Lean (Definition & History)

Lean, similar to Six Sigma is a process improvement that is solely based on the fundamental goal of waste elimination and flow maximization.

In other words, meeting customer requirements faster, quicker and better, that is in a more effective and efficient way.

Lean manufacturing, as management philosophy, came mostly from the Toyota Production System (TPS). The term "lean" was first introduced in article "Triumph of the Lean Production System" written by John Krafcik in 1988.

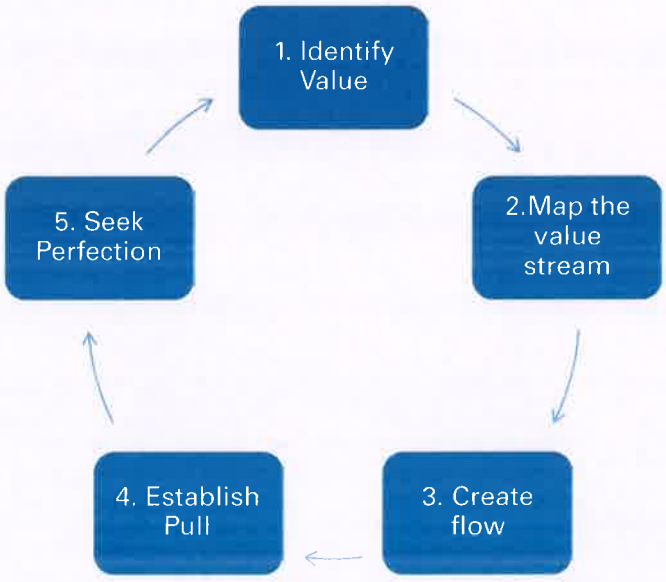
Kiichiro Toyoda, founder of Toyota Motor Corporation, discovered many problems in their manufacturing process. In 1936 his processes hit new problems and he developed the "Kaizen" improvement teams. Toyota's view is that the main method of lean is not the tools, but the reduction of three types of waste:

- muda ("non-value-adding work")
- muri ("overburden")
- mura ("unevenness")

Taiichi Ohno, considered to be the father of the Toyota Production System, was instrumental in improving overall customer value by focusing on reduction of the process wastes at Toyota.

Principles of Lean Thinking

The Lean Enterprise Institute (LEI), founded by James P. Womack and Daniel T. Jones in 1997, introduced the five key lean principles: value, value stream, flow, pull, and perfection.



Principle 1 - Identify Value

What is value?

Who defines value?

According to Womack and Jones – Value is expressed in terms of a specific product or service (or both) which meets customers' need at a specific price at a specific time.

The key question to be asked here is – What is the timeline? What is the price point? What are the other requirements that must be met?

Providing value to the customers is the only reason for the existence of our business.

Principle 2 - Map the value stream

According to Womack and Jones – Mapping the value stream is a step in taking a specific product or service (from scratch) to its final recipient i.e. the end customer.

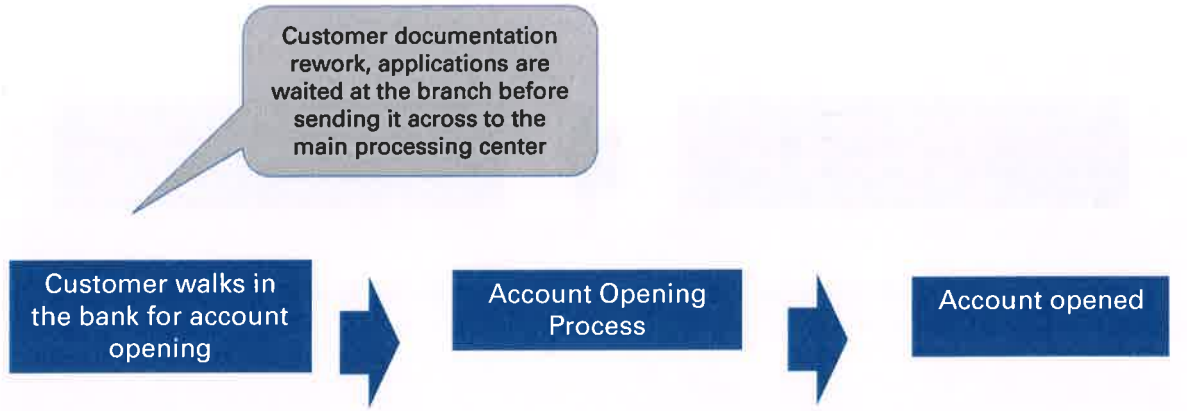
What is a Value Stream?

- Value stream map is a sequence of steps taken to create product / service to the end customer
- Value stream mapping identifies the Value Added (VA) / Non-Value Added (NVA) / Value Enablers (VE) steps in a process and quantifies time spent on each step
- Eliminate the NVA's that contribute to the highest time to the process.

Principle 3 - Create Flow

What is a Flow?
It is a movement of the product or service from the supplier to the end customer
Womack and Jones advises – *"make the value creating steps occur in tight sequence, such that the product or service flow smoothly towards the end customer."*

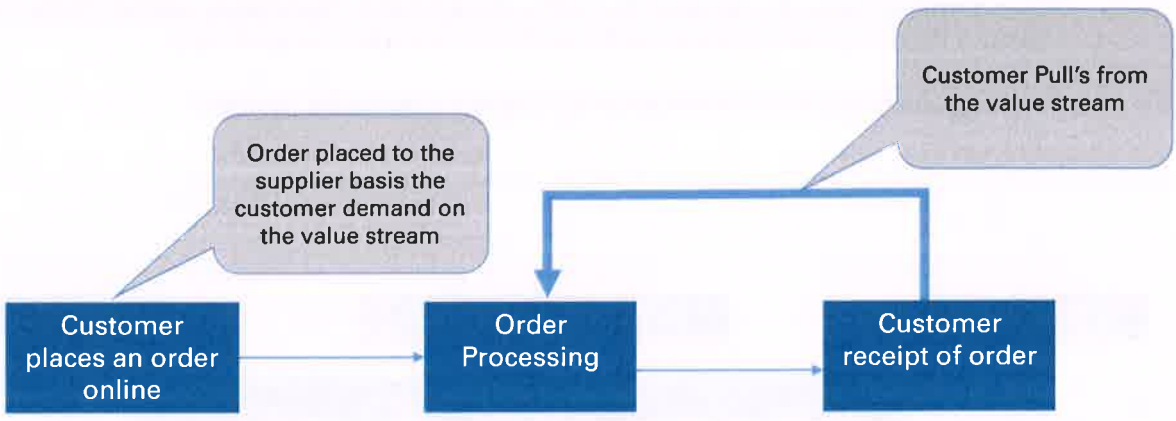
- The rationale behind flow is that the product or service flow smoothly in the value chain without interruptions
- Waiting time and hand-offs are eliminated from the process flow



Principle 4 - Establish Pull

Pull is the movement of product or service from the supplier to the customer only when the customer needs it.

- Making or processing the product only when there is a customer demand
- Create a "Just in Time" manufacturing or delivery
- Reduced storage, stockpile, inventory



Principle 5 - Seek Perfection

Perfection or Continual Improvement is a never ending journey towards delivering world class product or service to your end user or customer.

- Mistake proof the process
- Include process improvement as part of the organization culture
- Continuously keep fine tuning the process
- Restart from 1 to 4

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Process Door Approach

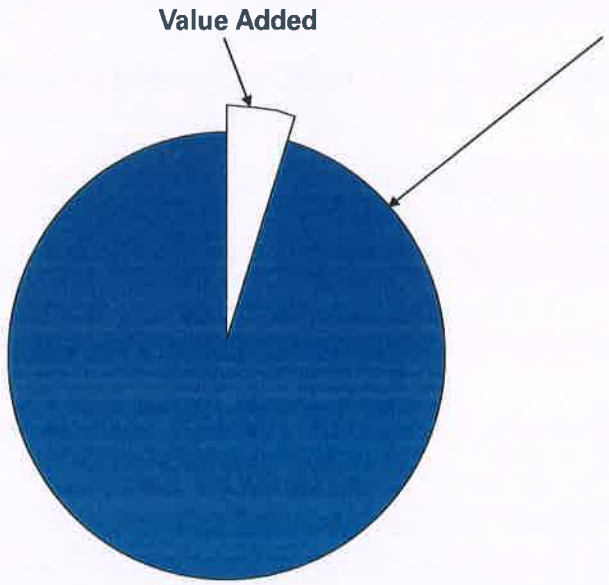
Types of Waste

Types of Waste

What is a Waste?

- Any element of the production, processing, service, delivery, or distribution that adds no value to the end user or customer or business or the final product is termed as waste.
- Waste adds cost, effort and time
- Waste is a symptom and not a root cause of the problem

Identifying Waste



Typically 95% of all lead time is Non-Value Added

Identifying Waste

- **T**ransportation – poor layout, poor flow
- **I**nventory – large batches, complexity to complete task
- **M**otion – poor organization, no standard work
- **H**uman Intellect– old guard thinking, politics, high turnover, low investment in training
- **W**aiting – unbalanced work loads, slow system response, incomplete information, approvals
- **O**verproduction – releasing work before next process can work on them, unbalanced work loads
- **O**ver-processing – excess communication, lack of communication, unnecessary approvals, customer requirements are not clearly understood
- **D**efects – incomplete or incorrect information

Waste Examples

Waste Type	Definition	Example
Transportation	Unnecessary movement of items resulting in wasted efforts and cost.	Conveyor Belts for transporting raw material from warehouse to plant
Inventory	Pile up of semi processed or finished goods that block working capital and hold up cash flow.	Loan Applications pied up on the managers table for approval.
Motion	Unnecessary movement of people to perform an activity.	Pharmacist moving around the whole shop in order to fetch medicines from various drawers
Human Intellect	Overutilization or underutilization of talent.	Engineer being used as operator for operating machine.
Waiting	Waiting for the next process step.	Waiting for your turn to meet the doctor at OPD in hospital
Over-Processing	Too much processing of information.	Five to six reviews / signatures on Purchase Orders before sending to Supplier and yet wrong material gets delivered.
Over-Production	Producing more than the requirement.	Producing goods for maintaining machine utilization in spite of no customer need or order. Over production will always lead to inventory buildup.
Defects	Any process or activity that results in rework.	Car doors rejected in paint shop due to dents or surface unevenness.

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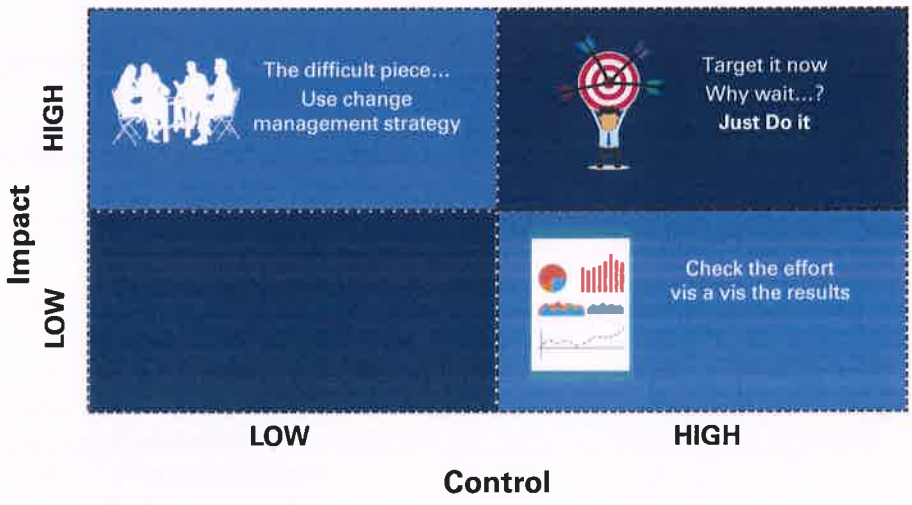
Identify Possible Causes

Control Impact Matrix

Control impact matrix

When we know the possible root causes...can we attack all?



We prioritize the root causes obtained in our root cause analysis using Control Impact Matrix

Control Impact Matrix

- Classify all the causes that the group arrives at in the brainstorming session for the control and impact matrix
- Use your team's process knowledge and business experience to list possible Xs in a control/impact matrix, then use process data to verify or disprove placement of the Xs

Prioritization steps

- Using the control/impact matrix, examine each X in light of two questions:
  a) What is the impact of this X on our process?
  b) Is this X in our team's control or out of our team's control?
- With your team, place each X in the appropriate box on the matrix
- Use process data to verify or disprove your assertions
- The validated matrix is a guide used to addressing the Xs. Begin with the 'high impact/in our control' category
- 'Out of our control' Xs may require special solutions and CAP (change accelerating process) tools for successful sustainable solutions

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Data Door Approach

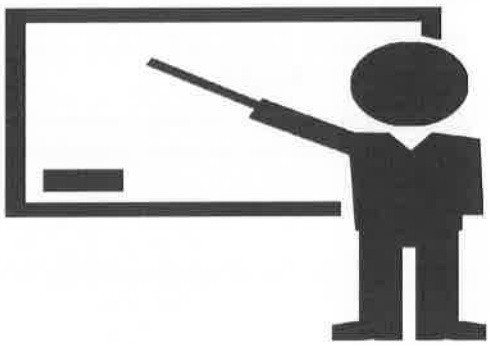
Hypothesis Testing

What is a Hypothesis?

A Hypothesis is a claim or statement about a property of a population (such as mean, variance, proportion).

The American Heritage College Dictionary defines Hypothesis as –

"a tentative explanation that accounts for a set of facts and can be tested by further investigation."



What is Hypothesis Testing?

Measurements are organized into statistics to provide us insights by looking at the spread, shape, consistency and location of the process

Hypothesis Testing is simply a statistical method of comparing reality to an assumption and re-confirming – *did things actually change?*

In other words, Hypothesis Testing is a statistical way of checking whether observed differences between two or more samples are due to random chance or is there an actual difference in the sample.

We use hypothesis testing to test the assumptions established during problem analysis and investigation.

The practical meaning of Hypothesis Testing is that decisions taken based on the test results, with regards to implementing change will yield true and sustainable results.

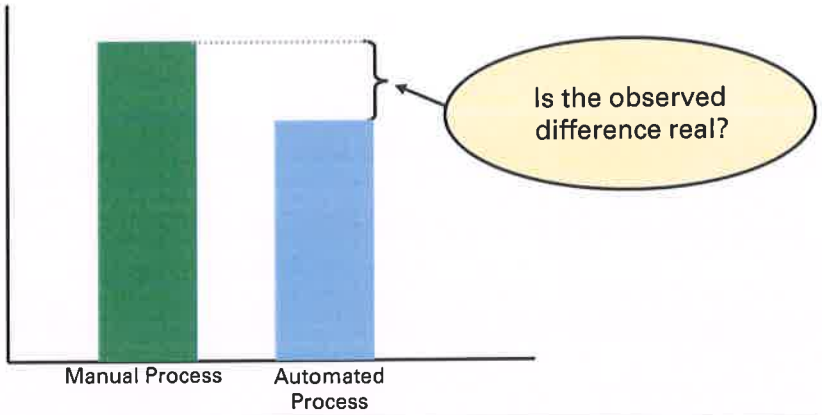
Why Hypothesis Testing?

We use hypothesis testing in the Analyze phase of our DMAIC journey
- to verify that a suspected cause (X) truly impacts the CTQ (Y)

And post implementation of solutions
- to verify the improvement or change in CTQ (Y)

Let us look at an example here:
A team suspects that manual processing of documents (AS-IS process being followed) results in rework and delay in opening accounts for their customers.

Y = High TAT for account opening



Key Terms in Hypothesis Testing

Null Hypothesis (Ho)
- There is "no evidence of difference"
- It is assumed to be true unless proven otherwise
- We never prove it, we only fail to reject it
- Can only contain the condition of 'equality'
- In other words, the Null Hypothesis is the antithesis to our claim regarding the relationship of two or more data sets.

