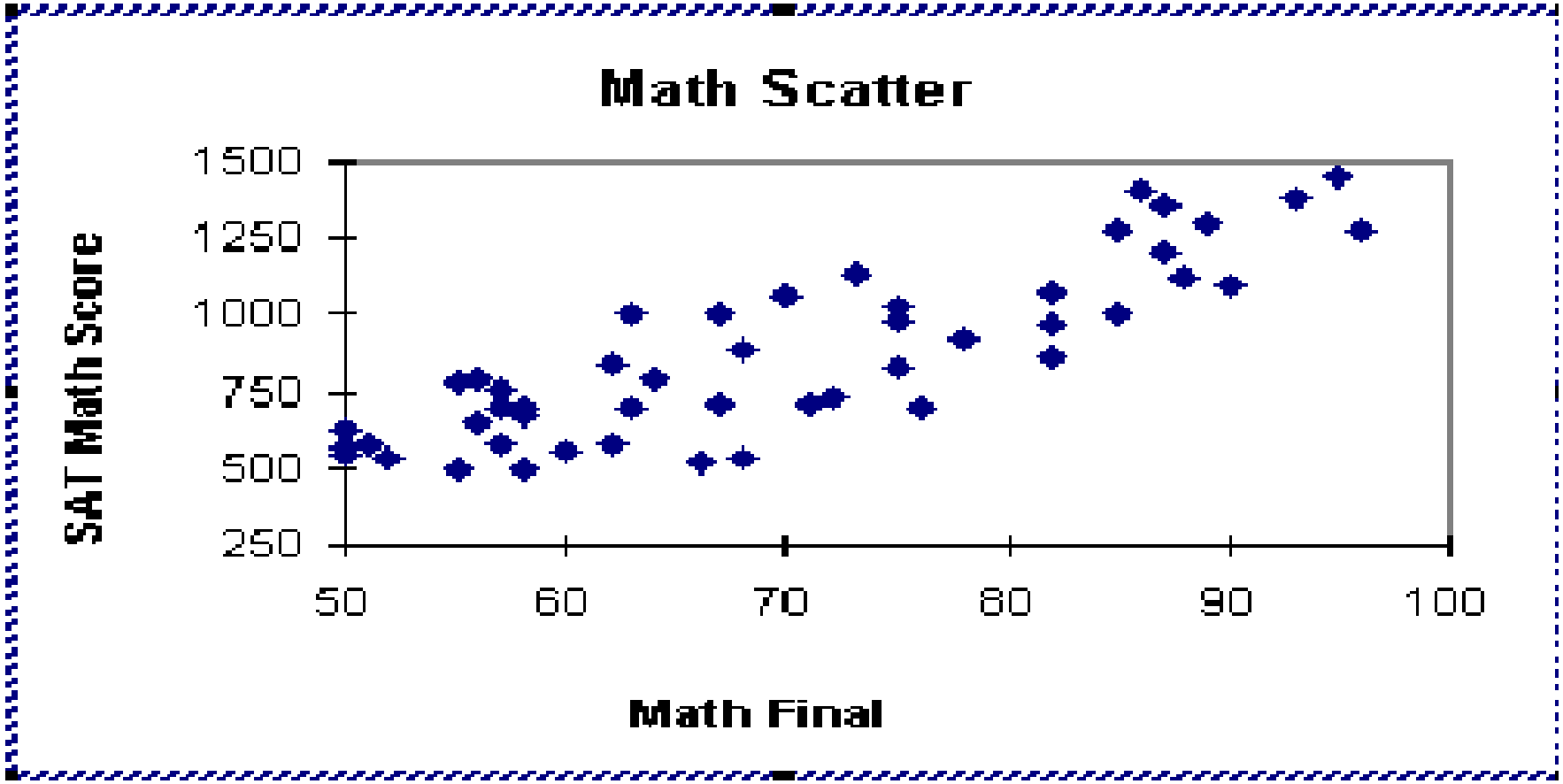
Interpretations

- The Car Age / Price is negative correlation, that is, as the amount of variable x increases, the variable y decreases.

- It is tempting to think this is a cause/effect relationship. This is an incorrect thinking pattern, because correlation does not necessarily mean causality.

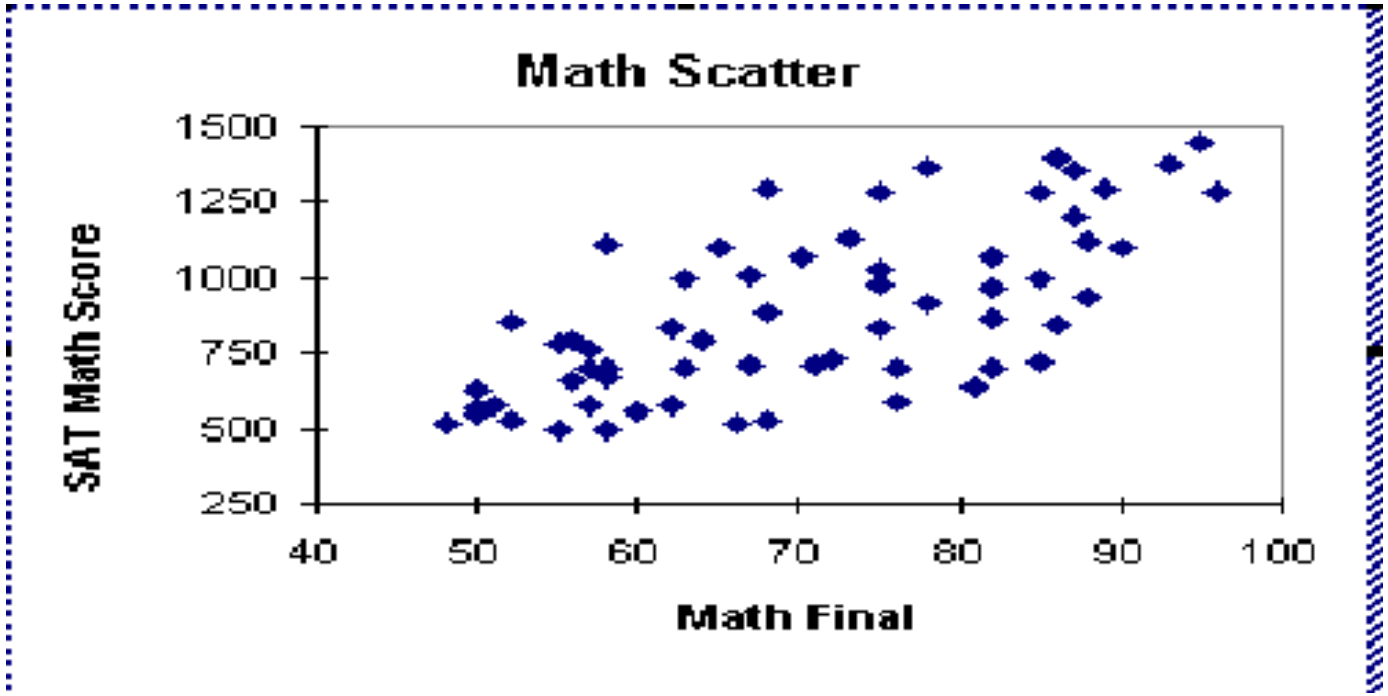
- This simple relationship could be caused by something totally different. For instance, the two variables could be related to a third, such as curing time or stamping temperature. Theoretically, if x is controlled, we have a chance of controlling y.

1. Positive Correlation



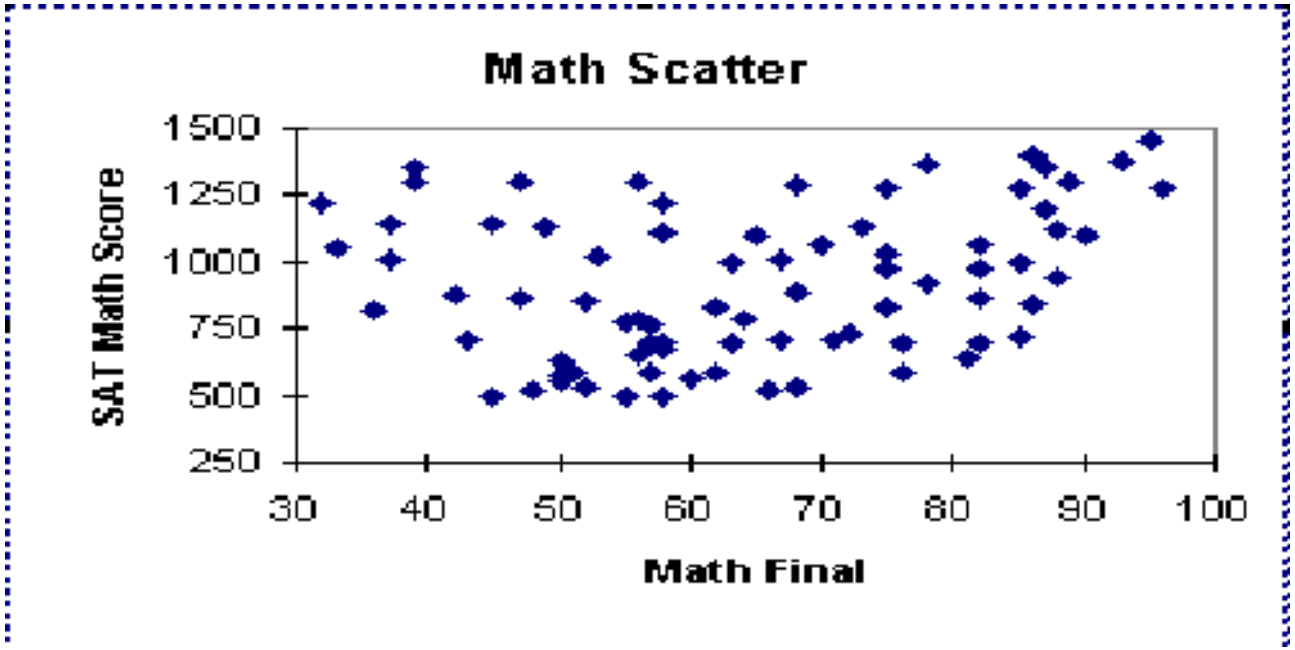
2. Possible positive correlation

- 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.