Alternate Hypothesis (Ha)
- The statement that we would like to show is true
- It is a claim that is being studied
- Also known as research hypothesis
- It usually defines the direction of desirable change, can be either < / > / not equal
- It is the hypothesis that we are attempting to prove or test
- Is the statement that must be true if Null Hypothesis is false

The Null and Alternate Hypothesis are mutually exclusive and together complete the entire set of probabilities.

Group Exercise

The average time taken to fill open positions for an analyst is 56 days

After implementing improvements, new data was collected.

The average is now 28 days. Workers claim the process has changed.

1. Define the null hypothesis?
2. Define the alternative hypothesis?

Hypothesis Testing: P- Value

Our basis of taking a decision depends on the P-value

So what is a P-value?

The P-value is the probability of obtaining a particular sample if the null hypothesis (Ho) is true

The P-value is based on an actual or assumed reference distribution like Normal Distribution, F-Distribution, Chi Square Distribution, etc..

Hypothesis Testing: Level of Significance

How do we take a decision now?

Generally, if P-Value < (less then) α, we reject the null hypothesis.

What is the level of significance (α)?

- The level of significance (α) is always set before the hypothesis test is done
- The α is most often set at 0.05 at 95% confidence

Hypothesis Testing - Decisions

How do we infer the Hypothesis Tests?

As a result of the hypothesis test, we will either....

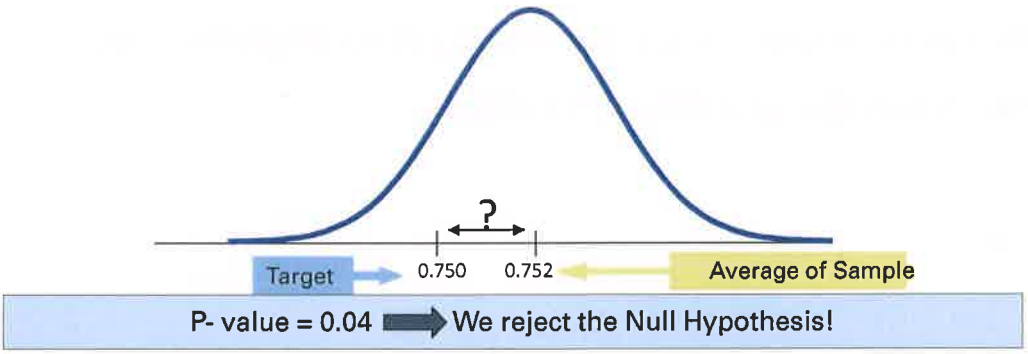
- Reject the Null Hypothesis, or
- Fail to Reject the Null Hypothesis

We always work with the Null Hypothesis; the test result will tell us if we can reject or fail to reject the Null Hypothesis

Hypothesis Testing: How to interpret the P-value

Let us consider a situation as below:

Ho: The process mean equals target mean
Ha: The process mean does not equal target mean



From the P-value (Minitab Output) we can interpret that there is only a 4% chance of obtaining this sample if, indeed, the process mean equals the target. Therefore, we are led to believe the process mean does not equal the target. Therefore, we reject the Null Hypothesis.

Risk of Hypothesis

Whenever a hypothesis test is run, there is a risk associated with the decision that is made.

There are two types of errors (risks):

Type I error: It is the probability of rejecting the null hypothesis when it is true. This is also known as alpha risk, denoted by α.

Type II error: The probability of accepting the null hypothesis when it is false. This also known as beta risk, denoted by β

Type I and Type II errors

Whenever a hypothesis test is run, there is a risk associated with the decision that is made. There are two types of errors (risks):

Decision	Reality: Null Hypothesis True	Reality: Null Hypothesis False
Accept Null Hypothesis	Correct decision	Type II error
Reject Null Hypothesis	Type I error	Correct decision

Steps for conducting Hypothesis Testing

- Define the Null and Alternative Hypotheses
- Determine the level of significance (α)
- Randomly select a representative sample of data
- Compute the P-value
- Compare the P-value to the level of significance (α)

Group Exercise

Define the Null and Alternate Hypothesis for the following situations:

- There is a difference between the average processing time from the two departments.
- A bolt with thread type A has a stronger torque, on average, than the bolt with thread type B
- There is a difference in the proportion of lost prototype seats between the two Business Units.

Steps for conducting Hypothesis Testing

Let us look at the steps with some illustration

Write Null Hypothesis	H_0 : x Sample A = x Sample B
Write Alternate Hypothesis	H_A : There is a difference between Samples A and B
Decide on the p value	p = 0.05 (typical for DMAIC projects at 95% confidence)
Choose hypothesis test	Choose the correct test, given the type of X and Y data
Gather evidence and test/conduct analysis	Collect data, run analysis, get p value
Reject H_0 /not reject H_0 and draw conclusion	If p>0.05 conclude H_0 is true If p<0.05 conclude H_0 is not true

Types of Hypothesis Testing

- There are many types of hypothesis tests.
- The choice of test depends on the ...
  - Type and distribution of the data and the
  - Kind of comparison that is being made.

Common Hypothesis Tests	Application
• One sample - t Test • Two sample – t Test • Paired t Test • One way ANOVA	Comparing Population **Means**
• One Proportion Test • Two Proportion Test • Chi Squared Test	Comparing Population **Proportions** or Percentages

We would cover only Test of Means and Test of Proportion for GB certification

Sample Size - Larger vs Smaller samples

When performing hypothesis test with variable data...

- The sample size is considered large when $n > 30$.
- The sample size is considered small when $n \leq 30$.

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Hypothesis Testing

Test of Means

1 sample z-Test: An Overview

The 1-sample Z test is used when....

- Testing the equality of a population mean to a specific value, and
- Sample size is large (n > 30)

1 sample z-Test: Example

You are attempting to assess the speed of delivery when ordering a specific commodity via two different modes.

Delivery via mode A has been traditionally assumed to generate the best response; but we need to test that assumption against mode B.

Mode A:

Average delivery time = 6 days
Standard deviation = 2 days

A random sample of size 36 was collected from the Mode B, yielding:

Mode B:

Average delivery time = 4.7 days
Standard deviation = 2.0 days

Is there a difference in average delivery speed between Mode A and Mode B?

Define the Null and Alternate Hypothesis

1 sample z-Test: Example

- Define the Hypothesis

  Null Hypothesis: Average delivery time Mode A equals historical mean of 6 days

  Alternate Hypothesis: Average delivery time using Mode B does not equal 6 days.

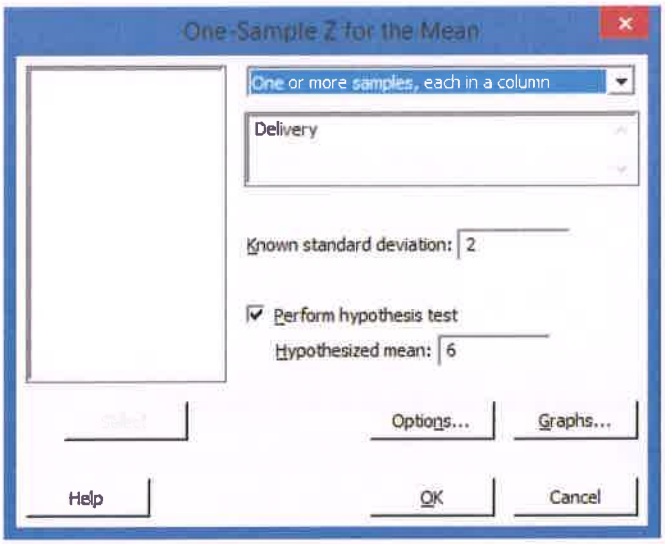
- Randomly select a representative sample of data (36 data points were collected with average of 4.7 days and standard deviation of 2 days)

- Compute the P-value: the probability of obtaining the observed sample if the null hypothesis is true. Using Minitab…

  Select: Stat > Basic Statistics > 1-Sample Z

1 sample z-Test: Example

We are performing a 1-sample Z test because we are testing the equality of a population mean to a specific value (6 days), and we have a large sample ($n \geq 30$).



Delivery Time	
6	6
7	3
3	2
6	2
7	4
8	3
5	4
3	6
2	4
5	7
3	4
9	4
5	1
5	4
4	7
6	3
4	4
5	9

Enter the data in Minitab. Standard Deviation 2, Hypothesized Mean 6

1 sample z-Test : Example

One-Sample Z: Delivery

```
Test of mu = 6 vs mu not = 6

The assumed sigma = 2

Variable           N      Mean     StDev   SE Mean

Delivery          36     4.722     1.966     0.333

Variable              95.0% CI             Z       P

Delivery         (4.069,   5.376)    -3.83   0.000
```

Since the P-value of 0.000 is less than the level of significance 0.05, we reject the Null Hypothesis.

The data provides sufficient evidence that the average delivery time when using Mode A does not equal the historical value of 6 days.

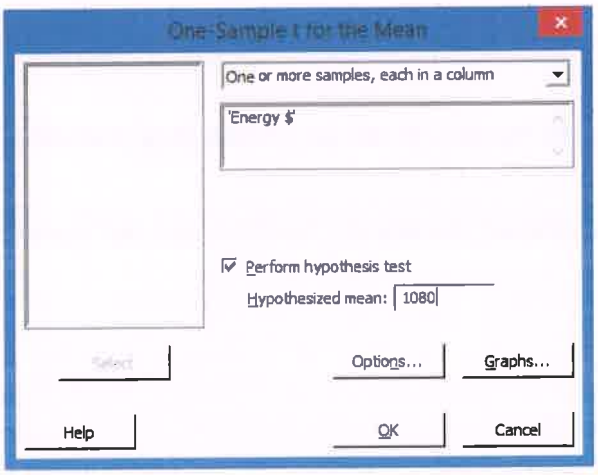
One Sample t-Test: Overview

The 1-sample t- test is used when....

- Testing the equality of a population mean to a specific value, and
- Sample size is large ($n \leq 30$)
- Refer worksheet ENERGY.MTW in Minitab
- **Select: Stat > Basic Statistics > 1-Sample t**

One Sample t-Test: Example

- Refer worksheet ENERGY.MTW in Minitab
- Select: Stat > Basic Statistics > 1-Sample t



Energy $
1211
1572
1668
1250
1478
1307
1184
865
1162
1308
1188
1111
1747
1326
1142

Define the Null and Alternate Hypothesis

One Sample t-Test : Example

- Define the Hypothesis

  Null Hypothesis: Mean expenditure =$1080

  Alternate Hypothesis: Mean expenditure does not equal $1080

- Compute the P-value: the probability of obtaining the observed sample if the null hypothesis is true.

One-Sample T: Energy $

Test of μ = 1080 vs ≠ 1080

Variable	N	Mean	StDev	SE Mean	95% CI	T	P
Energy $	15	1301.3	231.0	59.6	(1173.3, 1429.2)	3.71	0.002

Since the P-value of 0.002 is less than the level of significance 0.05, we reject the Null Hypothesis.

Two Sample Test: Overview

In this section we discuss about the 'Two sample tests' viz:

- Two Sample z-test
- Two Sample t-test

The Two-sample z test is used when testing the equality of two population means and the two samples are small (n > 30).

The Two-sample t test is used when testing the equality of two population means and the two samples are small (n ≤ 30).

Minitab does not offer a 2-Sample Z test. Therefore, we use the Two-Sample t test instead.

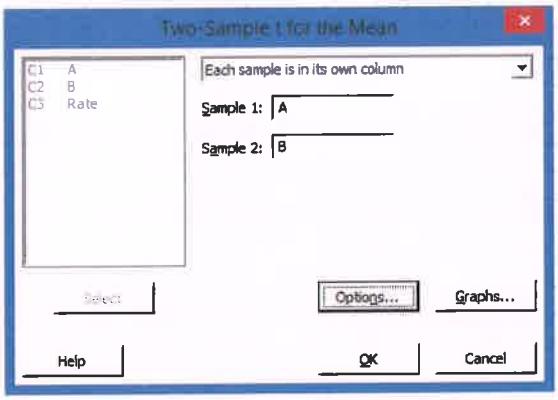
Two Sample Test: Overview

The Two-sample t test is used when the two samples are independent (not related, Unpaired data).

The conditions for using the student t distribution to conduct hypothesis tests with small samples are:

1. The population standard deviations are unknown.
2. The parent populations each have a distribution that is essentially normal.

- Refer worksheet HOSPITALRATINGS.MTW in Minitab
- **Select: Stat > Basic Statistics > 2-Sample t**



A	B
81	89
77	64
75	35
74	68
86	69
90	55
62	37
73	57
91	42
98	49
	59
	58
	65
	71
	67

Two Sample t-Test : Example

- Define the Hypothesis

  Null Hypothesis: Mean ratings for Hospital A and Hospital B is the same.

  Alternate Hypothesis: Mean ratings for Hospital A and Hospital B is different.

- Compute the P-value: the probability of obtaining the observed sample if the null hypothesis is true.

Two-Sample T-Test and CI: A, B

```
Two-sample T for A vs B

    N  Mean  StDev  SE Mean
A  10  80.7   10.6      3.4
B  15  59.0   14.2      3.7

Difference = μ (A) - μ (B)
Estimate for difference:  21.70
95% CI for difference:  (11.38, 32.02)
T-Test of difference = 0 (vs ≠): T-Value = 4.36  P-Value = 0.000  DF = 22
```

Since the P-value of 0.000 is less than the level of significance 0.05, we reject the Null Hypothesis. This means that there is a difference in the mean rating for hospital A and hospital B.

Paired t-Test: Overview

- If one sample is related to another, the samples are dependent (paired).
- For instance, if you made a claim about a drug designed to lower cholesterol, you would make cholesterol measurements on the same individuals before and after the use of the drug. You would need paired data.
- If you take a measurement on the same circuit boards before and after burn in, there is a relationship or dependency between the measurements.
- In these cases, you do not examine two different data sets. Instead, you look at the difference between the before and after data to see if the resulting differences are significant.

Paired t-Test : Example

A Black Belt conducted a study to determine if training was effective at reducing the time it takes to process orders. The process is not automated and is highly dependent on the knowledge and skill level of individual processors.

The orders used throughout the study are essentially identical in magnitude.

Processor	Before Training	After Training
1	23	21
2	17	11
3	8	6
4	9	10
5	7	5
6	25	22
7	16	11
8	11	16
9	12	10
10	9	5

- Define the Null and Alternate Hypothesis
- Use Minitab to test the equality of two dependent samples
- Select: Stat > Basic Statistics > Paired t
- Interpret the P-value

Data is processing time in hours.

One way ANOVA: Overview

When we need to test the equality of more than two population means we use One Way Analysis of Variance (ANOVA)

Assumptions:

- Independent random samples have been drawn from "r" normal populations with means: $\mu 1 = \mu 2 = \mu 3 = \mu 4 ,..., = \mu r$
- Each population has the same variance
- The random samples from each population do not need to be of the same size

One way ANOVA: Example

Suppose you are testing to see if there is a significant difference in average stiffness among three foam formulations. You collected the random samples:

Formulation A	Formulation B	Formulation C
338.2	340.4	344.4
331.0	328.2	338.5
323.0	338.5	348.9
317.9	333.7	326.6
327.9	332.8	342.6
328.1	323.4	355.4
308.3	335.3	337.0
312.8	326.2	339.2
324.0	344.0	331.3
342.4	310.3	336.3
326.2	317.5	342.3
328.1	322.0	338.6
337.6	321.2	323.9
320.3	321.4	345.7
311.0	342.6	333.1
328.1	334.7	331.3

One way ANOVA: Example

- Define the Null and Alternate Hypothesis
  - Null Hypothesis: Formulation A=B=C
  - Alternate Hypothesis: At least one mean is different
- Random samples of 16 foam pads were tested for each formulation.
- Use Minitab to test the hypothesis
- Select: Stat > Basic Statistics > One-Way
- Interpret the P-value

One way ANOVA: Example

One-way ANOVA: Formulation A, Formulation B, Formulation C

```
Source  DF      SS     MS     F      P
Factor   2  1420.8  714.4  8.36  0.001
Error   45  3846.6   85.5
Total   47  5275.4

S = 9.246   R-Sq = 27.08%   R-Sq(adj) = 23.84%


                                 Individual 95% CIs For Mean Based on
                                 Pooled StDev
Level           N    Mean  StDev ------+---------+---------+---------+---
Formulation A  16  325.35   9.72 (-------*-------)
Formulation B  16  329.52   9.75        (-------*-------)
Formulation C  16  338.43   8.18                        (-------*-------)
                                 ------+---------+---------+---------+---
                                   324.0     330.0     336.0     342.0

Pooled StDev = 9.25
```

P-value = 0.001 < a = 0.05

Therefore, we reject the null hypothesis. The data provides sufficient evidence that at least one formulation is different from the others.

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Hypothesis Testing

Test of Proportion

One proportion test: Overview

The 1-proportion test is used when....

- Testing the equality of a population proportion to a specific value
- Calculate a range of values that is likely to include the population proportion

Example: Purchase Orders

When purchase orders are selected out of the accounting system and examined for whether or not they contain a project number, history has shown that 18% do not. A new mistake proofing is attempted and 40 recent purchase orders are audited. Only 2 P.O.s now have a missing project number.

At the 5% level of significance, has the process been improved?

One proportion test: Example

Define the Hypothesis

- Null Hypothesis: The new process yields 18% or greater of purchase orders without project numbers
- Alternate Hypothesis: The new process yields less than 18% of purchase orders without project numbers

Randomly select a representative sample of data (Sample of 40 were randomly selected, only 2 P.O's were found to be missing project numbers)

Compute the P-value: the probability of obtaining the observed sample if the null hypothesis is true using Minitab...

Select: Stat > Basic Statistics > 1-Proportion

One proportion test: Example

Test and CI for One Proportion

```
Test of p = 0.18 vs p < 0.18

                                                        Exact
Sample       X       N  Sample p  95.0% Upper Bound  P-Value
1            2      40  0.050000           0.149152    0.017
```

Since the P-value is less than level of significance (0.05), we reject the null hypothesis.

This proves that the sample provides sufficient evidence that the proportion of defective purchase orders has decreased.

The process has improved!

Two proportion Test: Overview

The 2-proportion test is used to....

- Determine whether the proportions of two groups differ
- Calculate a range of values that is likely to include the difference between the population proportions

Two proportion Test: Example

A Black Belt is comparing two methods of processing cell phone and pager requests to determine which method is more accurate

Method	No. Audited	Number with Errors	Proportion Defective
Standard Paper	80	12	0.150
Intranet Form	80	5	0.063

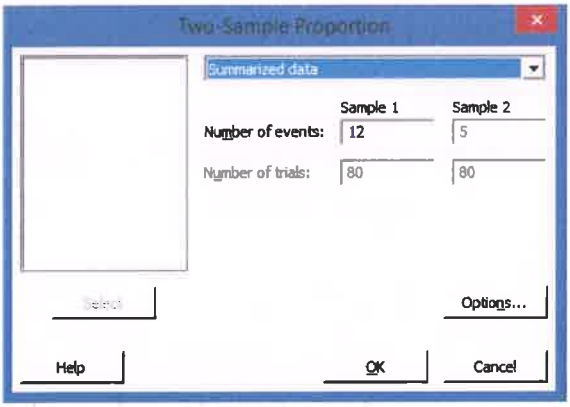
Define the Hypothesis

- Null Hypothesis: The methods of processing cell phone and pager requests in standard paper and intranet form is the same
- Alternate Hypothesis: The methods of processing cell phone and pager requests in standard paper and intranet form is significantly different

Compute the P-value: the probability of obtaining the observed sample if the null hypothesis is true. Using Minitab...

Select: Stat > Basic Statistics > 2-Proportions

Two proportion Test: Example



Since the P-value and Fisher's P value is greater than level of significance (0.05), we fail to reject the null hypothesis.

Thus proving that the methods of processing cell phone and pager requests in standard paper and intranet form is the same.

Test and CI for Two Proportions

```
Sample   X   N  Sample p
1       12  80  0.150000
2        5  80  0.062500

Difference = p (1) - p (2)
Estimate for difference:  0.0875
95% CI for difference:  (-0.00702985, 0.182030)
Test for difference = 0 (vs ≠ 0):  Z = 1.81  P-Value = 0.070

Fisher's exact test: P-Value = 0.122
```


Chi Square: Overview

The Chi Square test is used to....

- Test the equality of more than two population proportions
- A contingency table, using the Chi-Square test, can be used to determine if a difference exists among populations for proportion data.
- This test actually tests whether or not two variables are dependent on each other.

Chi Square: Example

The Personnel Department wants to see if there is a link between age (old and young) and whether that person gets hired

	Hired	Not Hired	Total
Old	30	150	180
Young	45	230	275
Total	75	380	455

Define the Null and Alternate Hypothesis

Chi Square : Example

Define the Hypothesis

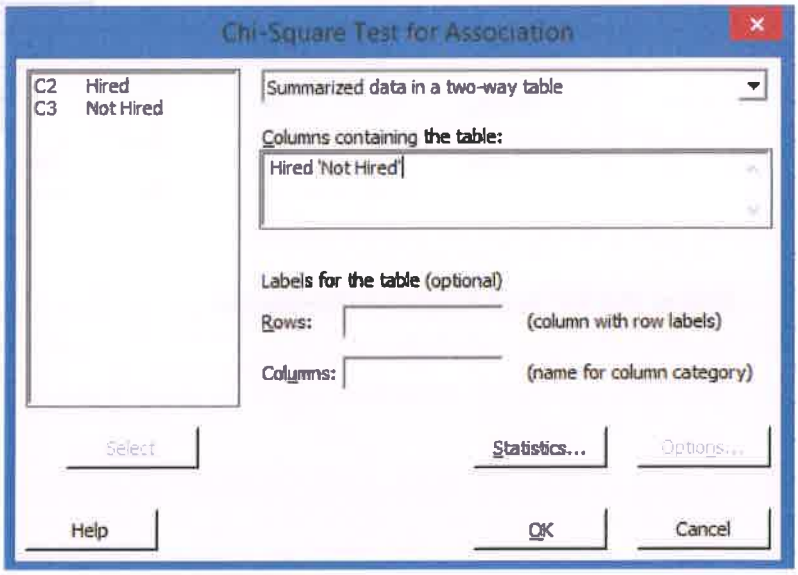
- Null Hypothesis: Age and Hiring are not dependent (independent)
- Alternate Hypothesis: Age and Hiring are dependent

Compute the P-value: the probability of obtaining the observed sample if the null hypothesis is true. Using Minitab...

Select: Stat > Tables > Chi Square Test for Association

Chi Square : Example

↓	C1-T	C2	C3	C4	C5
		Hired	Not Hired		
1	Old	30	150		
2	Young	45	230		
3					
4					
5					
6					



Chi Square : Example

Chi-Square Test for Association

Rows: Worksheet rows Columns: Worksheet columns

	Hired	Not Hired	All
1	30	150	180
	29.67	150.33	
2	45	230	275
	45.33	229.67	
All	75	380	455

Cell Contents: Count
Expected count

Pearson Chi-Square = 0.007, DF = 1, P-Value = 0.932
Likelihood Ratio Chi-Square = 0.007, DF = 1, P-Value = 0.932

Since the P-value is greater than level of significance (0.05), we fail to reject the null hypothesis.

Thus proving that Age and Hiring are independent

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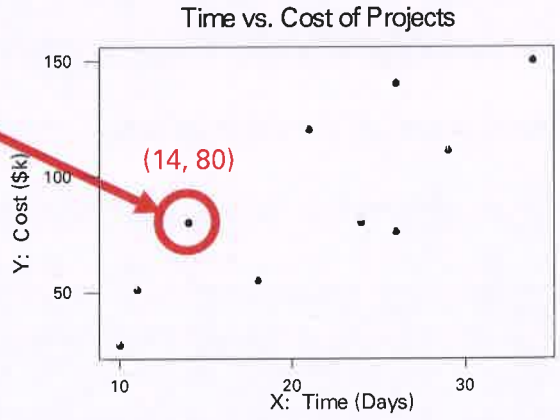
Data Door Approach

Scatter Plot

What is a Scatter Plot?

A scatter diagram is the graphical representation of paired (x,y) data. This type of graph is appropriate when the values in one data set correspond to values in another data set, and you wish to understand the relationship between the two.

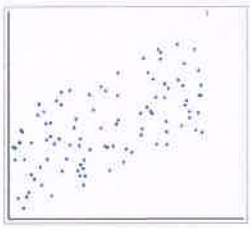
Project	Time (Days)	Cost ($k)
1.	14	80
2.	29	111
3.	26	76
4.	10	27
5.	18	55
6.	11	51
7.	34	150
8.	26	140
9.	24	80
10.	21	120



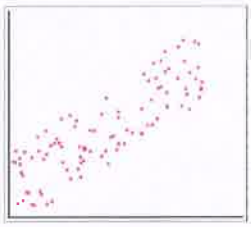
Interpreting a Scatter Plot

Let us assume for all charts below:

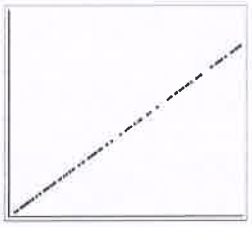
Y = Participant satisfaction (scale: 1 – worst to 100 – best)
X = No of hours spent by the trainer



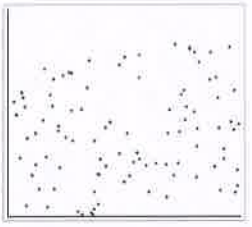
Positive Correlation



Strong Positive

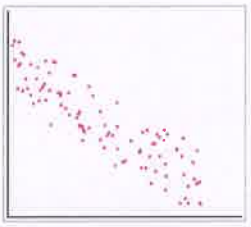


Perfect Positive

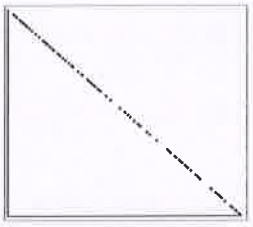


No Correlation

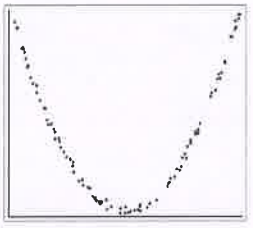
Negative Correlation



Strong Negative



Perfect Negative



Nonlinear Correlation

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Data Door Approach

Correlation Analysis

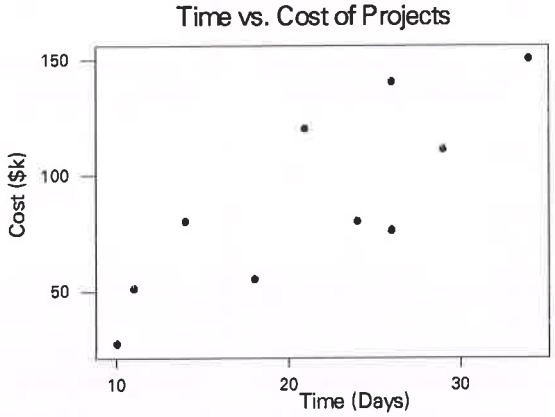
What is Correlation?

When two variables show a relationship on a scatter plot, they are said to be correlated, but this does not necessarily mean they have a cause-effect relationship.

If two variables X and Y, are related such that as Y increases / decreases with another variable X a correlation is said to exist between them. In other words, a correlation exists between two variables when they are related to one another in some way.

Let us consider this –

Project	Time (Days)	Cost ($k)
1.	14	80
2.	29	111
3.	26	76
4.	10	27
5.	18	55
6.	11	51
7.	34	150
8.	26	140
9.	24	80
10.	21	120

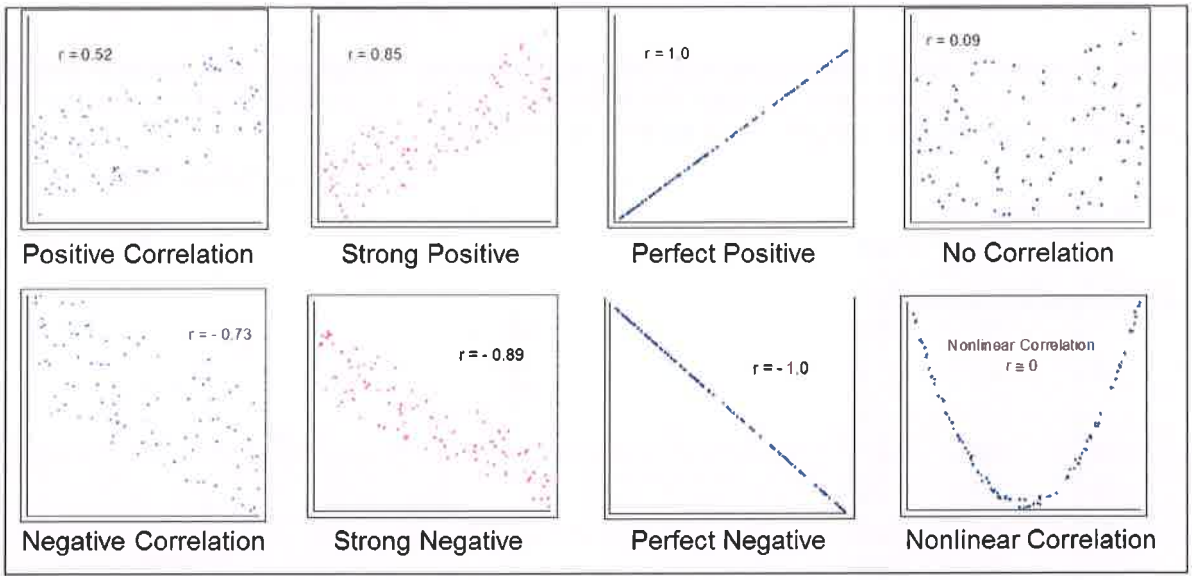


From the above plot, we can infer that as the project time increases, so does the cost.

Correlation Coefficient

- The correlation coefficient, r, is a statistical measure of the strength of the linear relationship between two variables.
- r is always between -1 and 1
- r is also known as Pearson's correlation coefficient
- When r is close to zero, no linear relationship is present.
- When a relationship exists, the variables are said to be correlated
  - Perfect negative relationship r = –1.0
  - No linear correlation r = 0
  - Perfect positive relationship r = +1.0

Correlation Coefficient Examples

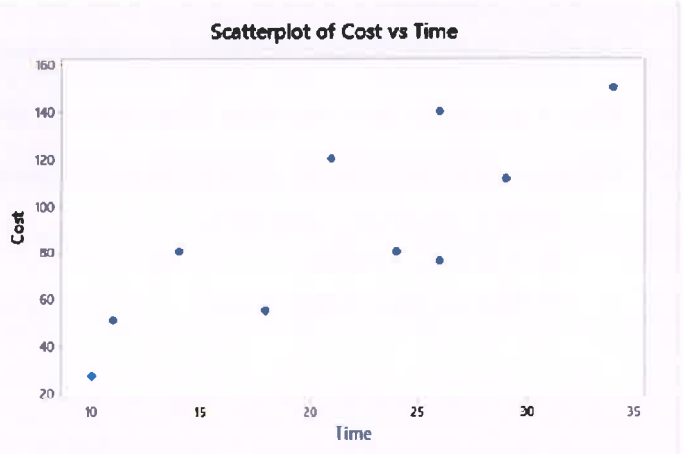


Note: r ≈ 0 means no linear relationship. The variables might be related, just not in a linear fashion.