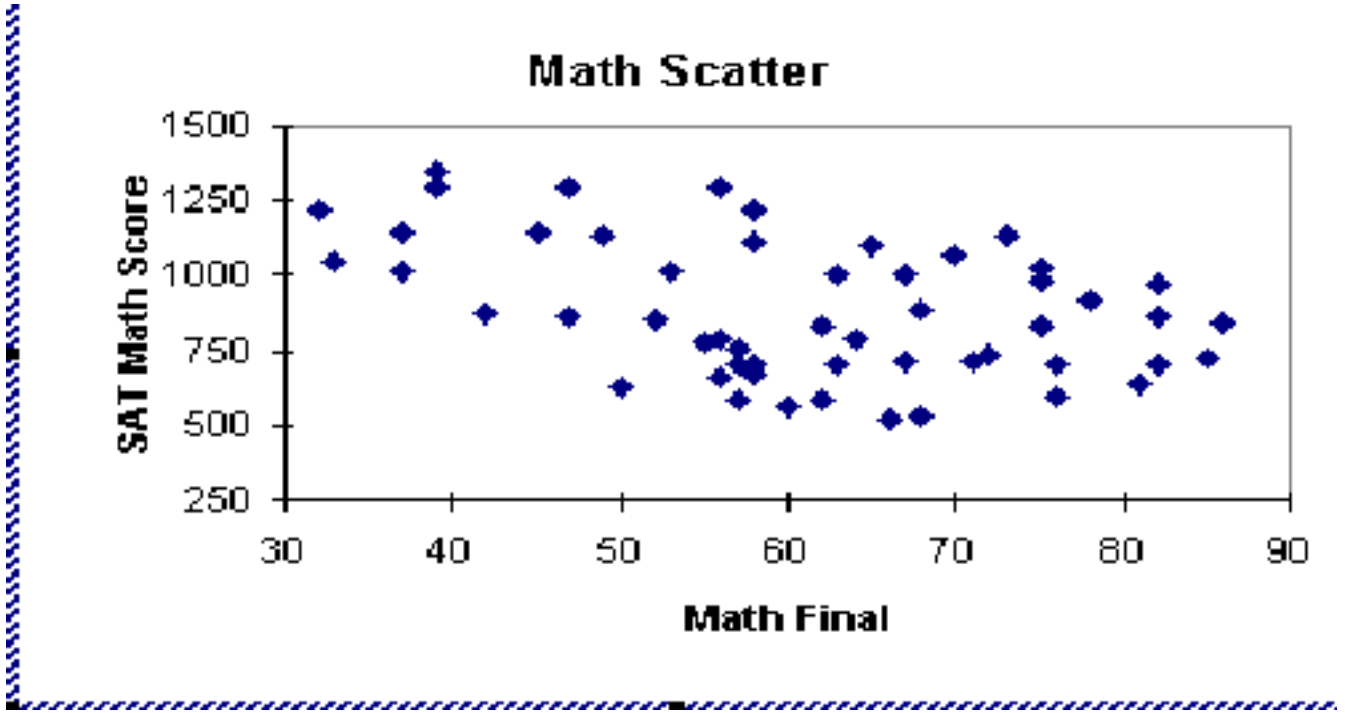
3. No correlation

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



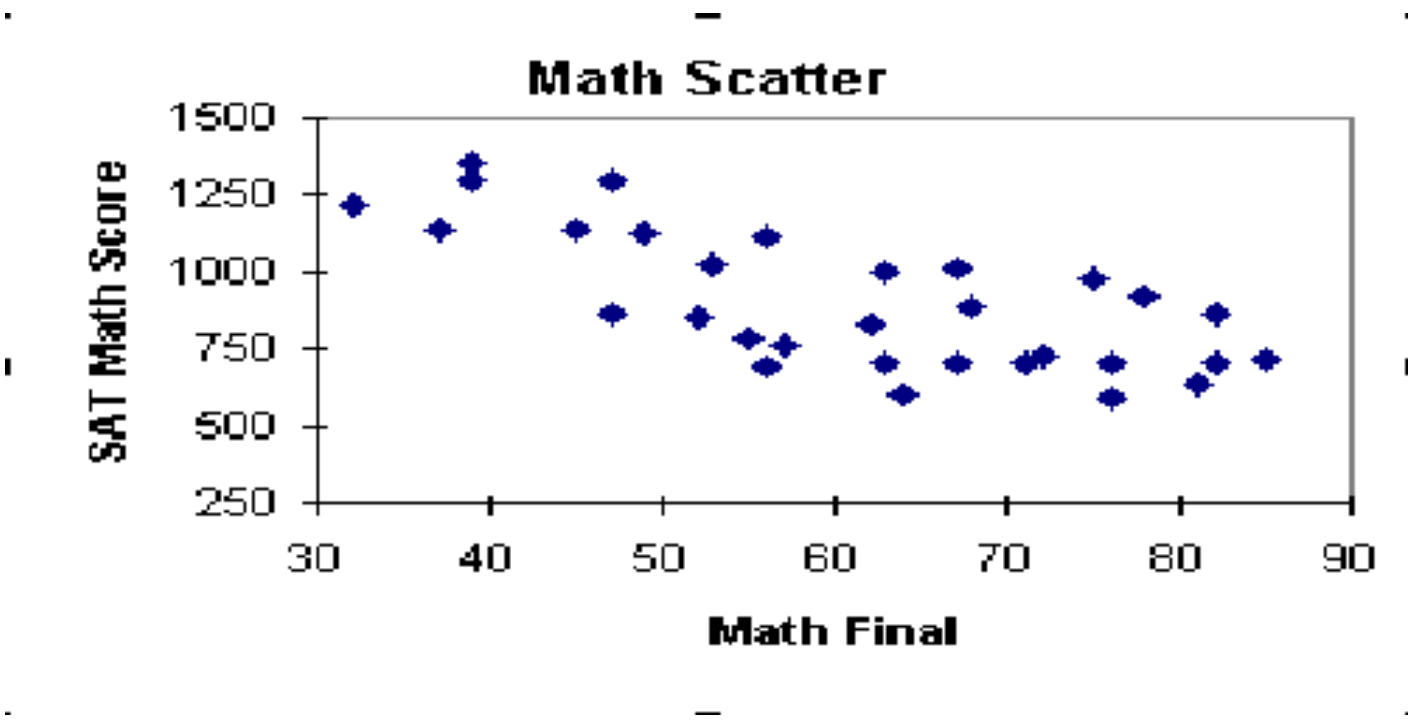
4. Possible negative

- 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.



5. Negative correlation

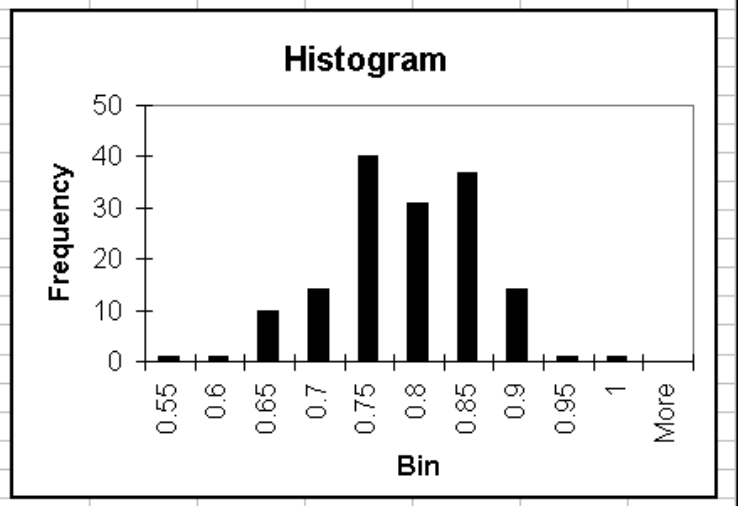
- Finally, we have the negative correlation category. An increase in x will cause a decrease in y. Therefore, if y is controlled, we have a good chance of controlling x.

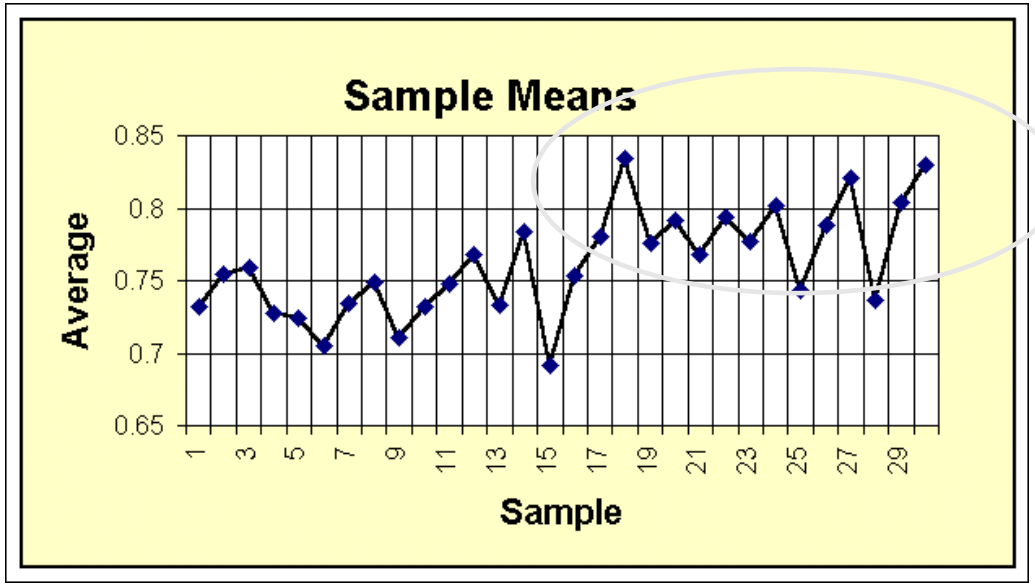


Why Control Charts?

Histograms do not take into account changes over time.

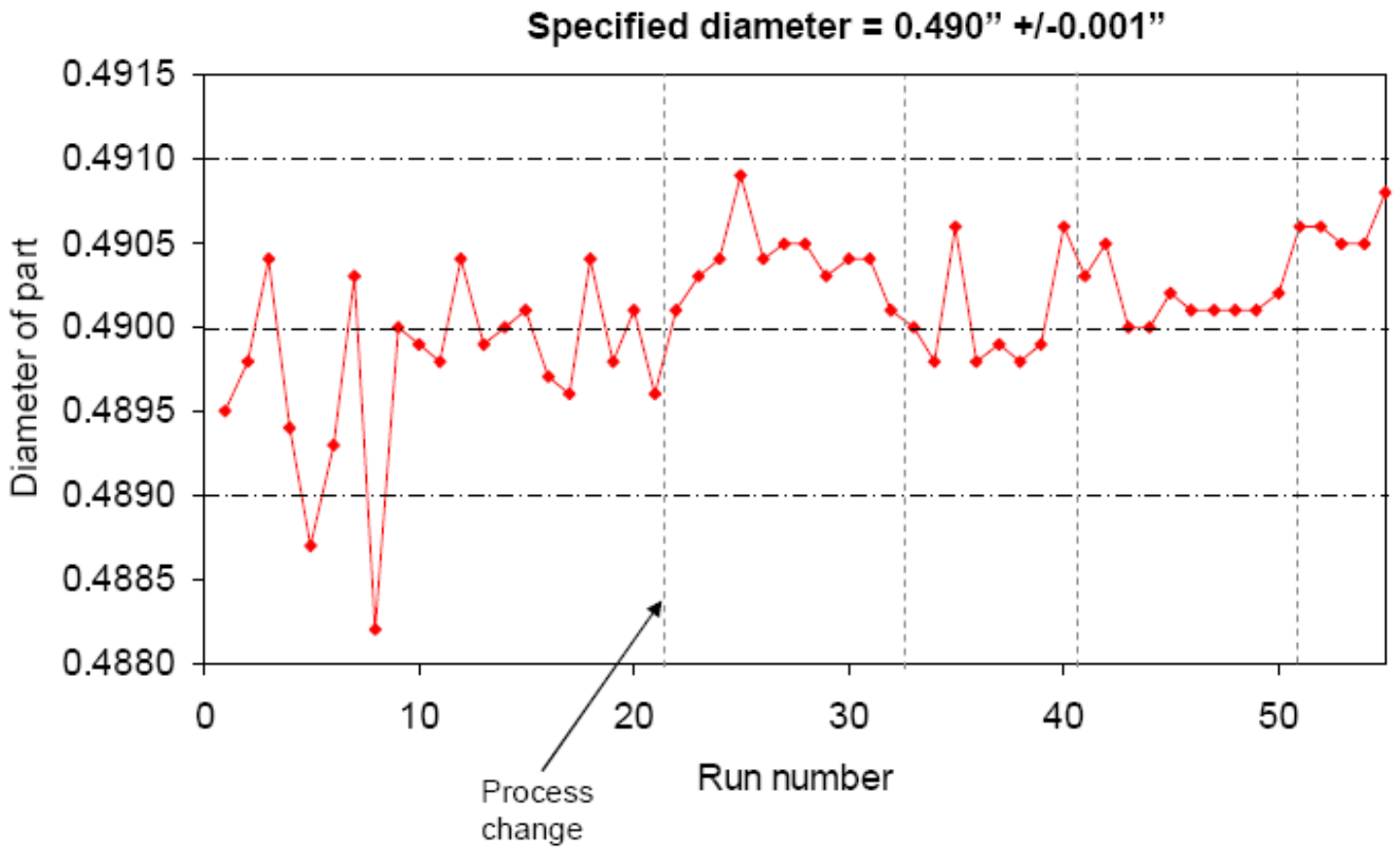
	A	B
1	**Frequency distribution**	
2	*Upper limit*	*Frequency*
3	0.55	1
4	0.6	1
5	0.65	10
6	0.7	14
7	0.75	40
8	0.8	31
9	0.85	37
10	0.9	14
11	0.95	1
12	1	1
13	More	0
14		
15	Average	0.762
16	Std. Dev.	0.0738





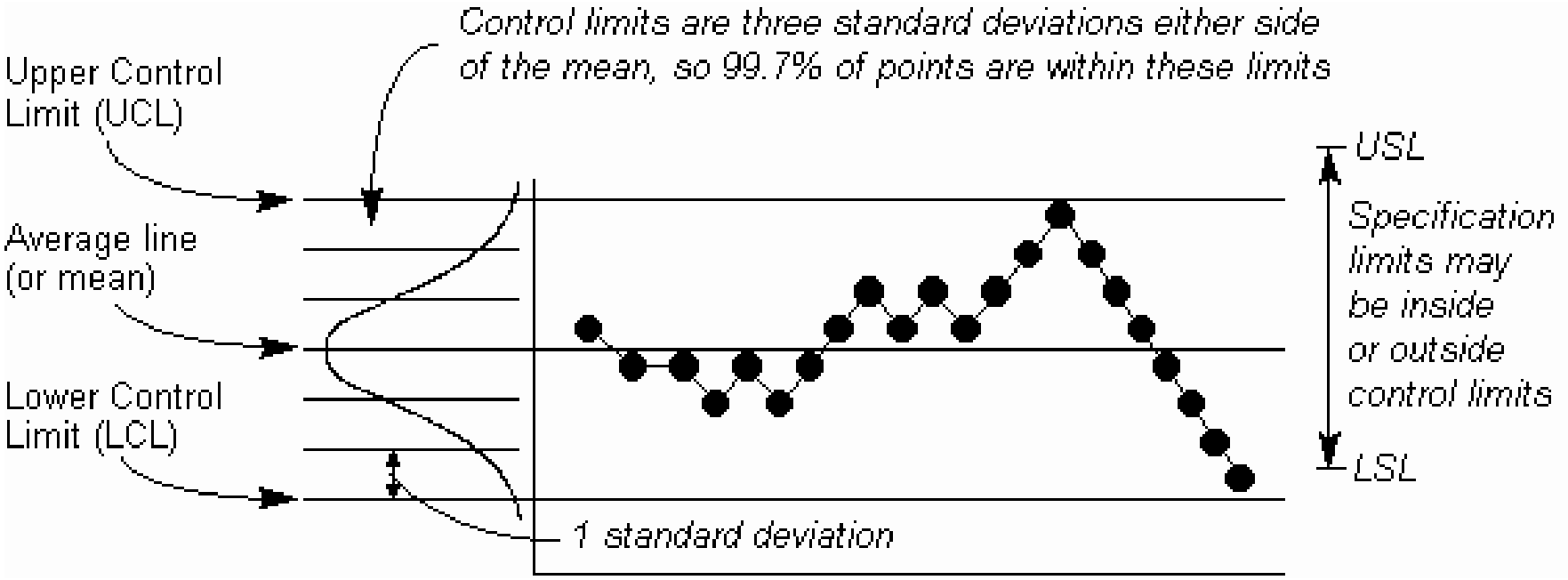
Control charts can tell us when a process changes

Run Chart – No Control Limits

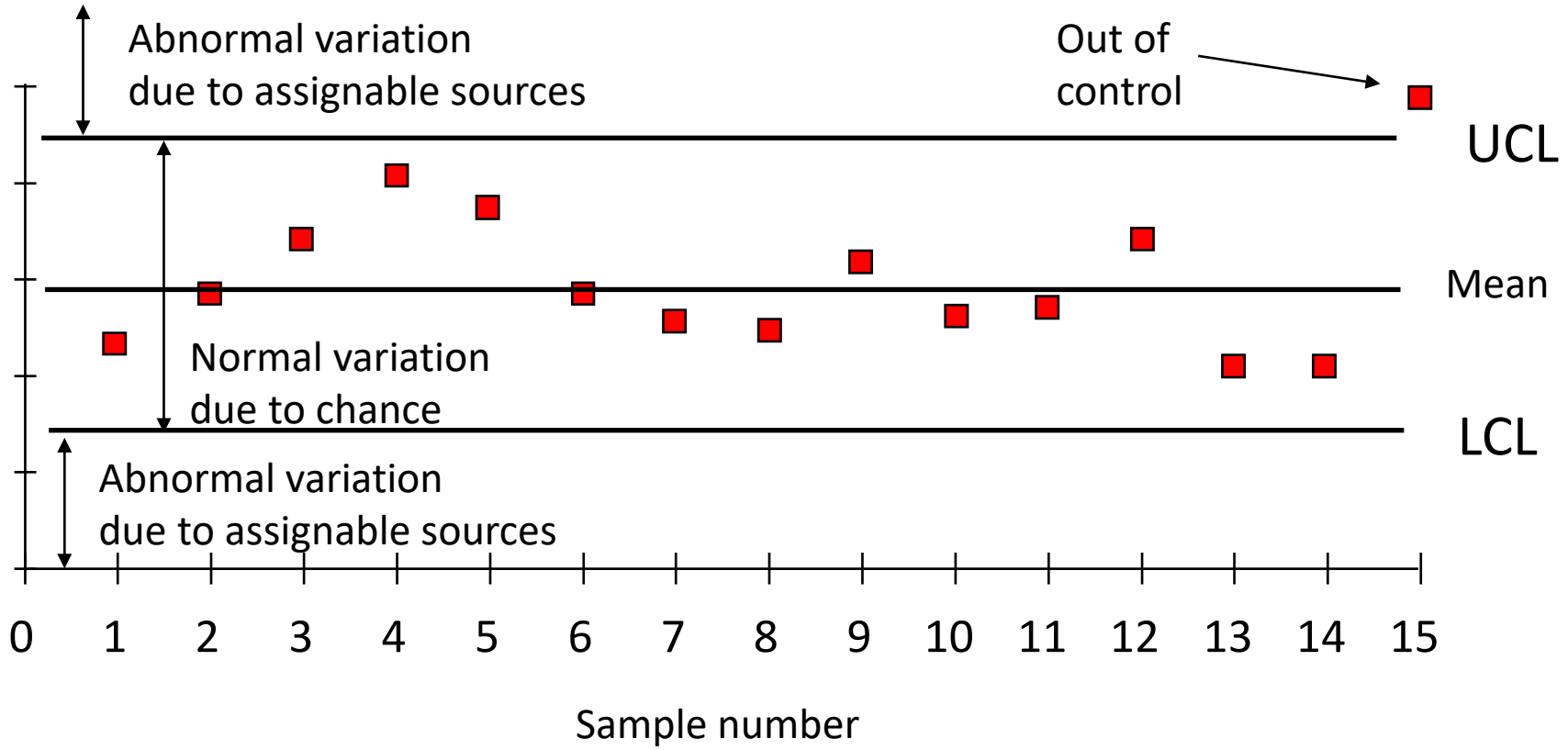


Shewhart control chart

- Graphical display of product characteristic which is important for product quality



Control Chart



What are the sources of variation in a process?