Scatter Plot and Correlation with Minitab

Let us consider the following data set for our analysis in Minitab to plot a Scatter Diagram

Project	Time (Days)	Cost ($k)
1.	14	80
2.	29	111
3.	26	76
4.	10	27
5.	18	55
6.	11	51
7.	34	150
8.	26	140
9.	24	80
10.	21	120



- Scatter Plot
- Go to Minitab
- Select: Graph > Scatter Plot > Simple
- Double click C2 -> Cost is put into the Y box
- Double click C1 -> Time is put into the X box

Scatter Plot and Correlation with Minitab

For the same set of data let us do a Correlation using Minitab

Correlation

- Go to Minitab
- Select: Stat >Basic Statistics > Correlation
- Double click C1, C2 -> C1, C2 are put into the variables box
- Click OK

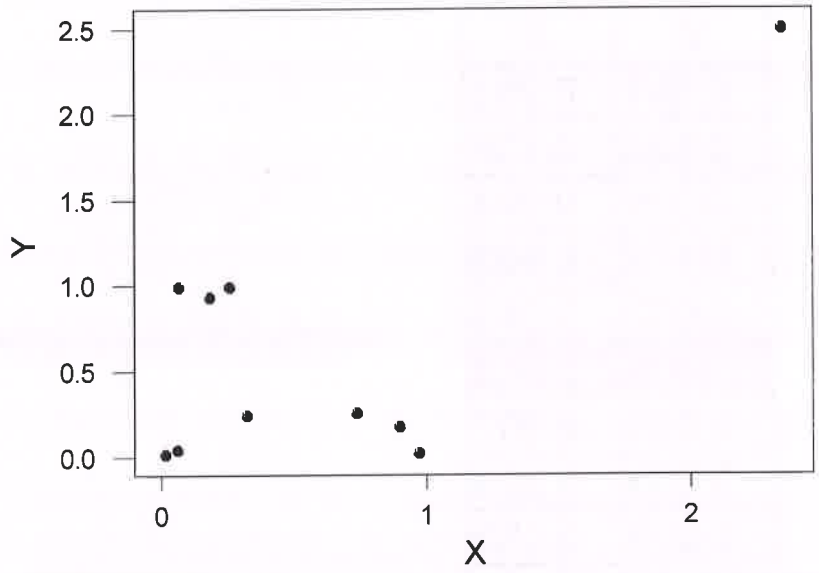
Correlations: Time, Cost

Pearson correlation of Time and Cost (r) = 0.819

P-Value = 0.004

Group Discussion

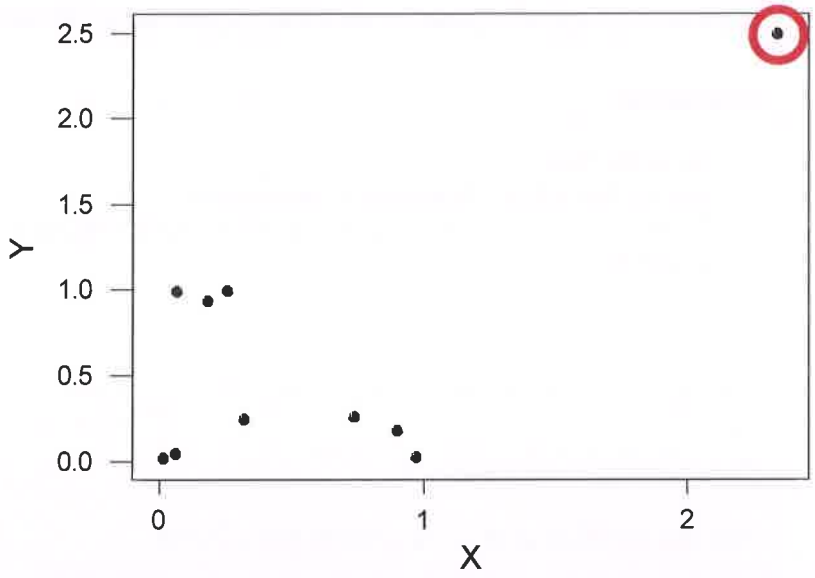
Y	X
0.991	0.261
0.255	0.736
0.015	0.973
0.175	0.900
0.012	0.015
2.490	2.345
0.991	0.067
0.239	0.323
0.036	0.062
0.926	0.186



Is there a correlation between Y & X?
Why or Why not? Use Minitab to tabulate the results

Group Discussion

Y	X
0.991	0.261
0.255	0.736
0.015	0.973
0.175	0.900
0.012	0.015
2.490	2.345
0.991	0.067
0.239	0.323
0.036	0.062
0.926	0.186



What is this point?

Group Discussion

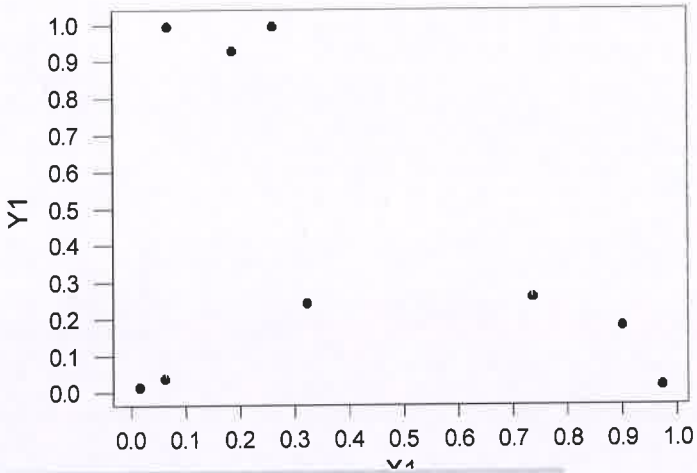
Y	X
0.991	0.261
0.255	0.736
0.015	0.973
0.175	0.900
0.012	0.015
2.490	2.345
0.991	0.067
0.239	0.323
0.036	0.062
0.926	0.186

Can this point be removed? What do we term them as?

Group Discussion

- Below is the data, graph and correlation test with the one dominant x,y pair removed:

Y1	X1
0.991	0.261
0.255	0.736
0.015	0.973
0.175	0.900
0.012	0.015
0.991	0.067
0.239	0.323
0.036	0.062
0.926	0.186

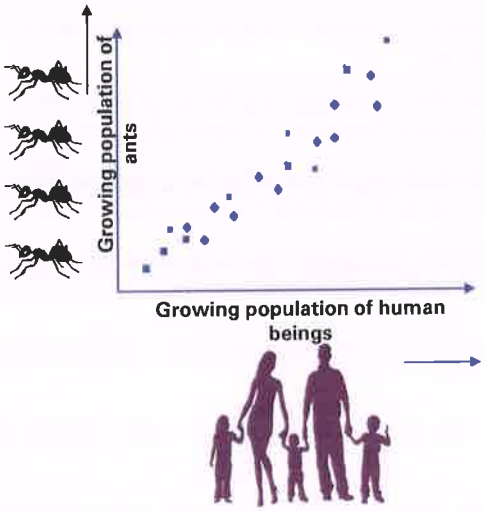


Is there a Correlation between them?

Avoid Pitfalls

Avoid Pitfalls

- To avoid these problems:
- Always examine the x,y data.
- Always look at an x,y plot.
- If there seems to be an outlier, drop that data point and rerun the correlation test.
- Never jump too quickly to your conclusion.



REMEMBER: Correlation does not imply causation

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Data Door Approach

Regression Analysis

What is Regression?

- Regression analysis is a statistical process for estimating the relationships among variables.
- Regression analysis is a form of predictive modelling technique which investigates the relationship between a dependent and independent variables.
- This technique is used for forecasting, time series modelling and finding the causal effect relationship between the variables.

For example, relationship between rash driving and number of road accidents by a driver is best studied through regression.

What is Regression?

There are multiple benefits of using regression analysis. They are as follows:

- It indicates the significant relationships between dependent variable and independent variable.
- It indicates the strength of impact of multiple independent variables on a dependent variable.

What is Regression?

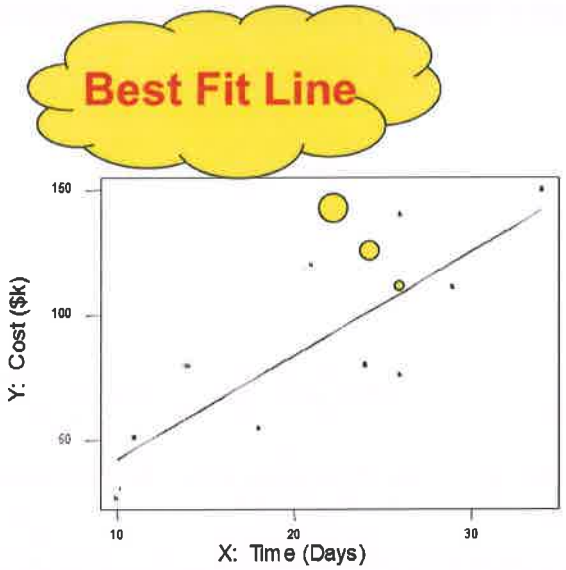
- In statistical modeling, regression analysis is a statistical process for estimating the relationships among variables.
- Regression analysis is a form of predictive modelling technique which investigates the relationship between a dependent (target) and independent variable (s) (predictor).
- In simple linear regression, you obtain the graph and the equation of the straight line that best represent the relationship between two variables.
- Given a sample of paired data, the regression equation

  $y = b_0 + b_1x$

  describes the relationship between two variables.
- The graph of the regression equation is called the regression line (or best fit line).

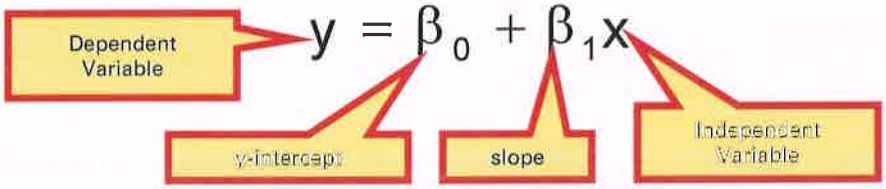
What is Regression?

- The graph of the regression equation is called the regression line (or best fit line).



Regression Equation

The regression equation:



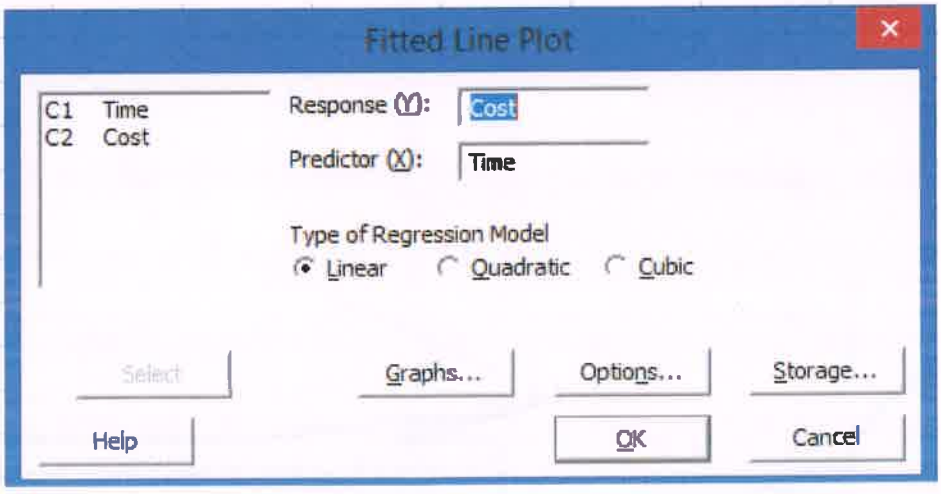
Simple Linear Regression: Example

Consider the below example of a relationship between Cost and Time

Time	Cost
14	80
29	111
26	76
10	27
18	55
11	51
34	150
26	140
24	80
21	120

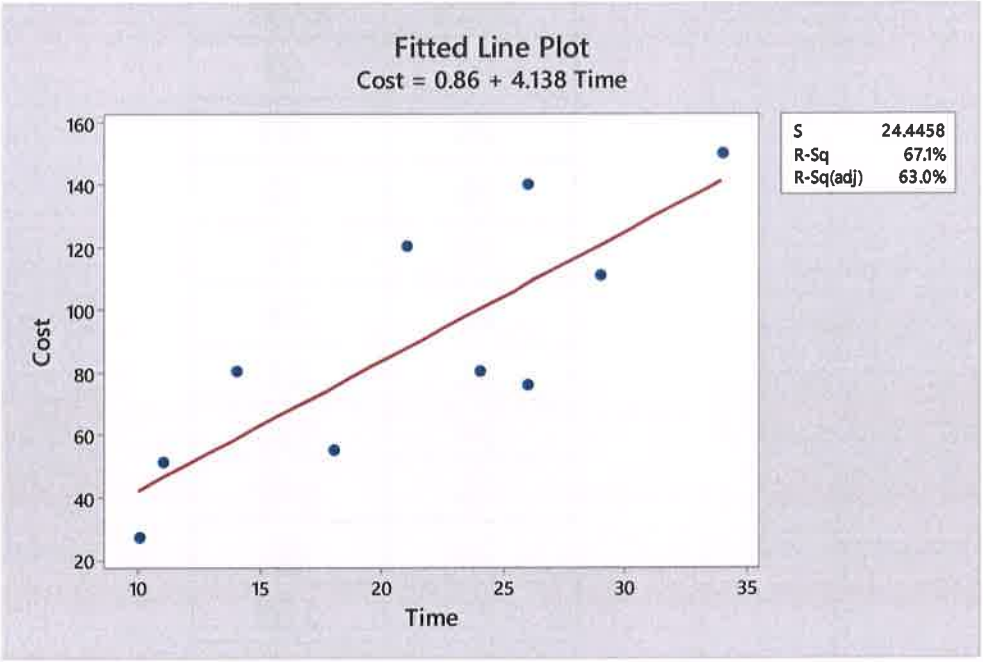
Fitting a Regression Model: Using Minitab

Select: Stat> Regression> Fitted Line Plot



Fitting a Regression Model: Using Minitab

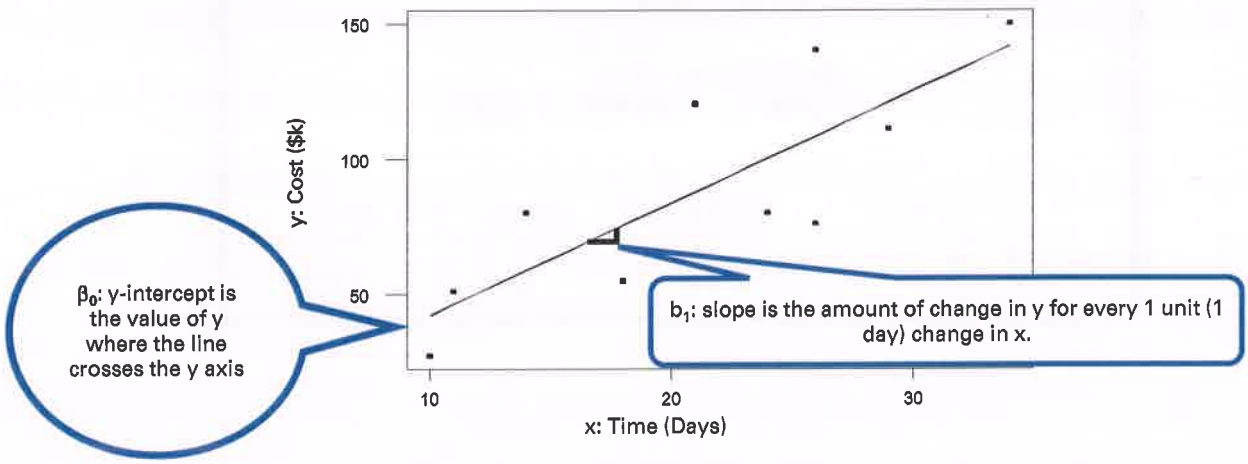
Select: Stat> Regression> Fitted Line Plot



Simple Linear Regression: Using Minitab

Consider the below example of a relationship between Cost and Time in Minitab

Select: Stat> Regression> Regression> Fit Regression Model



Simple Linear Regression: Using Minitab

Regression Analysis: Cost versus Time

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	1	9761	9761.2	16.33	0.004
Time	1	9761	9761.2	16.33	0.004
Error	8	4781	597.6		
Lack-of-Fit	7	2733	390.4	0.19	0.944
Pure Error	1	2048	2048.0		
Total	9	14542			

P - value = .004

Rejecting Null Hypothesis means we have convincing evidence of a linear relationship between Time and Cost.

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
24.4458	67.12%	63.01%	54.08%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.9	23.1	0.04	0.971	
Time	4.14	1.02	4.04	0.004	1.00

Regression Equation

Cost = 0.9 + 4.14 Time

The best fitting line is y = .9 + 4.14 x

R-Squared (R-Sq)

What is R-Sq?