- Machine variation
- Raw Material variation
- Different methods used
- Measurement variation
- Operator variation
- Environmental factors

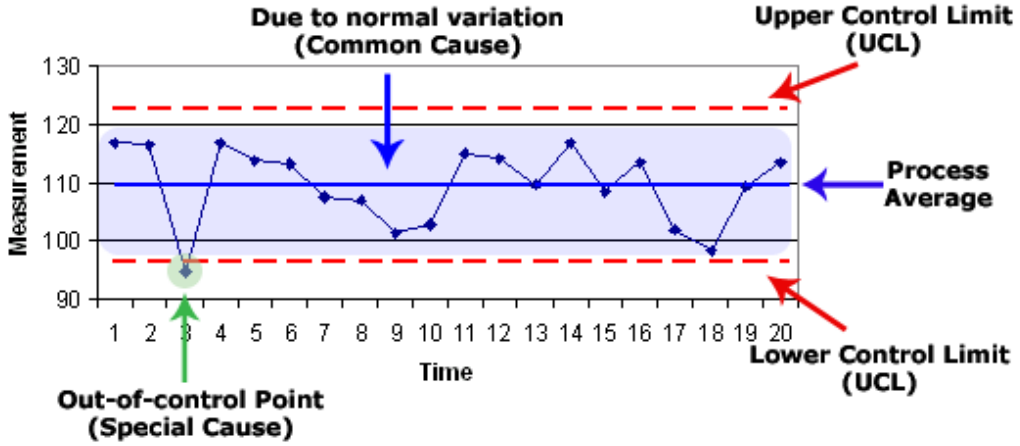
Variation and production processes

- Shewhart distinguished two forms of variation in production processes:

- Common causes
  - inherent to process

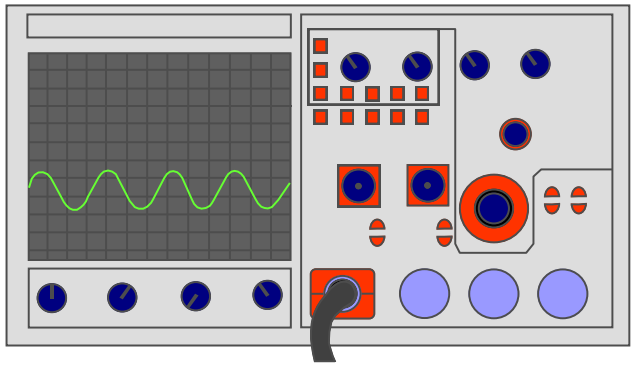
- Special causes
  - external causes
  - must be detected

  and eliminated

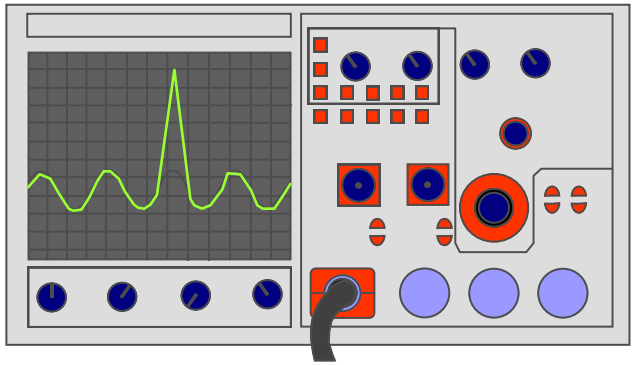


Variation - Two Main Causes

- Random, chance, constant, common, unknown causes
  - the "rhythm" of the process

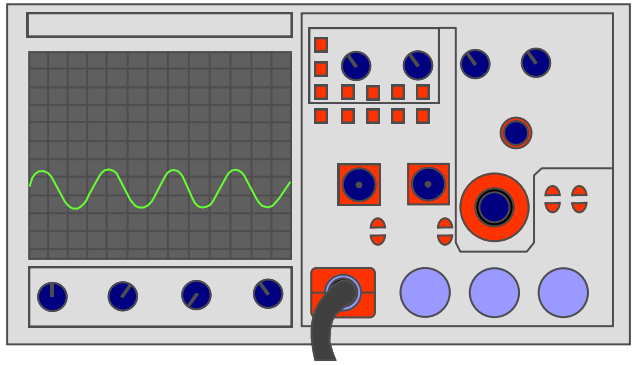


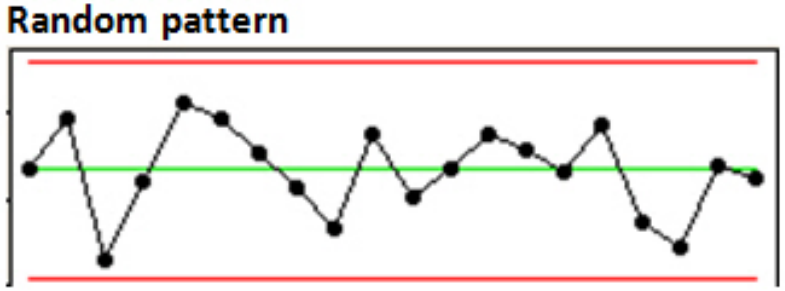
- Assignable, special causes
  - something has changed



Random - Chance Variation

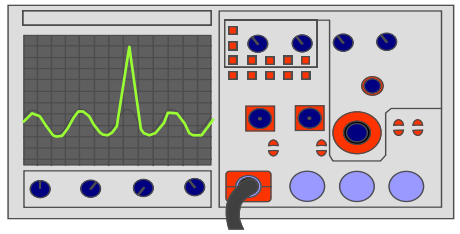
- "5M's and "E"
  - Machine
  - Material
  - Method
  - Measurement
  - Man (Operator)
  - Environment

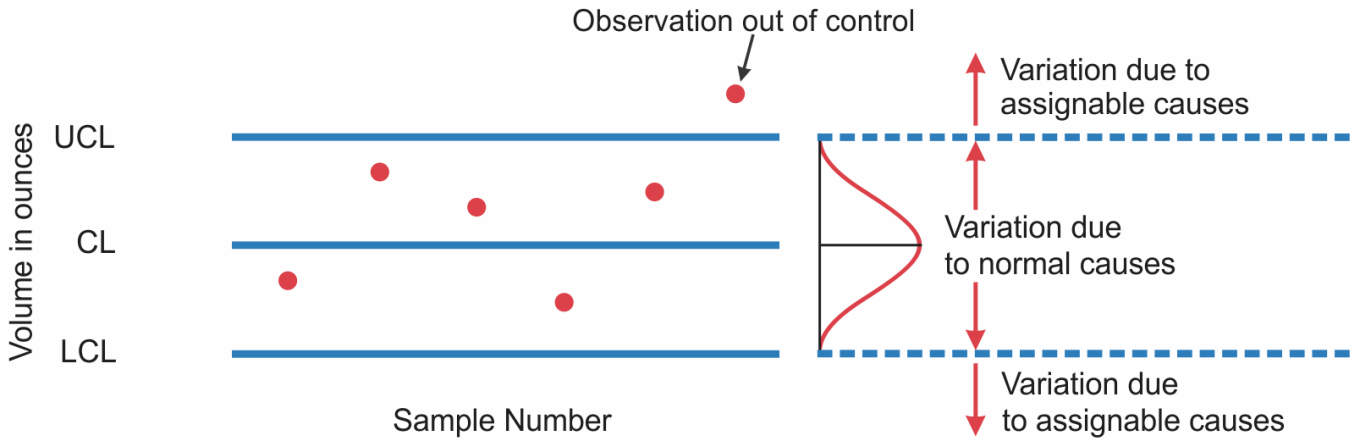




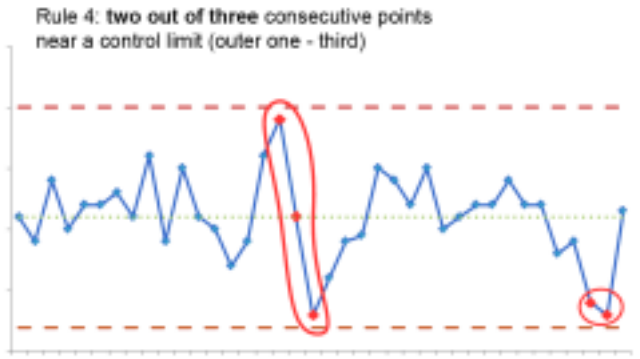
Assignable Causes of Variation:

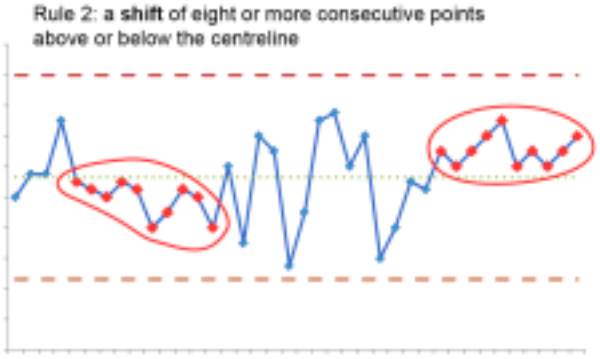
- Examples of things that may be assignable causes of variation:
  - Significant changes in raw material
  - machine troubles (damaged tool, plugged airpipe, etc.)
  - faulty measuring device
  - operator overcontrol
  - worker fatigue

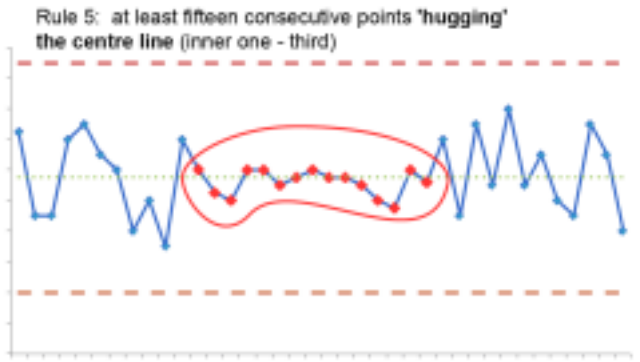


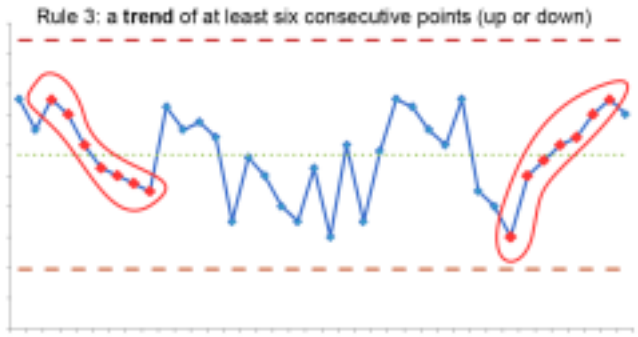


Assignable Causes of Variation:









Standard control chart rules for detecting special causes

Mistake Proofing

Mistake Proofing

- What is Mistake Proofing?
- Everyday Examples
- Effectiveness & ROI
- Error Proofing and SPC
- Inspection Techniques
- Types of Poka Yokes

What is Error Proofing?

- A Methodology, also know as Poka-Yoke, aimed at reaching zero defects through the improvement of processes and designs to minimize the chances of error and/or maximize delectability

- The idea is to stop defective parts from being passed on to the customer (internal or external)

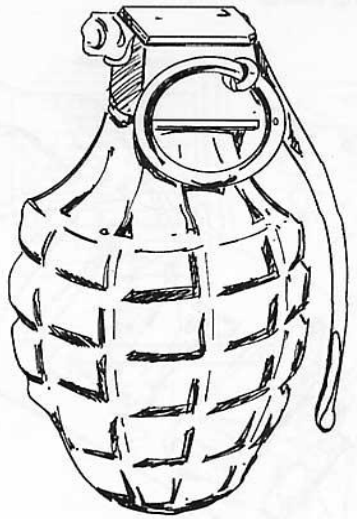
What is Mistake Proofing?

- The use of process or design features to prevent errors or their negative impact.
- Also known as ***Poka yoke,*** Japanese slang for “avoiding inadvertent errors” which was formalized by Shigeo Shingo.
- Inexpensive.
- Very effective.
- Based on simplicity and ingenuity.

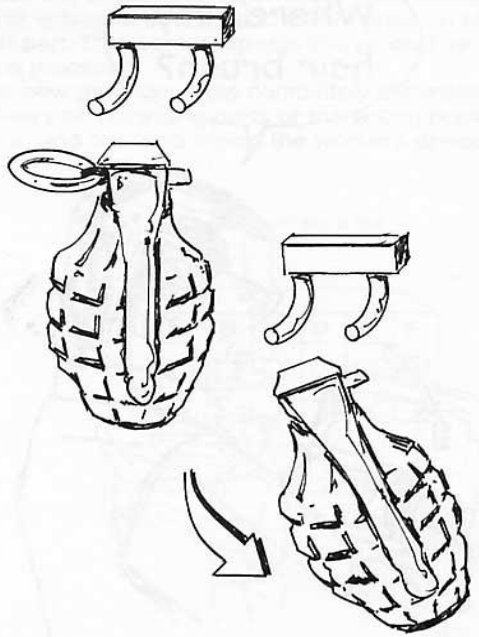
Poka Yoke – An Early Example

Description of Problem: Safety pins are inserted into hand grenades during assembly. If the pin is left out, the grenade will detonate if dropped.

Before Improvement
Because of the severe safety hazard, two inspectors originally observed each safety pin insertion. Even with two inspectors, a safety pin was accidentally omitted and the grenade killed a worker when it was accidentally dropped.

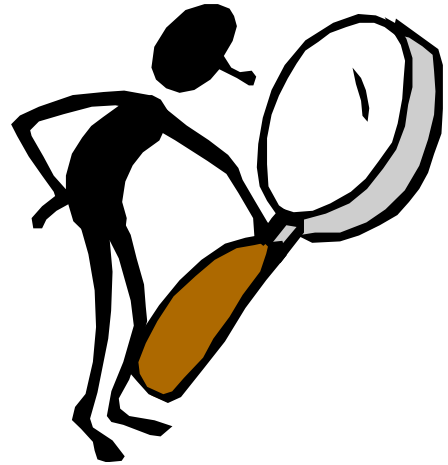


After Improvement
The holder for transporting the grenades to subsequent work areas was modified. Without the safety pin in place, it is impossible to load the grenade on the transport rack. Inspectors are no longer needed, and the hazard is eliminated. This concept was developed during World War II and is one of the earliest documented examples of mistake-proofing.



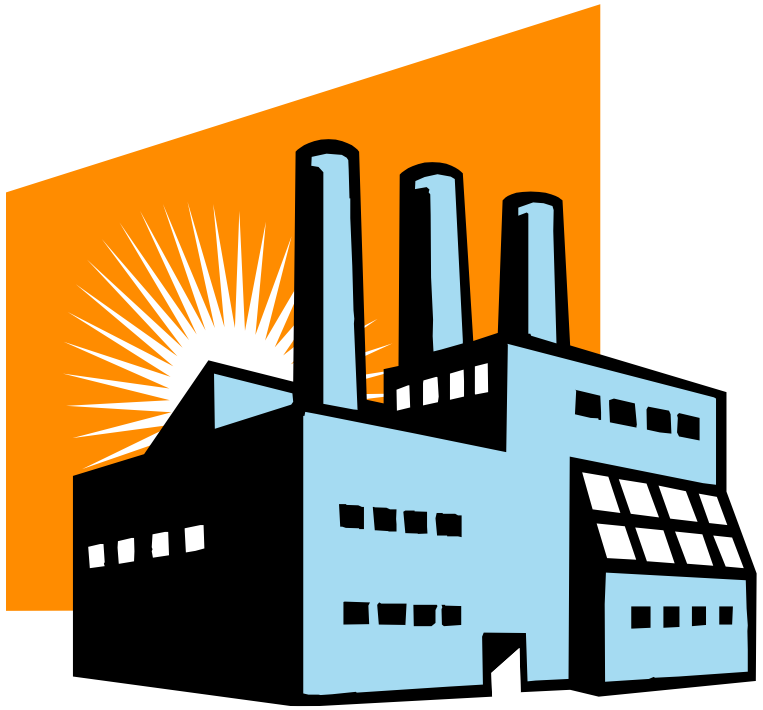
Why Use Error Proofing?

- Reduces chances of part defects, which …
  - Reduces customer complaints
  - Reduces cost of scrapped material
  - Reduces employee and machine time spent on rework and repairs
- Lessens the chance of damage to equipment
- Addresses the root cause of problems to prevent recurrences
- Acts as a 100% inspection point



Where is Error Proofing Used?

- Anywhere there is an opportunity to prevent error
  - Office
  - Design
  - Manufacturing



Office Error Proofing
Whose signature is required?

Before:

AUTHORIZING SIGNATURES

Operations Engineering Manager: _____ Date : _____

EM/EQA Supervisor: _____ Date : _____

Manufacturing Engineer: _____ Date : _____

Other (As Required): _____ Date : _____

Operations Manager: _____ Date : _____
(MED. or HIGH RISK ONLY)

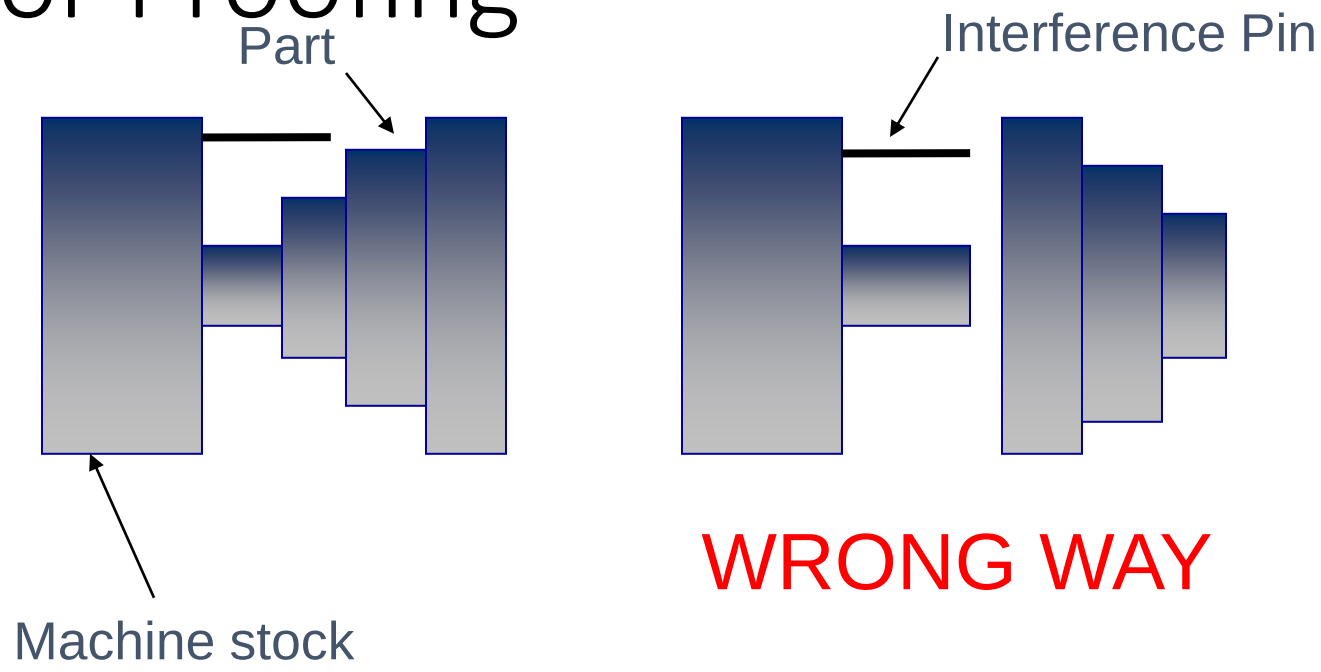
EQA Manager: _____ Date : _____
(MED. or HIGH RISK ONLY)

After:

Required Authorizing Signatures	Release/Audit update per SOP <or> Experiment Request	ECO Implementation	Part Reconditioning per SOP 12-FP-23-000	Non-ECO associated PCN RISK: VERY LOW, LOW (1.2)	Non-ECO associated PCN RISK: MODERATE, HIGH (3,4)	DATE
Originator						
CCB Eng. Rep.						
Ops. Supervisor*						
QA Supervisor*/QE						
Prod. Ops.Manager						
QA Manager						
Manuf. Eng or Other ex. CTS (as required)						

* *Supervisor of area affected by the change.*

Design Error Proofing



An interference pin prevents a worker from installing a part the wrong way. The best error proof solutions are simple, inexpensive, and fail-safe.

Everyday Examples I

Look Left on London Streets
(Knowledge in the World)

Fueling area of car has three error-proofing devices:

1. Insert keeps leaded-fuel nozzle from being inserted
2. Tether does not allow loss of petrol cap
3. Petrol cap has ratchet - to signal proper tightness and over tightening.