The coefficient of determination, R-sq is the amount of the variation in y that is explained by the regression line.

R-Sq = Explained Variation *100

Total Variation

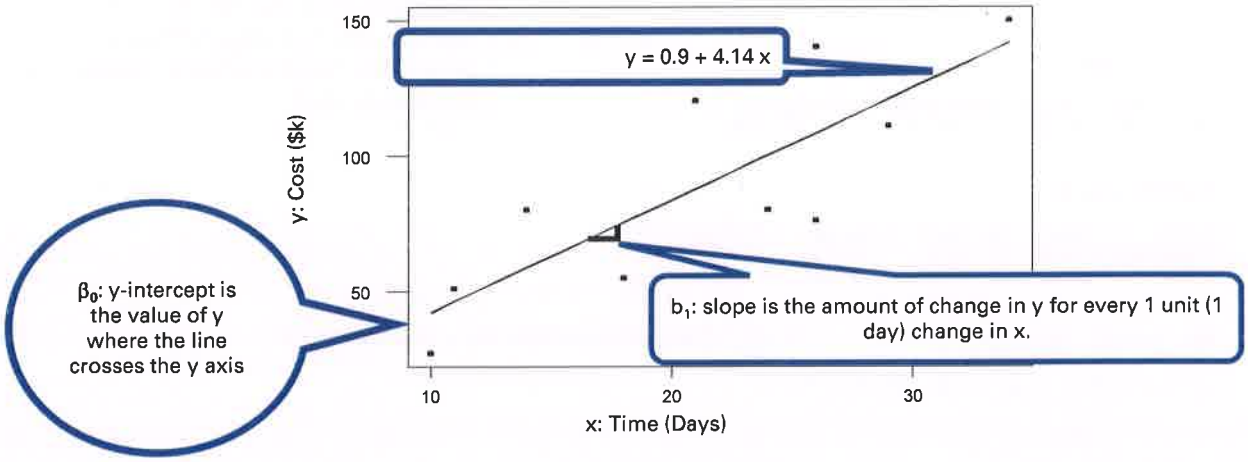
In the given illustration,

R-Sq = 9761/ 14542*100 = 67.1%

It means, 67.1% of the variability in cost can be explained by the relationship to time.

Regression Equation

Consider the below example of a relationship between Cost and Time



Group Exercises

1. Sachin wants to test the assumption that there is no difference between the mean life of motors of two companies. For his study, he picks up a sample of 10 motors with mean life of 4,050 hours and standard deviation of 200 hours from the first company and a sample of 9 motors with mean life of 4,300 hours and standard deviation of 260 hours from the second company. You are requested to help Sachin test the hypothesis, that there is no difference in the mean life of both the brands of motor at 95 percent level of confidence.

2. A team wants to see if there is relationship between ambient temperature and the viscosity of a material.

3. Ajay is exploring a brand of canned rasogullas to be sold in the chain of grocery shops which he represents. For him to select a particular brand, the drained rasogullas should not weigh less than 260 grams (in a 500 grams can). From the 11 cans he sampled at the distributor, the mean weight of drained rasogullas was 247 grams with a standard deviation of 30 grams. You are requested to help Ajay take a decision regarding procurement of Rasogullas at 95 percent level of confidence.

What type of tool would you use ? _____

Define: Ho and Ha

Group Exercises

4. The Personnel Department wants to see if there is a link between age (old and young) and whether that person gets hired.

5. A brand marketing firm wants to understand the television viewing pattern during cricket matches across countries. During a league cricket match involving players of 4 nationalities, following viewing patterns were observed in a randomly selected sample of 50 viewers across these countries (marked A, B, C and D). Please help the team understand if there is a relationship between the nationalities and the viewing patterns at 5 percent level of significance.

	A	B	C	D
Viewed	12	10	6	14
Did Not View	38	40	44	36

What type of tool would you use ? _____

Define: Ho and Ha

Inference from Analyze Phase

- Infer whether the causes were real i.e. were the causes statistically significant.
- Interpret scatter diagrams and the correlation coefficient, r, to determine if two variables are correlated.
- Perform Simple Linear Regression Analysis and interpret a regression equation.
- Interpret R^2 and P- values to determine the adequacy of a math model (regression equation).
- Make predictions using the math model.

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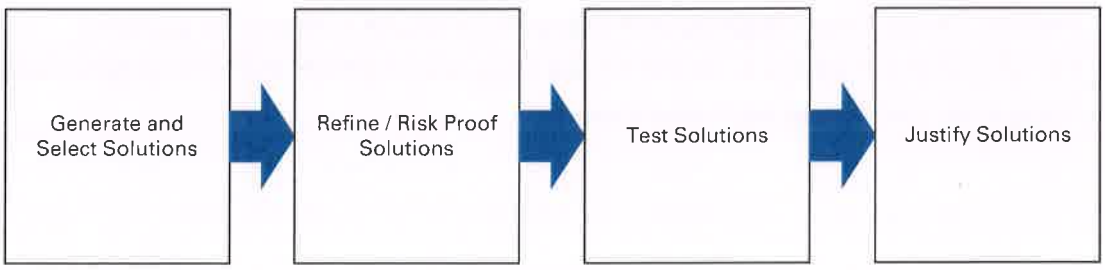
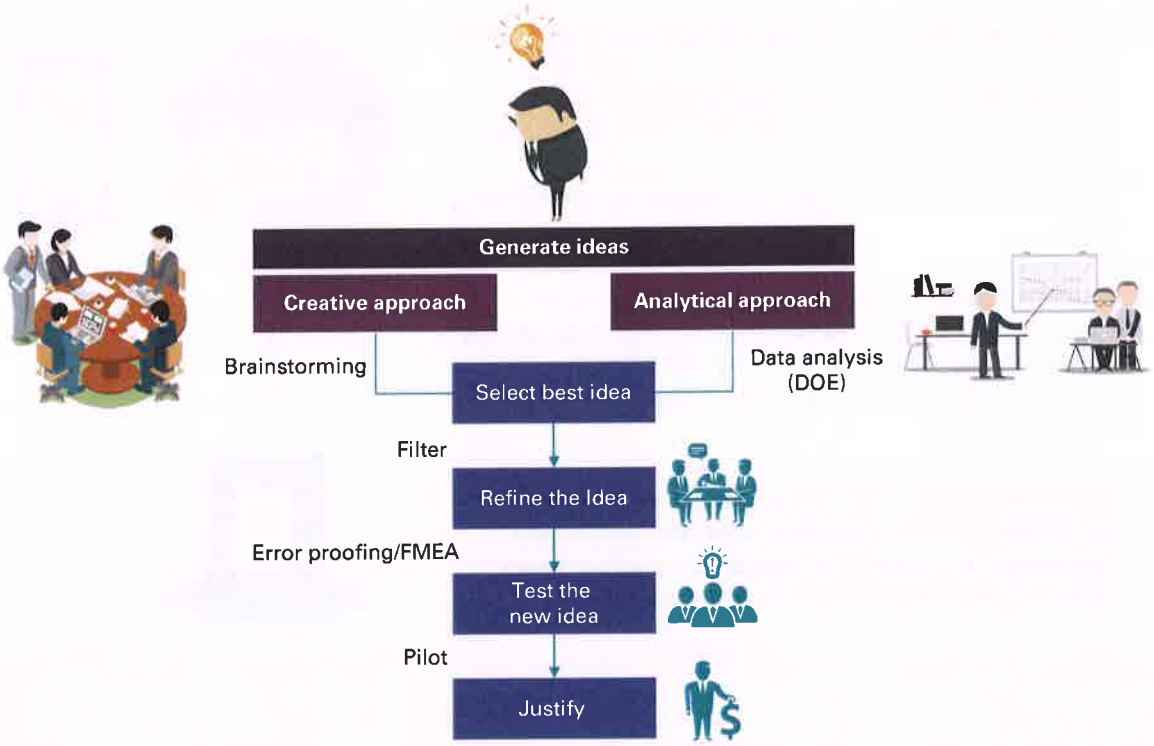
Improve Phase

Improve Phase - Roadmap



Improve: Steps



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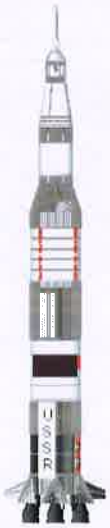
Generate and Select Solutions

Generate Solutions

TRIZ - Theory of inventive problem solving

- A theory of problem solving based on the recognition of the power of psychological inertia and the importance of having a process to move problem solving activities beyond this inertia by identifying contradictions (barriers to an ideal solution) and providing specific tools and strategies for eliminating them
- Genrikh Altshuller (developer of TRIZ) screened thousands of patents looking for inventive problems and how they were solved. Only 40,000 had inventive solutions; the rest were straightforward improvements.
- Altshuller categorised these patents by identifying the problem-solving process that had been used repeatedly. He found that the problems had been solved using one of forty inventive principles.

TRIZ - Key concepts



Overcoming psychological inertia

Psychological inertia is the sum total of an individual's personal bias, previous experience and technological knowledge. When challenged with a problem, the solution path will be constrained by the individual's psychological inertia. Psychological inertia predisposes not only the solution path, but the types of solutions as well. Psychological inertia defines the boundaries of the solution space; if the ideal solution for a problem demands 'out-of-the-box' thinking, psychological inertia confines the thought process to the conventional box.

TRIZ - Key concepts

Inventive principles are rules for system transformations. Each principle is intended to eliminate a single contradiction or several contradictions. Also, these principles can be used simply to stimulate, or initiate, the thought process to create the ideal solution to a problem. They can be used for inspiration in conceptual design, directly utilized in the case-based design or used in various forms of analogical reasoning.

Two of the forty principles are listed in next page with accompanying service examples.

Apply selected inventive principles to your contradiction/problem to develop innovative solutions

TRIZ - Key concepts

Principle 1: Segmentation

A) Divide an object into independent parts

- Divide an organization into different product centers
- Use a work breakdown structure for a large project
- Franchise objects
- Strength/weakness/opportunity/threat (SWOT) analysis
- Sectional furniture

B) Make an object easy to dissemble

- Flexible pensions
- Use of temporary workers on short-term projects
- Modular furniture/offices

C) Increase the degree of fragmentation

- Empowerment – segmentation of decision making
- Distance learning
- Virtual offices/remote working

Principle 22: 'Blessing in disguise'

A) Use harmful factors to achieve a positive effect

- Recast an attack on you as an attack on a problem
- Collect information to understand the harm, then formulate a positive action to remove it
- Making a fuss over customers who have experienced a problem with your goods or services

B) Eliminate the primary harmful action by adding it to another harmful action to resolve the problem

- Eliminate the fear of change by introducing fear of competition
- Put a problem person on an assignment in another area where he/she can do well and not be a problem in the original group

Brainstorming Techniques

- **Structured brainstorming:** This is a process in which the ideas are generated in a systematic method by moving from one person to another and obtaining an idea. The person who does not wish to provide an idea, passes. The process is continued until each participant passes and the facilitator determines no fresh ideas are being generated. As with all forms of brainstorming, the ideas are then taken up for discussion. At the end discard any ideas that are similar and debate on each idea to come up with the finalised list of possible solutions

- **Unstructured brainstorming:** In this form of brainstorming, ideas are generated randomly and there is no need to pass. The solutions are discussed freely and can be proposed at any time. This type of brainstorming process is effective when the representation of each of the diverse groups involved in the discussion is large. However, the facilitator should be careful that even in this randomized discussion with large representations, ideas may not be captured completely

Brainstorming Techniques

Structured brainstorming

- Smooth flow of ideas
- Everyone has an opportunity to express opinions
- Efficient process in terms of idea generation
- Less creative in approach

Unstructured brainstorming

- Smooth
- Random flow of ideas
- All opinions may not be captured
- Lesser number of ideas generated
- Effective process for creative ideas

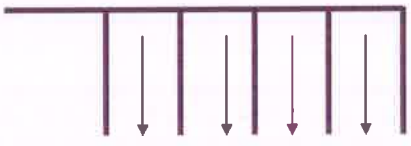
Brainstorming principles

Must be" for all brainstorming forms

- Allow free flow of ideas
- Prevent biases (group/function/subject)
- Create heterogeneous groups
- Manage time
- Focus on critical Xs and CTQs
- Scribe all details
- Avoid large groups (6 - 10 optimum)
- Use voting techniques

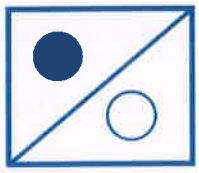
Prioritizing solutions

Channeling



Structured approach to brainstorm on specific category of solutions available to the team

Anti solution



Structured approach to brainstorm on the opposite of the objectives of the discussion

Prioritizing solutions

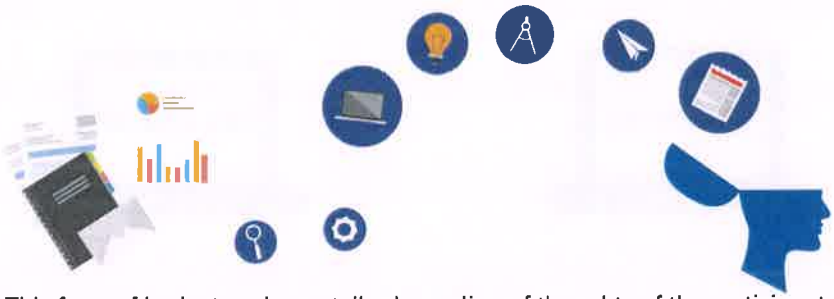
Analogy

Brainstorm on ideas on related topic to unblock the thought process

Brain writing

Build on ideas written on a sheet of paper randomly distributed amidst the group

Prioritizing solutions



Channeling: This form of brainstorming entails channeling of thoughts of the participants similar to the discussion in fishbone diagram. The discussion revolves on specific stream/section of solution. E.g while discussion on methods to improve the sales of soaps, potential solutions can be channeled into: Improvements related to the packaging, fragrance, cutting of costs or distribution system for the product

Antisolution: Here the objective of the team is reversed to exactly the opposite of what is to be determined. E.g. In an effort to improve the training programme, the team can debate about the ways in which the training programme can be worsened. The solutions are opposite of what is determined during the discussion

Analogy: Analogy form of brainstorming encompasses a discussion on a process/product that is similar to the one which is being improved. E.g. Instead of discussing on 'what are ways to improve the productivity of call center associates for an insurance customer service call center, the team can discuss opinions on productivity of associates in the customer service call center for automobile leasing'. Make associations at the end of the discussion

Brain writing: Written ideas are exchanged in this process. Each person who receives a written idea tries to expand on it or adds a totally new idea to it. The pieces of paper are rotated and a collections of ideas or solutions are then debated and prioritised. This is used when the team members are unknown to each other

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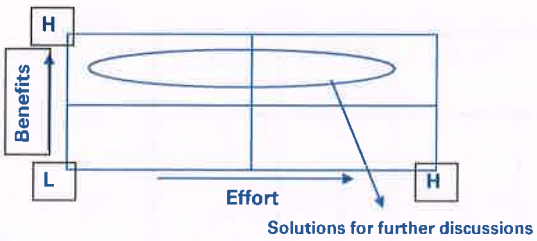
Generate and Select Solutions

Select Solutions

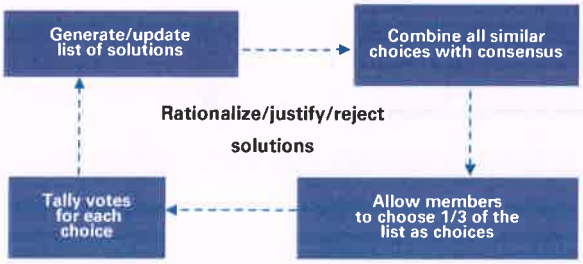
Various approaches to selecting solutions

Pay off matrix



Screening against 'Must Be'

N/3 voting



Criteria based matrix

Establish Criteria	Assign Wt.	# of Votes	Soln. 1	Soln. 2
• Ease of Use • Inter site availability • Preparation of Charts • Information Real time • Auto escalation of unresolved issues • Filters and regulated access				
		Total score:		

Criteria Based Matrix (CBM)

Where to use CBM

- More than a few criteria for solution selection
- Solutions scoring differently under each criteria
- The weight for each criteria differs

How to use CBM

- Identify criteria and assign weightage
- The team members to give votes to each idea
- The votes are then multiplied with the weights of the criteria established for selection
- The total scores obtained at the bottom of the solution are used to select the same

N G T: Nominal Group Technique

What is the best method to reduce cost per transaction?