Everyday Examples II

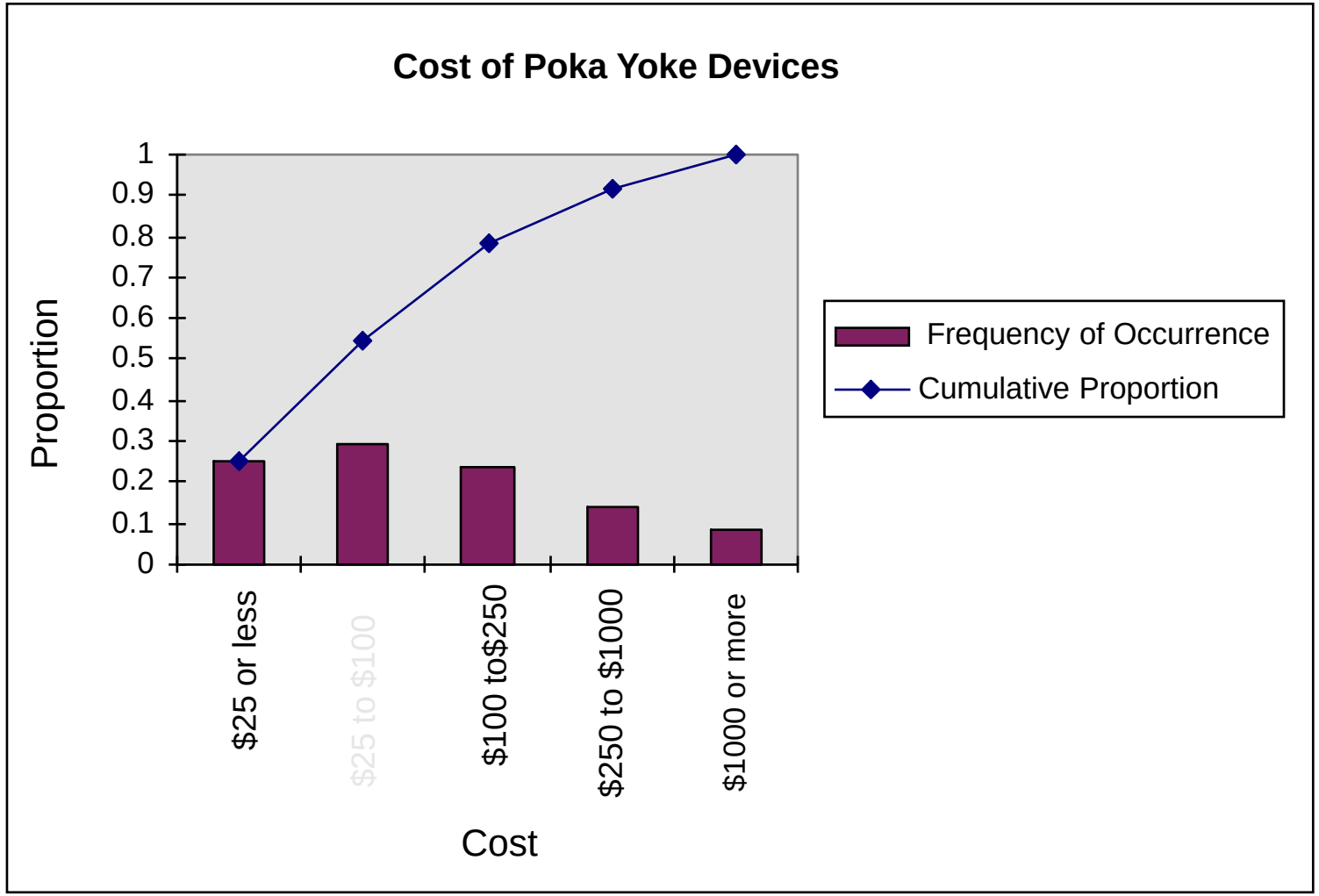
In the US, new lawn mowers are required to have a safety bar on the handle that must be pulled back in order to start the engine. If you let go of the safety bar, the mower blade stops in 3 seconds or less.

Everyday Examples III

This three-handled cup, a Tyg, was used in England in the late 1700s to allow easy passing of a cup from person to person.

Ref: www.jnd.org/GoodDesign.html

Cost of Poka Yoke Devices



Cost of Defects

Does it cost more to make processes better ?
NO

Making processes better leads to reduced

- Rework
- Scrap
- Warranty costs
- Inspection costs

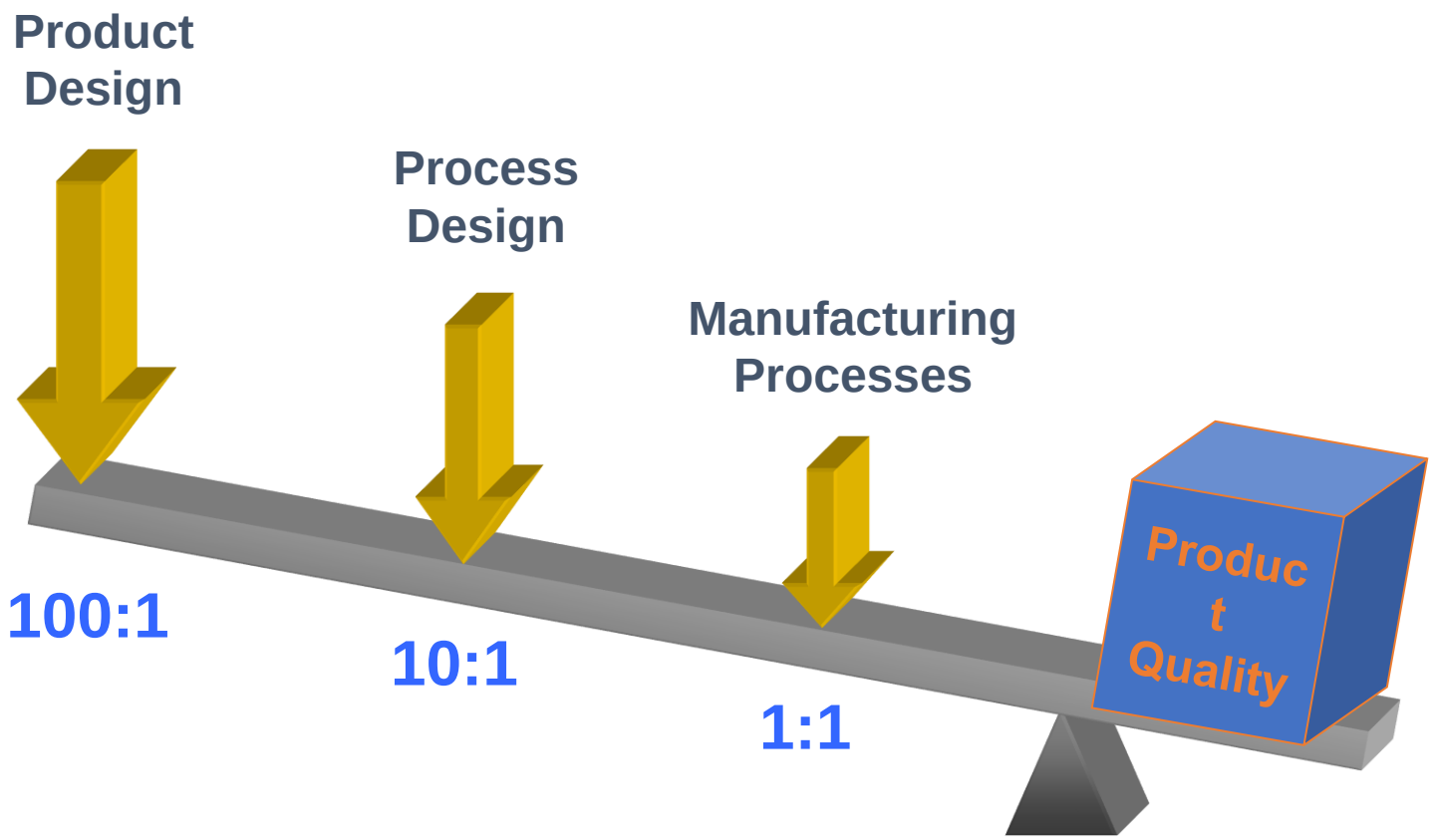
1-10-100 Rule

The 1-10-100 rule states that as a product or service moves through the production system, the cost of correcting an error multiplies by 10.

Activity	Cost
Order entered correctly	$ 1
Error detected in billing	$ 10
Error detected by customer	$ 100

Dissatisfied customer shares the experience with others…

When to Start Error Proofing



As Early As Possible

Mistake proofing Puts "Knowledge in the World" In addition to "Knowledge in the Head"

Head:

- "Improve" SOPs (increasing complexity?)
- Retrain
- Re-certify skills
- Manage & enhance attentiveness

World:

- Provide clues about what to do
- Change process design: embed the details in the process
- Frees mind to consider the "big picture"
- Facilitates "knowledge work"

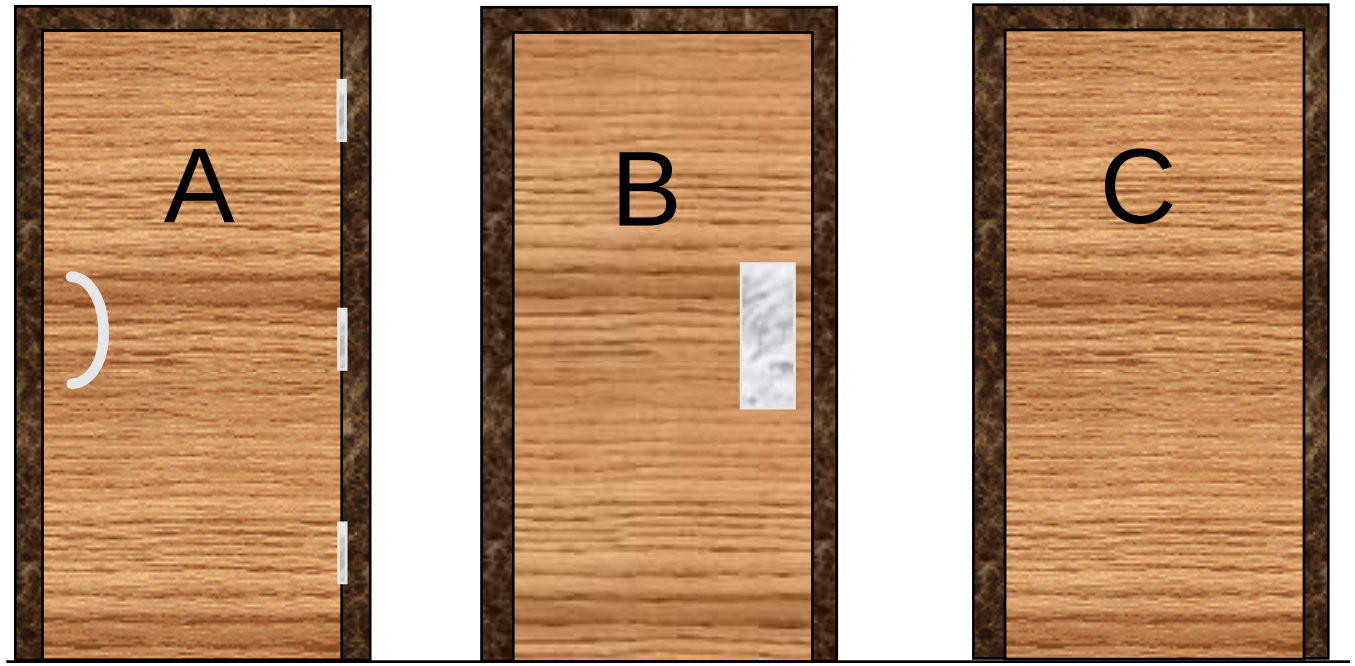
Natural Mappings
Which dial turns on the burner?
Ref: Figure 1.8

Stove A

Stove B

Natural Mappings
How would you operate these doors?

Push or pull? left side or right? How did you know?



Visibility and Feedback

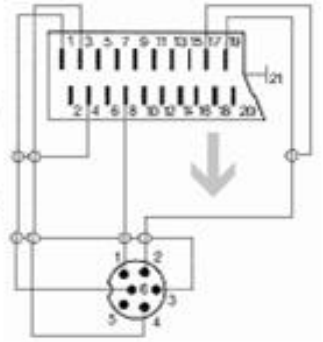
- Visibility means making relevant parts visible, and effectively displaying system status.
- Feedback means providing an immediate and obvious effect for each action taken.
  - Eg. Google Spelling Mistake

Electronic Connectors

- Shapes and colours extensively used to prevent equipment being incorrectly connected







Appliances

- Microwave
  - Will not work until the door is shut

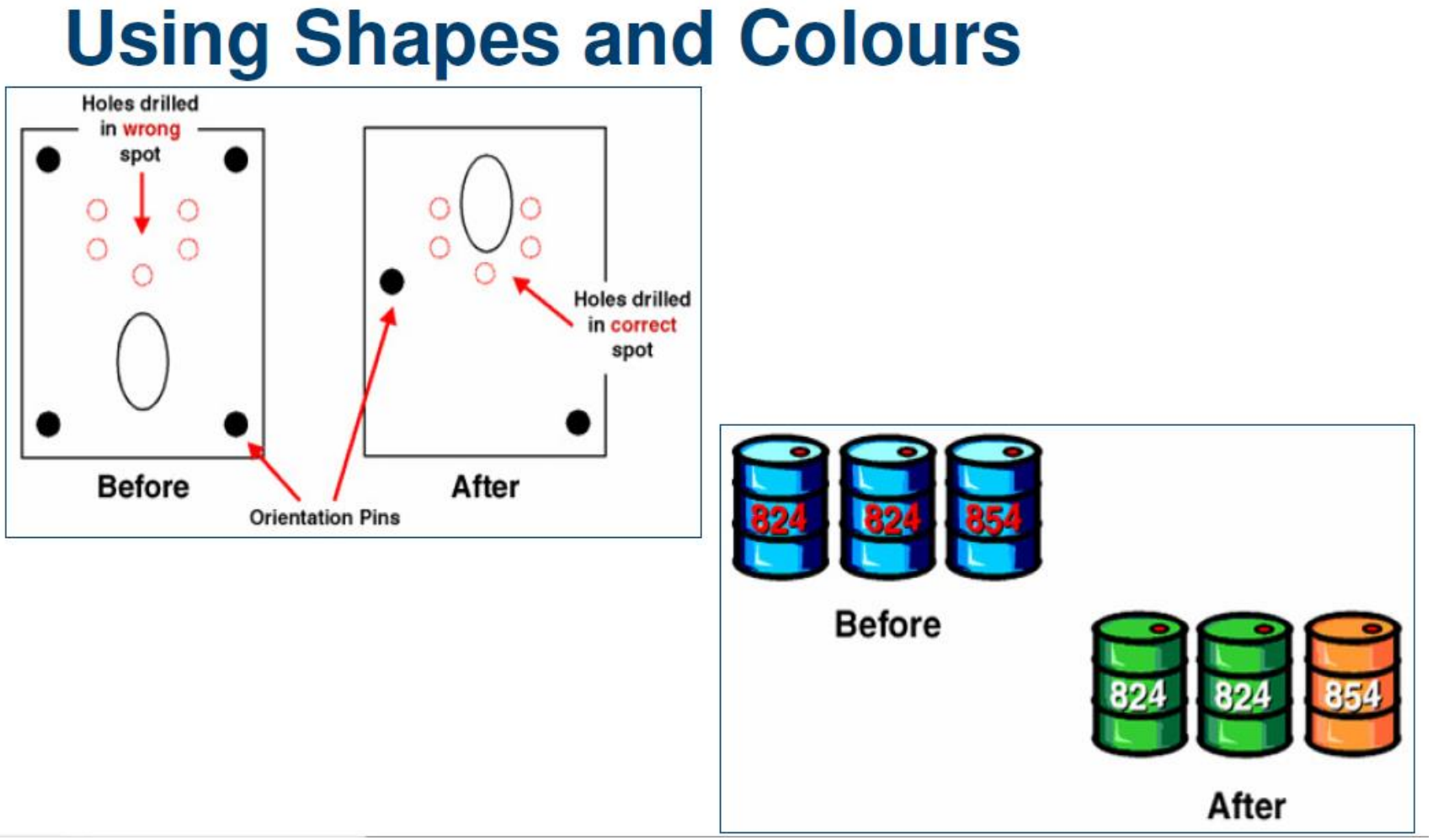
- Washing machine
  - Will not start until door is closed
  - Will not allow door to be opened until cycle is complete

Automotive

Low Brake Pad Warning Indicators

- Brake pad wear indicators are fitted to most modern cars. They are made up of 2 insulated wires which fit in a hole inside the brake pad
- As brake pads wear the insulated cables become exposed and the metal brake disk connects them like a switch
- An electrical signal then lights up a warning lamp on the cars dashboard alerting the driver before the brakes fail

Using Shapes and Colours



Using Lights and Sounds

Using Lights, Sounds, Signs and Barriers

Control or Regulatory Functions

Table 1.3. Control (or regulatory) functions

Regulator function	Mistake prevention	Mistake detection
Forced control	Physical shape and size of object or electronic controls detect mistakes that are being made and stop them from resulting in incorrect actions or omissions.	Physical shape and size of object or electronic controls detect incorrect actions or omissions before they can cause harm.
Shut down	The process is stopped before mistakes can result in incorrect actions or omissions.	The process is stopped immediately after an incorrect action or omission is detected.
Warning	A visual or audible warning signal is given that a mistake or omission is about to occur. Although the error is signaled, the process is allowed to continue.	A visual or audible warning signal is given that a mistaken action or omission has just occurred.
Sensory alert	A sensory cue signals that a mistake is about to be acted upon or an omission made. The cue may be audible, visible, or tactile. Taste and smell have not proved to be as useful. Sensory alerts signal mistakes but allow the process to continue.	A sensory cue signals that a mistake has just been acted upon or an omission has just occurred (Figure 1.10).

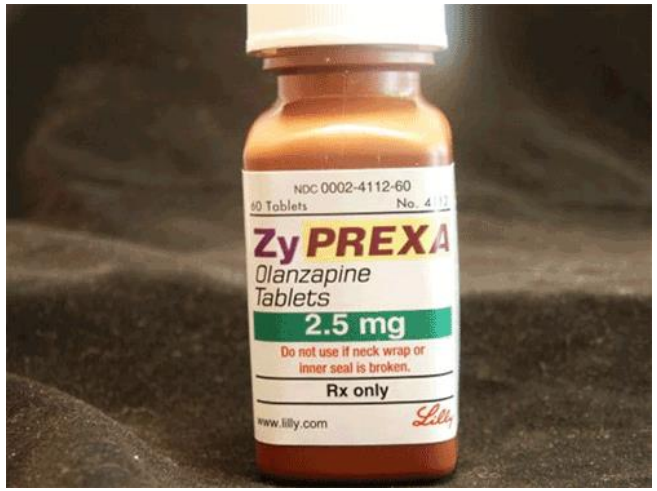
Control or Regulatory Functions

Figure 5.5. Anti-scald valve.

The device in Figure 5.6 is inserted into the end of the shower pipe and works much like the previous device. It also contains a valve that closes when water becomes too hot. This device installs in a few minutes using an Allen wrench and is completely hidden once installed.

Each gas is colour coded and has a uniquely sized fitting to avoid inappropriate gas usage

Tall Man lettering



Tall Man lettering (is the practice of writing part of a drug's name in upper case letters to help distinguish sound-alike, look-alike drugs from one another in order to avoid medication errors.
For example, in Tall Man lettering,

"prednisone" and "prednisolone" should be written

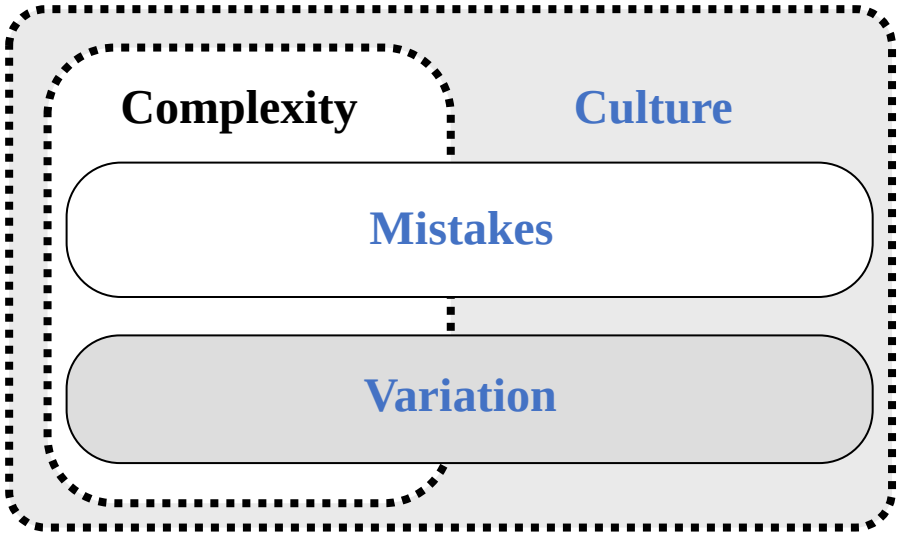
"predniSONE" and "prednisoLONE", respectively.