Solutions	Member 1	Member 2	Member 3	Totals
• Simplify Application process	6	4	6	16
• Automation	1	1	1	3
• Employ Six Sigma	3	3	2	8
• Consolidate sites	5	6	4	15
• Implement Web Services	4	5	3	12
• Reduce Workforce	2	2	5	9

SIMPLIFY APPLICATION PROCESS & CONSOLIDATION

Various approaches to selecting solutions

Pay-off matrix: After the possible solutions are generated, they can be assigned to different quadrants of the pay off matrix. The ideas which are low on benefits, are rejected. The discussion is then focused on the high effort/high benefits and these are rationalized for implementation. Some of the solutions in this quadrant are so prohibitively expensive that they can be eliminated without further analysis. Caution needs to be maintained when eliminating potential solutions from this quadrant

Screening against 'Must be' criteria: Company policies, local laws and social considerations are extremely important before proceeding further on any solution. Finally, the extent to which the customer CTQs of the project are satisfied is a key consideration for selection (use KANO model to evaluate expected extent of satisfaction generated)

N/3 voting: The key consideration in this form is that all rejected solutions should be justified

Criteria matrix: Solutions scoring differently under each defined criteria

Nominal Group Technique: Simplify application process & consolidation

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Solutions with Lean Approach

Kaizen

Kaizen

- "Kai" means "change"
- "Zen" means "good (for the better)"
- Gradual, orderly, and continuous improvement
- Ongoing improvement involving everyone

What is a Kaizen?

- Kaizen is a Japanese word for the philosophy that defines management's role in continuously encouraging and implementing small improvements involving everyone.
- It is the process of continuous improvement in small increments that make the process more efficient, effective, under control, and adaptable.
- It focuses on simplification by breaking down complex processes into their sub processes and then improving them.

Why use Kaizen?

When to use Kaizen?

- To solve problems (without already knowing the solution)
- To eliminate waste (Muda)
- Transportation, Inventory, Motion, Waiting, Over-production, Over-processing, Defects
- Create ownership and empowerment
- Support lean thinking

What is a Kaizen Blitz?

- Total focus on a defined process to create radical improvement in a short period of time
- Dramatic improvements in productivity, quality, delivery, lead-time, set-up time, space utilization, work in process, workplace organization

Kaizen Themes

Kaizen Themes:

- Red Tagging (getting rid of clutter)
- Visual Control (instructions in the workplace)
- Better (any small improvement)
- Benchmark (adopt other industry service)
- Clarity (communication without confusion)
- Pit Stop (streamlining critical activity)
- Service Supreme (using our best experience as our standard)

Kaizen Advantages:

- Do Right Things (effectiveness)
- Do Things Right (efficiency)
- Do Things Better (improve)
- Do Away With Things (cut)
- Do Things Others Do Well (adapt)
- Do What No Other Is Doing (unbeatable)
- Do What Can't Be Done (incredible)

Kaizen Cycle

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Solutions with Lean Approach

Kanban

Kanban

- Kanban literally means "visual card," "signboard," or "billboard."
- Toyota originally used Kanban cards to limit the amount of inventory tied up in "work in progress" on a manufacturing floor
- Not only is excess inventory waste, time spent producing it is time that could be expended elsewhere.

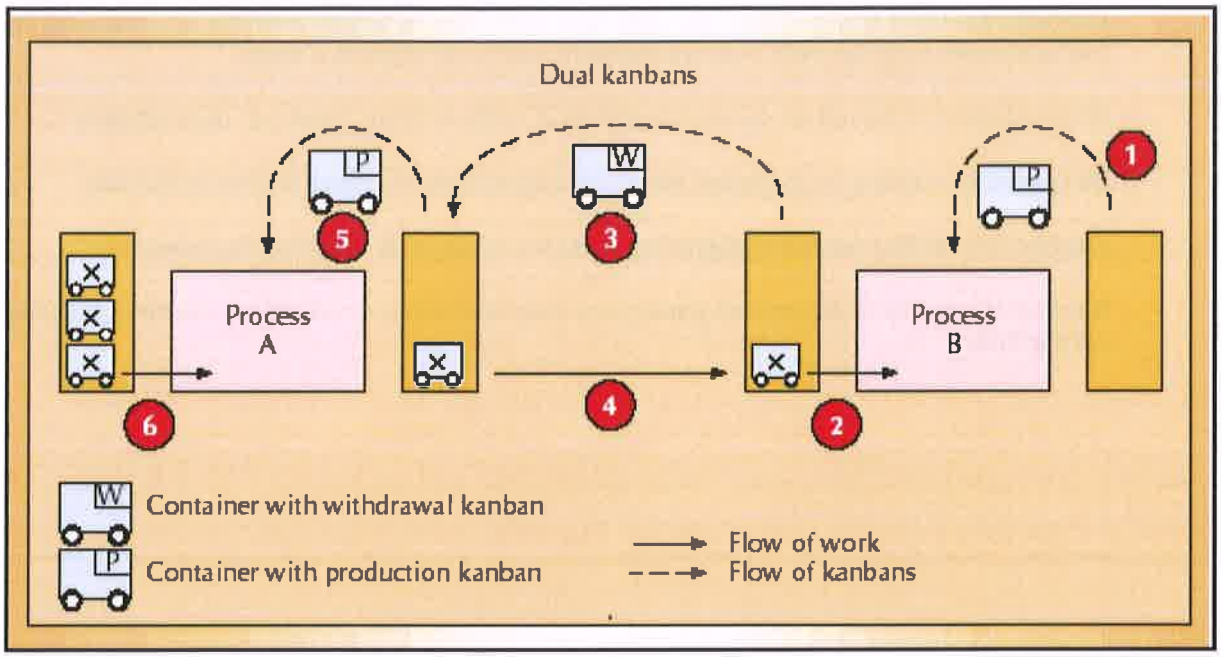
Why Kanban?

- Kanban is a "pull" system that involves cascading or signaling production and delivery instructions from downstream to upstream activities in which nothing is produced by the upstream supplier until the downstream customer signals a need.
- All production is based on consumer demand, with nothing "pushed" downstream.
- Simply said, nothing is produced without a signal from the next station in the line.
- Kanban acts as the means of signaling used for material & information movement
- Kanban is usually in a piece of paper in a vinyl envelope or container; outline marking on the floor

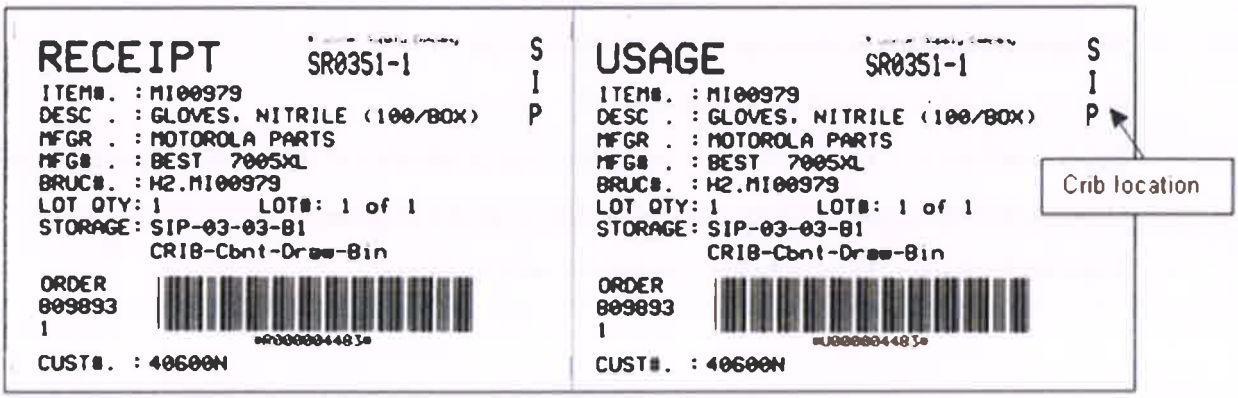
Types of Kanban

- **Production Kanban:** authorizes production of goods
- **Withdrawal Kanban:** authorizes movement of goods
- **Kanban square:** a marked area designated to hold items
- **Signal Kanban:** a triangular Kanban used to signal production at the previous workstation
- **Material Kanban:** used to order material in advance of a process
- **Supplier Kanban:** rotates between the factory and suppliers

Diagrammatic Representation of Kanban



Kanban Card



Source: Slideshare.net

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Solutions with Lean Approach

Five S (5's)

5S

What is 5S?

A systematic approach to organize and standardize the workplace. 5S was originally developed within the Toyota Production

Why 5S?

- To improve efficiency and productivity
- To maintain safety and cleanliness
- To maintain good control over the processes
- To maintain the good product quality

5S

- **SEIRI** → **Sort / Segregate**
- **SEITON** → **Self Arrange**
- **SEISO** → **Spic and Span**
- **SEIKETSU** → **Standardize**
- **SHITSUKE** → **Self Discipline**

Objectives of 5S

Objectives of 5S

- Promote Safety
- Improve Work Flow
- Better Product Quality
- Reduce Inventory Waste
- Give People Control of Their Workplace

Step 1: Sort (Seiri)

- Ensuring each item in a workplace is in its proper place or identified as unnecessary and removed.
- Sort items by frequency of use
- Get rid of unnecessary stuff

Can tasks be simplified?

Do we label items, and dispose of waste frequently?

While Sorting (Seiri) keep in mind:

- How often things are used.
- What is the life of the material.
- Cost of the material
- Be sure to throw the things, otherwise you may repent.

Step 1: Sort (Seiri)

Consequences of not Sorting (Seiri):

- The wanted is hard to find when required
- More space is demanded
- Unwanted items cause misidentification
- Misidentification causes errors in operation
- Maintenance cost of the equipment increases

Step 2: Set in Order (Seiton)

Identifying places to arrange the things and placing them in proper order for prompt usage.

"A place for every thing and everything in its place."

While arranging or setting things in order (Seiton) keep in mind:

- The right location where the things will be used
- FIFO (First in First out) arrangement
- Labeling of the area and the equipment is very important
- Keep proper gaps between two things to avoid confusion
- Good SEITON includes use of labels signs, indications, display, cautions
- Use of labels signs, indications, display, cautions highlights difference between normality and abnormality.
- Non - users of the equipment also become aware of its use and precautions

Step 2: Set in Order (Seiton)

Consequences of not arranging things in order (Seiton):

- Things are seldom available when needed
- Items get lost
- Items get mixed up
- Visual control not possible
- Failure to achieve targets

Step 3: Shine (Seiso)

- Sweep your workplace thoroughly so that there is no dust/dirt/scrap anywhere
- The area should say " Who I'm" and its neatness should give you a natural welcome

While arranging or setting things spic and span (Seiso) keep in mind:

- Cleaning should be done regularly
- Use the best cleaning agent
- All the nooks and corners should be cleaned
- Keep all the labels intact
- All the labels should correct, visible and legible to all

Step 3: Shine (Seiso)

Consequences of not being spic and span (Seiso):

- Performance of machines deteriorates
- The quality / aesthetic quality deteriorates
- Dirty place is unpleasant and hazardous to health
- Sends uncaring and irresponsible message to the team members and society at large
- People working at dirty areas are generally found to have low desire to excel and their motivation level is low

Step 4: Standardize (Seiketsu)

- Always aim at maintaining the standard level of cleanliness, hygiene and visual control
- Keep all the 4 M's (Man., Machine, Material and Method) intact, a lapse in any one of them will make you loose the rest of the three

While standardizing (Seiketsu) keep in mind:

- The standards should be arrived at unanimously
- Always keep the standards flexible to changes and improvements
- Standards should be known to all and displayed

Essence of standardizing (Seiketsu):

- It is the proof that 3-S (SEIRI, SEITON, SEISO) are being religiously carried out
- It is the barometer which indicates the control level based on the 5-S of all the workers

Step 4: Standardize (Seiketsu)

Consequences of not standardizing (Seiketsu):

- Dual standards yield multiple results
- Multiple results lead to conflicts and confusions
- Rework increases
- Rework increases the basic cost of the finished product without any value addition

Step 5: Sustain (Shitsuke)

If you are disciplined. :

- Rules will always be followed
- Laid down targets will be achieved
- Improvements will be promoted
- The no. of defects will be reduced
- The cost will not increase

To ensure success:

- Train all team members on 4-S
- Correct wrong practices on the spot
- Punctuality is the backbone of 5S
- Follow work instructions

Advantages of 5S

Advantages:

- Assemble a 5S Lead team
- Define the work area 5S boundaries (list them)
- Assign work group members to their 5S areas
- Determine 5S targets, activities, and schedule
- Review/finalize plans with work group and site leadership

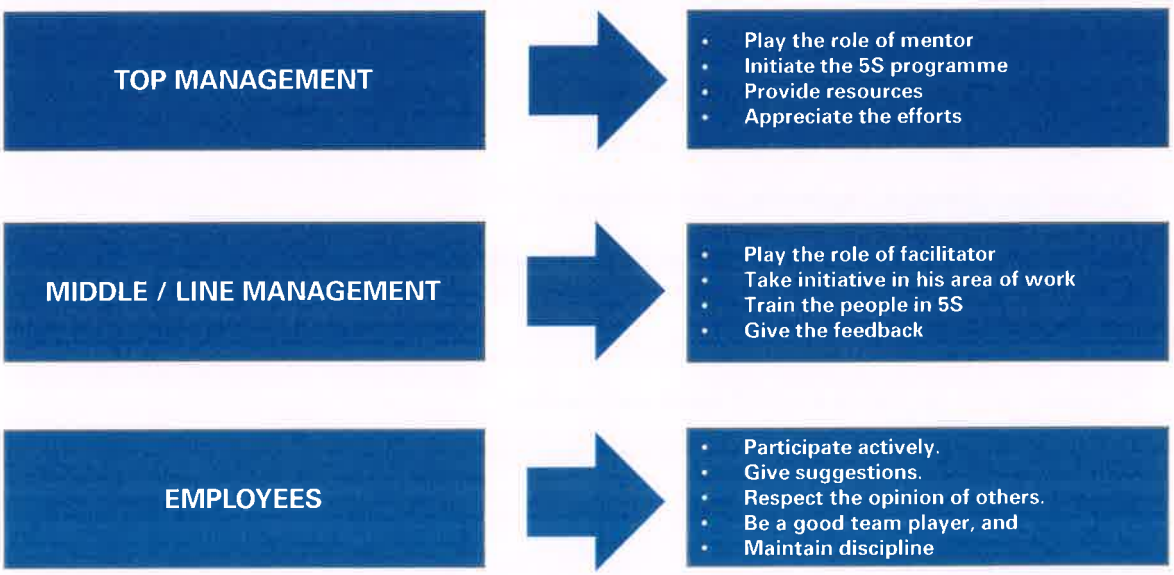
How to plan for 5S?