Similarily for Zyprexa and Zyrtec.
http://www.fda.gov/Drugs/DrugSafety/MedicationErrors/ucm164587.htm

Where does mistake proofing fit?

- *Non-Conformances come from many sources including:*
- **Variation**
- **Culture**
- **Complexity**
- **Mistakes**

Each must be managed to improve quality and reliability.



The difficulties with human error
Why existing tools are not enough

<u>Motorola findings:</u>

...it became evident early in the project that achieving a C_p greater than 2 would go only part of the way. Mistake proofing the design would also be required ... Mistake proofing the design is an essential factor in achieving the [total number of defects per unit] goal.

Smith, B. IEEE Spectrum 30(9) 43-47

Error proofing & SPC

- SPC is good at detecting shifts in the process mean or variance. Changes to the process must be ongoing to be readily detected.
- Human errors tend to be rare, intermittent events. They are not readily detected by control charts.
- Use error proofing (not SPC) to reduce defects caused by human error

Motorola got an order of magnitude closer to their goal using a combination of SPC and error proofing.

To err is human

Have you ever done the following:

- Driven to work and not remembered it?
- Driven from work to home when you meant to stop at a shop to buy milk?

It happens to workers, too

- Workers finish the shift and don't remember what they have done.
- After building green widgets all morning, the workers put green parts on the red widgets in the afternoon.
- The mistakes I would like to focus on are some times called slips. They occur when an action is executed on "**autopilot**" but has an unintended result.
- Mistake-proofing usually(but not always) will involve precluding behaviors that **under other circumstances would be correct.**
- Putting green parts on widgets is a correct behavior when the widgets are green, but not when they're red.

“Be more careful” not effective

- “The old way of dealing with human error was to scold people, retrain them, and tell them to be more careful … My view is that you can’t do much to change human nature, and people are going to make mistakes. If you can’t tolerate them ... you should remove the opportunities for error.”

- “Training and motivation work best when the physical part of the system is well-designed. If you train people to use poorly designed systems, they’ll be OK for awhile. Eventually, they’ll go back to what they’re used to or what’s easy, instead of what’s safe.”

- “You’re not going to become world class through just training, you have to improve the system so that the easy way to do a job is also the safe, right way. The potential for human error can be dramatically reduced.”

Chappell, L. 1996. The Pokayoke Solution. *Automotive News Insights,* (August 5): 24i.
LaBar, G. 1996. Can Ergonomics Cure ‘Human Error’? *Occupational Hazards* 58(4): 48-51.

A New Attitude Toward Preventing Errors

"Think of an object's user as attempting to do a task, getting there by imperfect approximations. Don't think of the user as making errors; think of the actions as approximations of what is desired."*

*Source: Norman

A New Attitude Toward Preventing Errors

- Make wrong actions more difficult
- Make it possible to reverse actions —to “undo” them—or make it harder to do what cannot be reversed.
- Make it easier to discover the errors that occur.
- Make incorrect actions correct.

Operator Error?

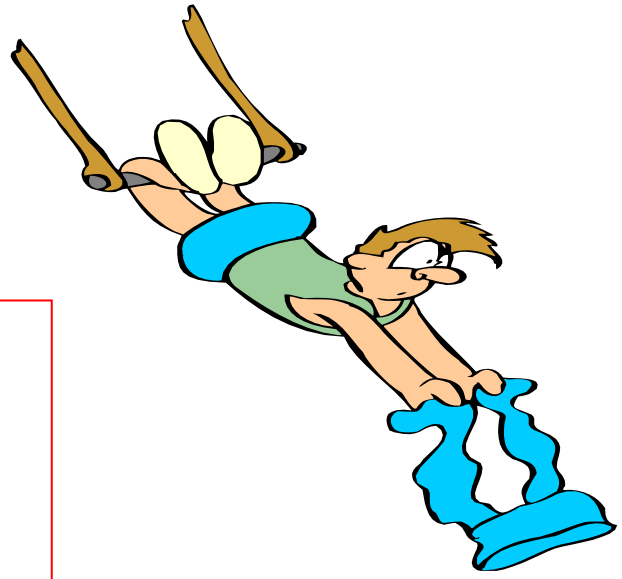
No Finger Pointing.

Operators and Machines will sometimes make mistakes.

Find ways to keep errors from becoming defects!

Error Proof your Process

Recognize that it is natural for people to make mistakes.



Not noticing that an error is made or a machine is not functioning does not make a person stupid or foolish.

Ten Types of Human Mistakes

Simple errors-the most common cause of defects-occur unpredictably.

- Forgetfulness
- Misunderstanding
- Wrong identification
- Lack of experience
- Willful (ignoring rules or procedure)
- Inadvertent or sloppiness
- Slowliness
- Lack of standardisation
- Surprise (unexpected machine operation, etc.)
- Intentional (sabotage)

Human Error Categories

- Learning Gap – don't know or don't understand – no training or poor quality training

- Memory Gap – know, but don't remember – after break, after holidays, long absence – after recent change not reinforced

- Application – know, but did not use correctly – over burden - stressed

(*Source Talsico ; www. Talsico.com)

Human Error Categories

- Attention- know but distracted by other factors – wrong position – visual inspection units wrong place
- Omission – know, but missed a step – overburden, pressure
- Decision – incorrect decision is made – decisions are emotional why was wrong one made?
- Procedure – inconsistent performance due to poorly documented procedure

(*Source Talsico ; www. Talsico.com)

Corrective Action

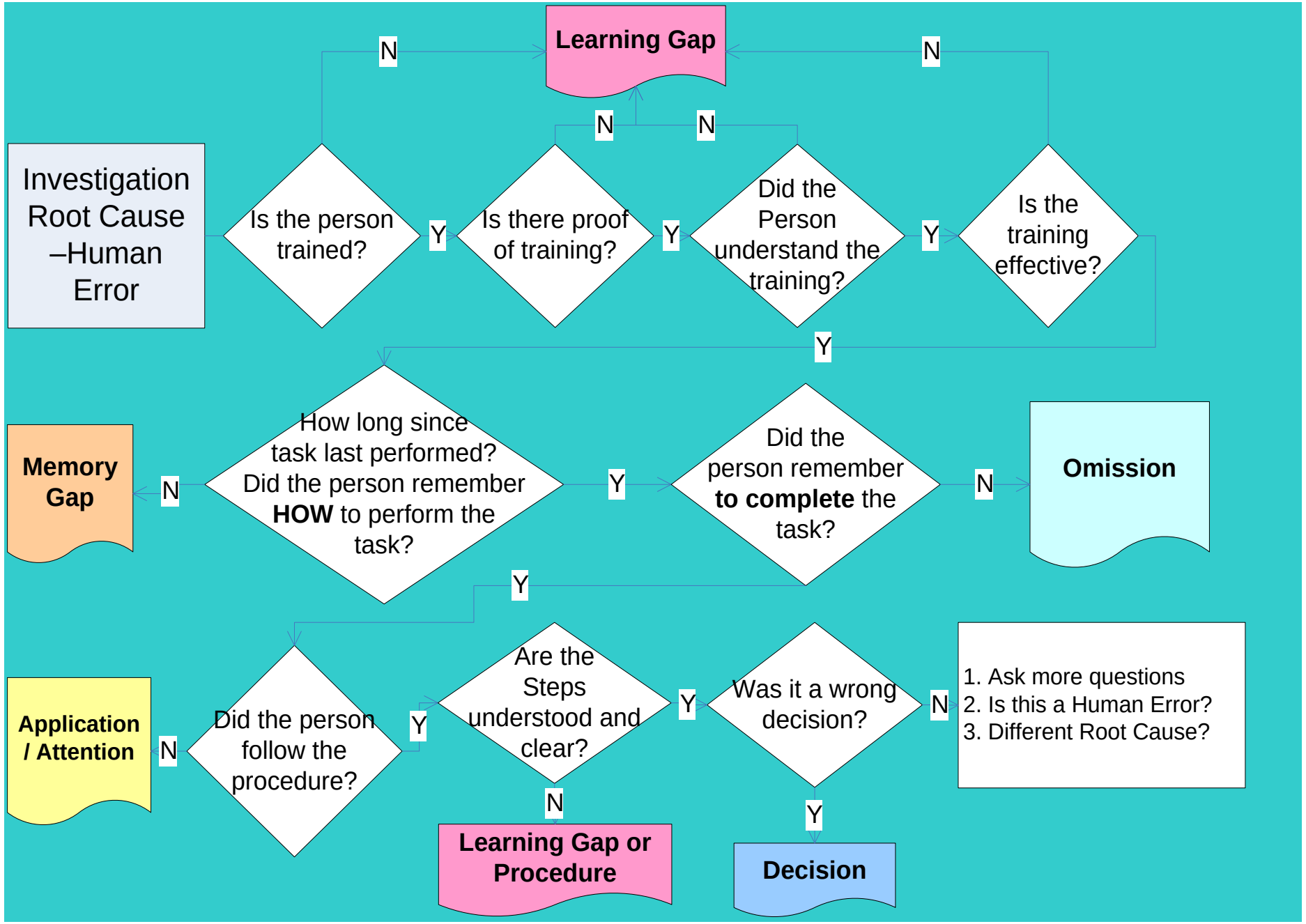
- Recent poll on the Quality newsgroup on the internet: A majority reported at least 20-30% of corrective actions were “worker reprimanded and retrained.”

- The admonition to “be more careful” or “pay attention” are not effective for humans, especially in repetitive environments.

Corrective Action Effectiveness

Type of Action	**Effectiveness %**
Improve or introduce inspection	0
Do it better next time	0-30
Improve product documentation	30-60
Improve process documentation	30-60
Add to common errors list	30-60
Education / Training	30-60
Redesign / Rewrite Test Code	60-100
Redesign part / subassembly	60-100
Tool / (Avoid or Remove)	60-100
Improve System or Production	60-100

Note:
1) Action taken may include multiple Corrective Actions from the above list.



Corrective Action-Error Control Hierarchy

1. Mistake-Proof (Poka-Yoke control)

– eliminate potential for errors – Engineering Controls

e.g Machine won't start unless door is locked

2. Error Prevention (Poka-Yoke warning)

– SPC, alarms, dress code signs, yellow lines

e.g Alarm sound if car lights left

3. Error Detection

– Ability to "catch" error before accident or batch release

e.g Batch Record review, visual inspection

4. Redundancy

– Duplication of effort

e.g. multiple checks

Human Error Analysis

5 Whys

- Method for getting people to think about true root cause
- Prevents the investigation team from being satisfied with superficial solutions that won't fix the problem in the long run
- Gets to real Human Error Category

Summary - Error Proofing Steps