- Provides basis for being a world-class competitor
- Starts the foundation for a more systematic approach to the workplace
- Improves productivity and morale
- Empowers employees
- Increases profit

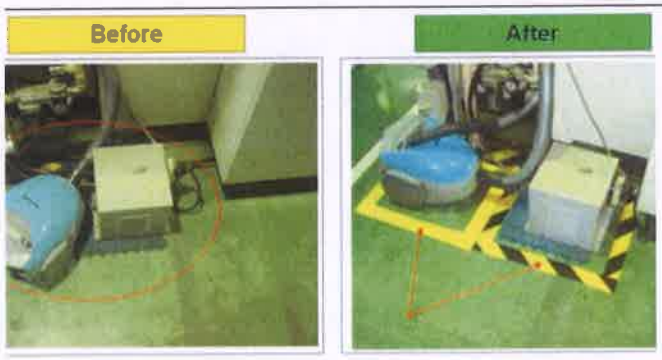
5S Implementation

- Obtain existing standards for color-coding and signage
- Decide on 5S color-coding and signage standards
- Communicate, communicate, communicate! (e-mail, signs, one on one)
- Install 5S communication board
- Set acceptable time table for completion

Roles for 5S implementation



Examples with 5S



Source: Internet

Examples with 5S

Source: Internet

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Solutions with Lean Approach

Poka-Yoke (Mistake Proofing)

Poka-Yoke

- Poka means "Mistake" or "Error" and Yoke means "Proofing" or "Avoid".
- In other words, Poka-Yoke means *Error Proofing* or *Mistake Proofing* or *Avoidance of Error*.
- Poka-Yoke is a Japanese improvement strategy for mistake-proofing to prevent defects (or nonconformities) from arising during production processes.
- The Poka-Yoke concept was created in the mid-1980s by Shigeo Shingo, a Japanese manufacturing engineer.
- Mistake Proofing is a method for avoiding errors in a process.
- The simplest definition of 'Mistake Proofing' is that is a technique for eliminating errors by making it impossible to make mistakes in the process.
- It is often considered the best approach to process control
- Poka-Yoke device is any mechanism that either prevents a mistake from being made or makes the mistake obvious at a glance.

Why Poka-Yoke?

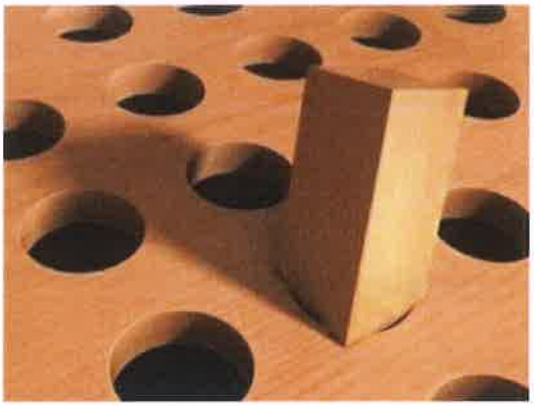
- Error free designs or processes
- Eliminate the possibility of setting the X's beyond the limits
- Warns operators before the X's move to the outside limit so that the preventive action can be taken
- Can also be used in conjunction with the risk management or SPC
- The opportunity for error needs to be minimized or eliminated

Get it right during process design…!

Poka-Yoke - Examples

Source: Internet

Poka-Yoke - Examples



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Refine / Risk Proof Solutions

Failure Mode and Effects Analysis

Failure Mode Effects Analysis (FMEA)

A Failure Mode and Effects Analysis is a systemized team activity intended to:

- recognize and evaluate potential failure and its effects
- identify actions which will reduce or eliminate the chance of failure
- document analysis findings

A team activity with the subject matter experts…!

FMEA

Objective of FMEA

- Identify the high priority failure modes and causes of defects in an operational or transactional process.
- Identify high priority input variables (Xs) that impact important output variables (Ys).
- Evolve a consensus on the recommended corrective actions and procedures to follow.

FMEA

When to use FMEA

- FMEA is designed to prevent failures from occurring or from getting to internal and external customers.
- FMEA is essential for situations where failures might occur and the effects of those failures occurring are potentially serious.
- FMEA can be used on all improvement projects.
- FMEA serves as an overall control document for any given process.

FMEA Steps

1. FMEA is carried out on a new process/product or redesigned process/product
2. For each process step, list requirements for each process step.
3. For each requirement, list the failure mode for each requirement.
4. For each failure mode, list the effect of failure for each failure mode.
5. For each effect of failure, estimate the severity.
6. For each failure mode, list causes.
7. For each cause of failure, estimate the likelihood of occurrence.
8. For each cause of failure, list the current process controls.
9. For each process control, estimate the detection.
10. For each cause of failure, calculate the Risk Priority Number by multiplying the scores associated with severity, occurrence and detection
11. For high priority causes of failure and/or failure modes, develop recommended actions.
12. For each recommended action, assign responsibility and completion dates.
13. For each recommended action, implement the action and note its effect.
14. For each implemented action, re-estimate the severity, occurrence and detection rankings and recalculate the RPN

FMEA Worksheet

Process Step/Part Number	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Resp.	Actions Taken	SEV	OCC	DET	RPN
								0							
								0							
								0							
								0							

RPN = Severity X Occurrence X Detection

FMEA - Example

Process Step	Potential Failure Mode	Potential Failure Effect	SEV	Potential Causes	OCC	Current Controls	DET	Risk Priority Number (RPN)
Cash Dispense Process at ATM	ATM does not dispense cash	• Customer Dissatisfaction • Incorrect entry in customer account • Discrepancy in customer's cash balance	8	ATM out of cash	5	Cash Alert	5	200
				Machine jammed	3	Monthly audits	10	240
				Power Failure	2	None	10	160
	ATM dispenses too much cash	• Bank loses money • Discrepancy in the cash balance	7	Denomination in wrong tray	3	Visual Verification	7	147
				Cash Stuck	2	Loading Procedure	4	56
	ATM takes too long to dispense cash	• Customer dissatisfaction • Customer annoyed	4	Network traffic	7	None	10	280
				Power Failure	2	None	10	80

Severity Scale

RPN = Severity x Occurrence x Detection

High

Low

More the severity, higher is the rating

Severity scale	
Rating	Criteria – A failure could:
10	Injure a customer or employee
9	Be illegal
8	Render product or service unfit for use
7	Cause extreme customer dissatisfaction
6	Result in partial malfunction
5	Cause a loss of performance which is likely to result in a complaint
4	Cause minor performance loss
3	Cause a minor nuisance, but be overcome with no performance loss
2	Be unnoticed and have only minor effect on performance
1	Be unnoticed and not affect the performance

Occurrence Scale

RPN = Severity x Occurrence x Detection

High

Low

More often it occurs, higher is the rating

Occurrence scale	
Rating	Criteria – A failure could:
10	More than once per day
9	Once every 3-4 days
8	Once per week
7	Once per month
6	Once every 3 months
5	Once every 6 months
4	Once per year
3	Once every 1-3 years
2	Once every 3-6 years
1	Once every 6-100 years

Detection Scale

RPN = Severity x Occurrence x Detection

Low

High

Lower the ability to detect, higher is the rating

Detection Scale	
Rating	**Definition**
10	Defect caused by failure is not detectable
9	Occasional units are checked for defect
8	Units are systematically sampled and inspected
7	All units are manually inspected
6	Units are manually inspected with mistake-proofing modifications
5	Process is monitored (SPC) and manually inspected
4	SPC is used with an immediate reaction to out-of-control conditions
3	SPC as above with 100% inspection surrounding out - of-control conditions
2	All units are automatically inspected
1	Defect is obvious and can be kept from affecting the customer

Risk Priority Number (RPN)

- The RPN number is calculated from the team's estimates of Severity, Occurrence and Detection.
- RPN = S x O x D
- If you are using a 1 - 10 scale for Severity, Occurrence and Detection, the worst RPN = 1000 (10 x 10 x 10), while the best would be RPN = 1 (1 x 1 x 1).
- Use RPN numbers to prioritize failure modes and/or causes of failures in order to work on the highest priority issues.

FMEA - Useful Tips

Suggestions for completion of the activity in time:

- Similar to a process map, FMEA is also a "live" document used throughout the DMAIC journey
- Make it a "team effort."
- Analyze new processes to avoid problems before they happen.
- Address concerns from a process perspective and not business contingency perspective
- Analyze existing processes to find and fix problems.
- Analyze existing processes to discover the high priority ("key") process input variables.

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Test Solutions

Testing for solutions

Why test solutions

- Confirm to potential solution
- Obtain feedback and buy-in for proposal
- Opportunity for refining solution

How to test solutions

- Small scale experimentation-piloting
- Modeling-physical models
- Simulation- computer models

Testing Essentials

Create A data collection plan and Monitor Activities For data Consistency and stability

Verify that the process has improved-process capability, hypothesis testing for evaluating statistical significance of the old and the improved process

Why collect data? → What to collect? → How to collect? → Ensure consistency & stability

Help ensure robust measurement plan for testing the solution

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Justify Solutions

Justify solution

Tangible benefits

- Savings
- Incremental revenue
- Interest cost and income
- Cash flow
- Reduced workforce

Intangible benefits

- Customer retention
- Improved VOB/VOC
- Ease of work
- Better governance

Prepare net financial gains and supplement with intangible gains and obtain business and finance leader approvals before proceeding

Cost Benefit Analysis (C B A)

Hard Gains		
Cost Heads	**Vendor**	**In House Training**
Trainer Cost	250,000	0
T and L	30,000	0
Q Team Support	4,444	11,111
Facilities	20,000	20,000
Equipment	1,000	1,000
Stationary and Manuals	15,000	10,000
GB Examination	50,000	2,222
Total Cost	370,444	44,333
Estimated annual cost		
	Cost with Vendor	Cost with Quality Team
Per Training	370,444	44,333
12 Training per year	4,445,333	532,000
Cost of creating the training manual		
Man Days Spent	Average per day cost	Total Cost incurred
30	2,222	66,667
Savings per year		
3,846,667		
Assumptions		
1. Hypothetical Costs assumed		
2. Recurring cost of upgrading the content is INR66,667		
* All Figures in INR		

Inference from Improve Phase

- Shortlist the appropriate solution
- Risk proof the solution using FMEA
- Validate the improvement by testing the solutions
- Justify the benefits of the project to the management

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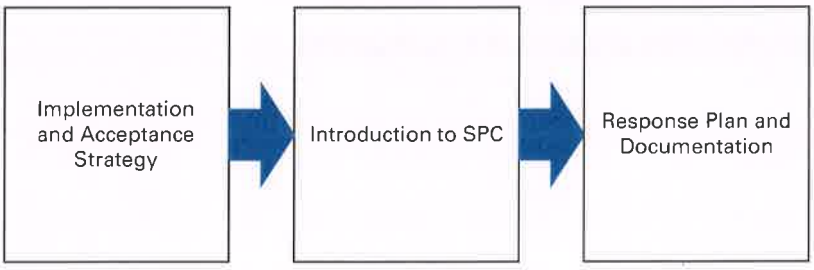
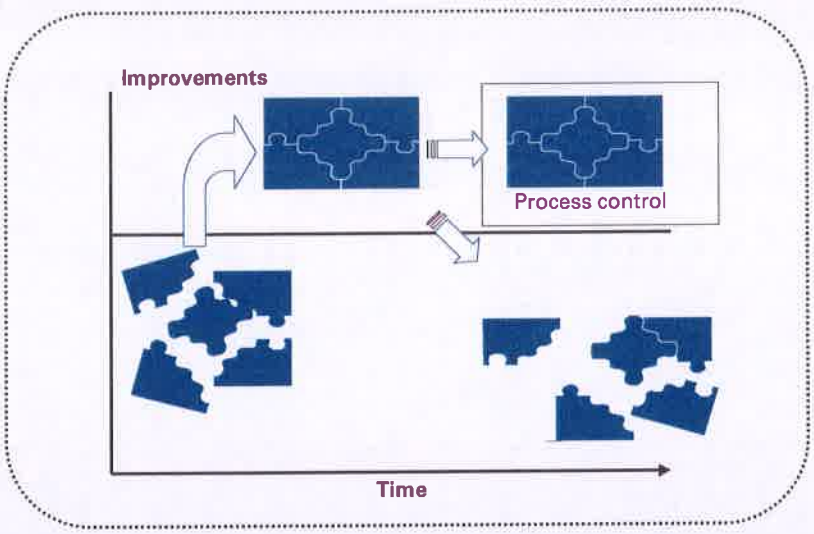
Control Phase

Control Phase - Roadmap

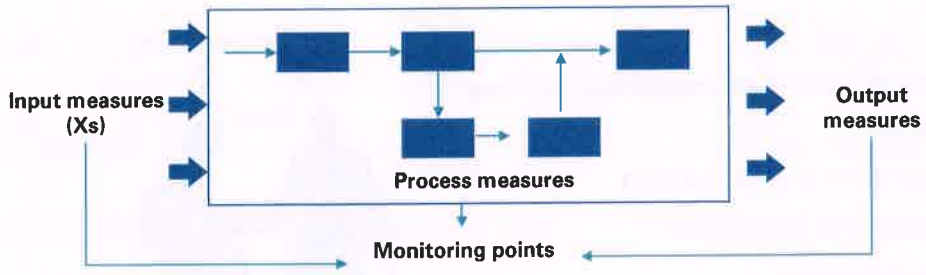


Why control?



To hold the gains of the DMAIC project there by help ensuring that the efforts of the project team are not written off

What to control?



- At the barest minimum, measure CTQs
- Strive to measure the critical Xs to provide chances to make corrections
- Install the appropriate data collection plan
- Audit appropriately
- Early warning system prevent $$ impact (rework reduction)

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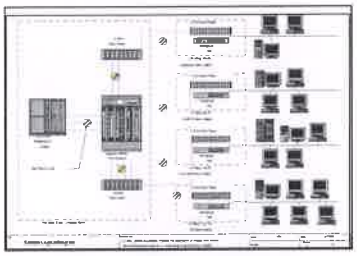
Implementation and Acceptance Strategy

Implementation

Elements of good implementation planning:

- Objectives
- Incorporation of pilot learning
- Resources and time frame
- Influence strategy
- Control plan
- Documentation

Implementation Strategy



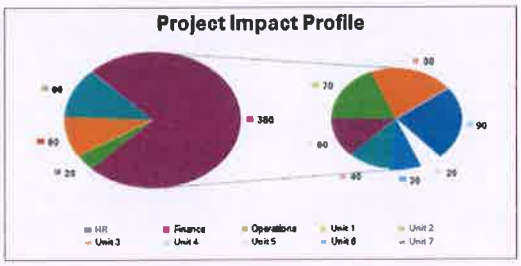
Quality of solution x **Acceptance of solution**

=

Effectiveness of implemented solution

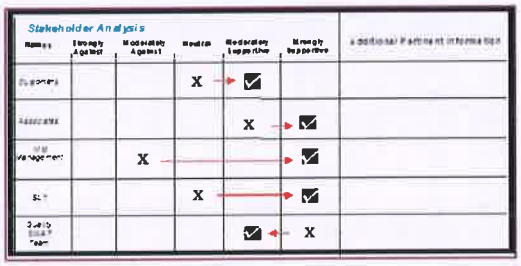
Acceptance Strategy

Key constituents map



Identify stake holders to be addressed first

Stakeholders analysis



Identify stakeholder support profile

Influence strategy

	Issue/ Concern	Identify Wins	Strategy
Stakeholder 1			Data
Stakeholder 2			Demonstrate
Stakeholder 3			Demand

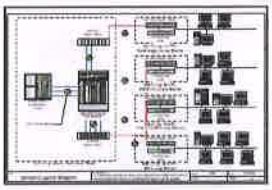
Determine influence strategy

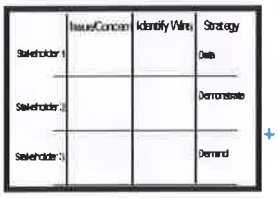
TPC analysis

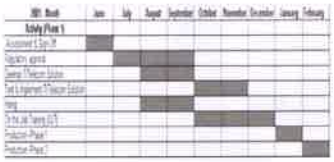
	Cause of resistance	Examples	Ranking
Technical			
Political			
Cultural			

Identify causes for stakeholder resistance

Implementing Solutions







Project management tools

Successful Implementation

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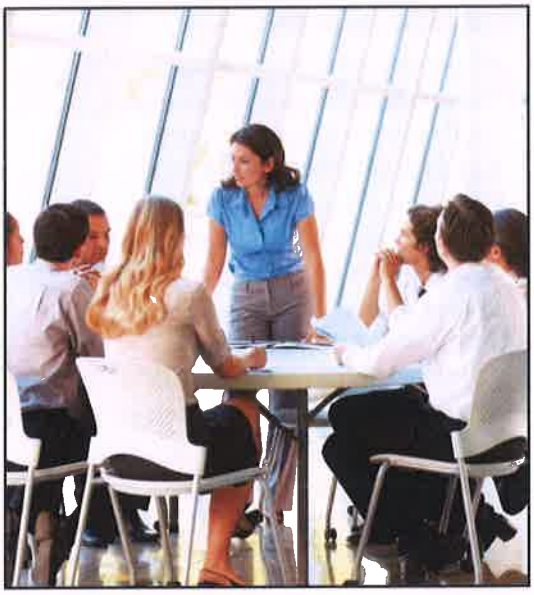
Introduction to SPC

Why control?



Process control is essential to prevent the loss of gains over a period of time

Detect the out of control state of processes and determine the appropriate actions

Control system incorporates risk management, SPC, measurement and audit plans, response plans, documentation and ownership

Statistical Process Control (SPC): An Overview

Control charts

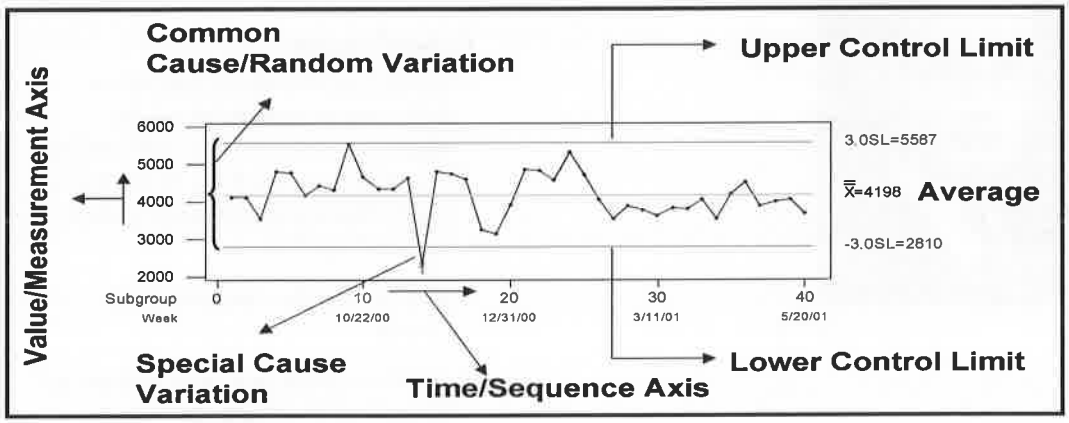
- Statistical Process Control or SPC was conceptualized by Walter A Shewhart to determine if a business process (back then manufacturing process) is in a state of control.
- SPC primarily uses Control Charts
- Control charts are also known as Shewhart charts, or process behavior charts

Statistical Process Control (SPC): An overview

Fundamentals of SPC

- All processes display variation
- There are two types of variation i.e. Common Cause Variation and Special Cause Variation
- Common Cause Variation is inherent, steady, common, undiscoverable
- Special Cause Variation is intermittent, special, discoverable, removable
- The Control Charts are set at ± 3σ from the mean

Control Limits



- Select process, measures to be charted
- Establish data collection and sampling plan
- Calculate the statistics
- Plot control charts

Special Cause vs. Common Cause Variation

True variation type...	Common causes	Special causes
Common causes	Focus on systematic process change	**Mistake 1 Tampering** (increases variation)
Special causes	**Mistake 2 Under-reacting** (missed prevention)	Investigate special causes for possible quick-fixes

Low — High

In Our Control

Statistical Process Control (SPC): Why and When Control Charts?

Control charts

- Control Charts monitor changes in the Xs and detect changes that are due to special causes
- Used when the Xs cannot be mistake proofed or need to be controlled for inherent variations

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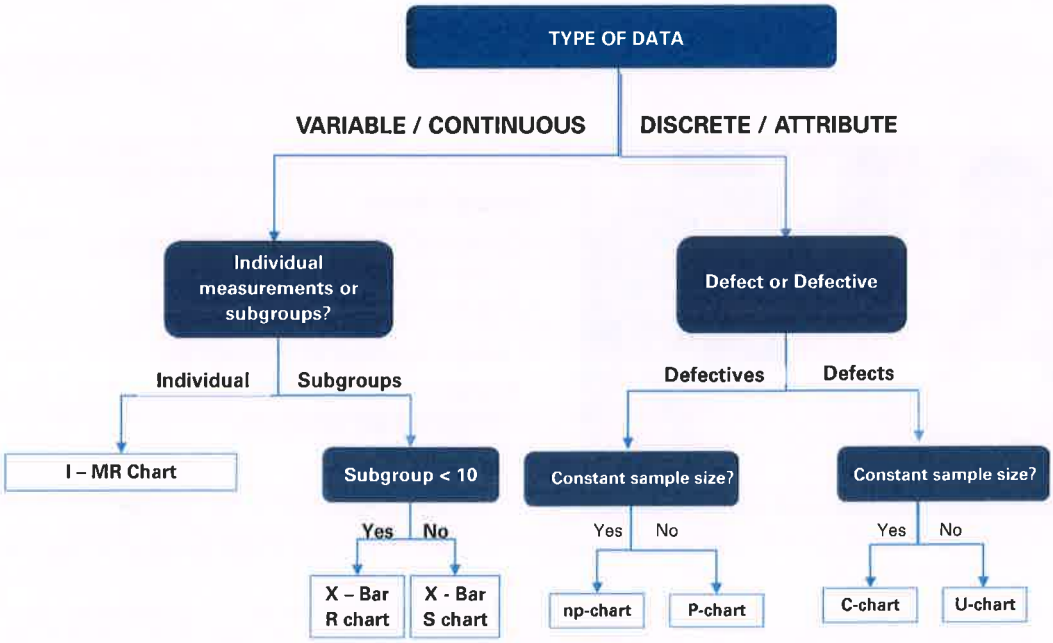
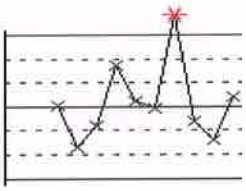
Introduction to SPC

Types of Control Charts

Selecting Control Charts

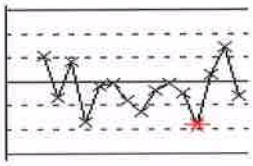


Identifying Special Cause Variations



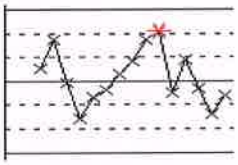
Test 1. Points beyond Control Limits:

Points beyond control limits are isolated high or low points. 1 point more than 3σ from center line



Test 2. Points on one side of the center line

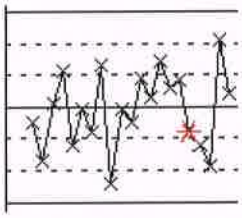
9 points in a row on same side of center line



Test 3. Trend

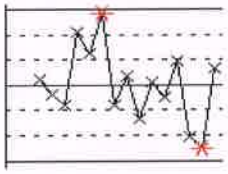
Trends will continue up or down without a well defined end. Six points in a row, all increasing or all decreasing

Identifying Special Cause Variations



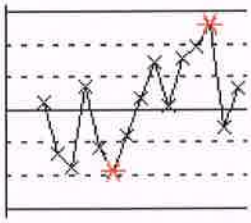
Test 4. Variation pattern

A cycle produces a pattern of up and down points, very much as if the values of the points were time dependent. Fourteen points in a row, alternating up and down



Test 5. Points on same side

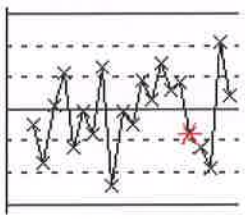
Two out of three points more than 2s from the center line (same side)



Test 6. Points on same side

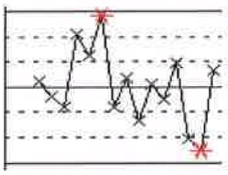
Four out of five points more than 1s from the center line (same side)

Identifying Special Cause Variations



Test 7. Identifies a pattern of variation

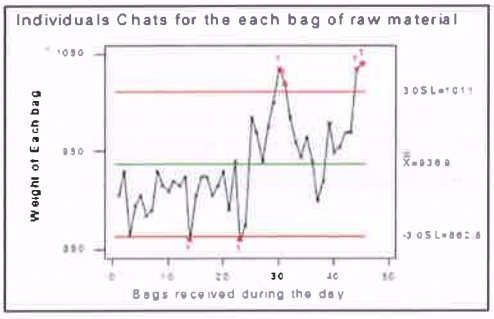
Fifteen points in a row within 1s of center line (either side)



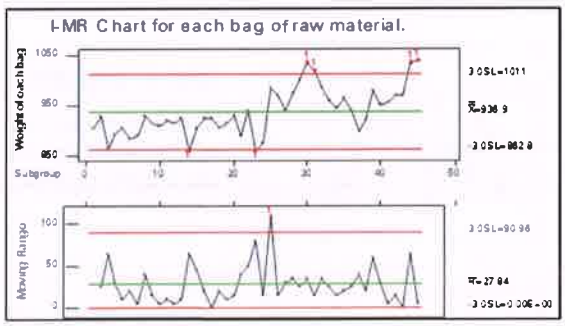
Test 8. Mixture Pattern

Eight points in a row more than 1s from center line (either side)

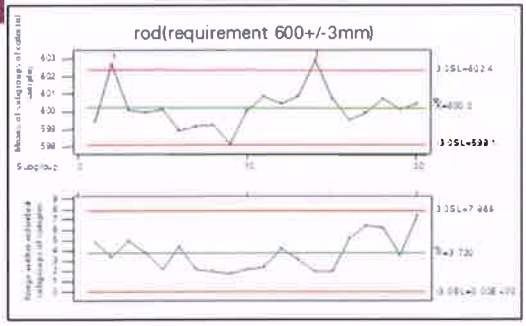
Control Charts - Variable / Continuous Data



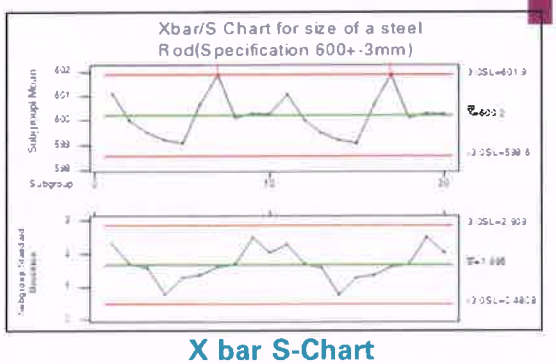
Individual-Chart



I MR -Chart

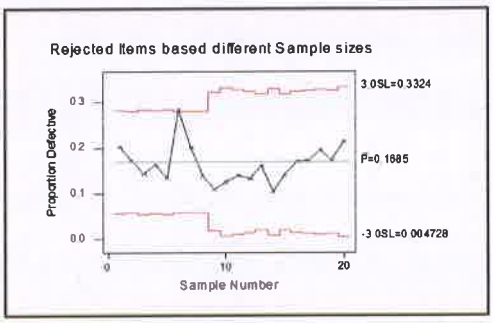


X bar R-Chart

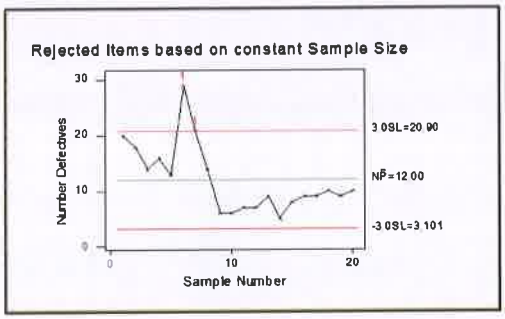


X bar S-Chart

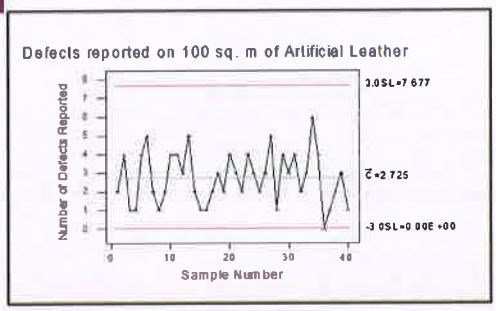
Control Charts - Attribute / Discrete Data



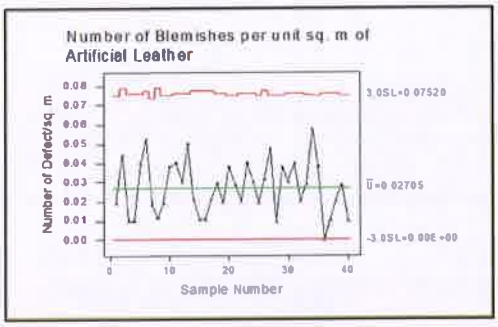
p-Chart



np-Chart



c-Chart



u-Chart

Benefits of Control Charts

- Control Charts reduces defects by keeping processes centered
- Improves overall quality by reducing chances of quality deviations
- Aids in timely troubleshooting
- Serves as a communication tool for changes in CTQs
- Sustain improvements

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Response Plan and Documentation

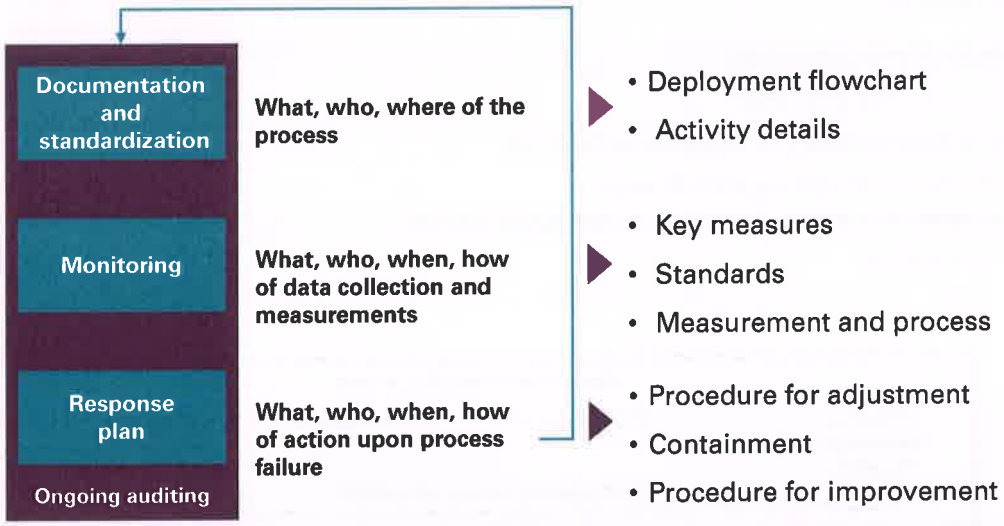
Project Closure

Essentials of project closure:

- Document and communicate results
- Recommend translation opportunities
- Evaluate team success-results, process and relationships
- Celebrate
- Disband project team

Process Management System

New special cause variations identified



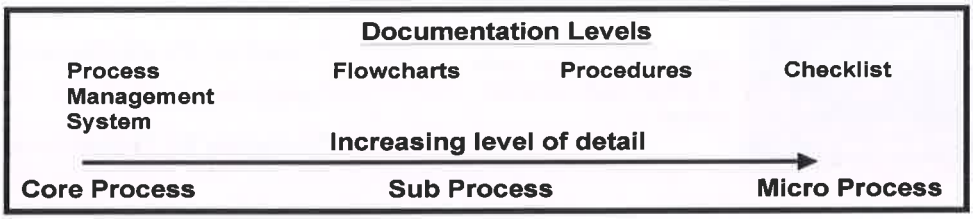
Process Management System

DOCUMENTATION		MONITORING			RESPONSE PLAN		
The plan for doing the work		Checking the work			The response to special causes		
Deployment flowchart	Details on key tasks	Key process and output measures	Monitoring standards	Method for recording data	Containment	Procedure for process adjustment	Procedure for process improvement

Documentation

Documentation process is an activity that help ensure that the knowledge gained by the project team is:

- Implemented successfully
- Retained by the business
- Used to standardize the business processes
- Future resources can be trained easily
- Improvements can be shared and translated across
- Institutionalized



Inference from Control Phase

- Develop and implement control plans.
- Identify the appropriate KPIVs to be measured.
- Identify the appropriate control chart.
- Transfer knowledge and responsibility for process control to appropriate position(s).

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Thank You

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