PDHonline Course P222 (5 PDH)

Project Management Guidebook_Part 2 – Application Tools

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Contents:

I. INTRODUCTION:

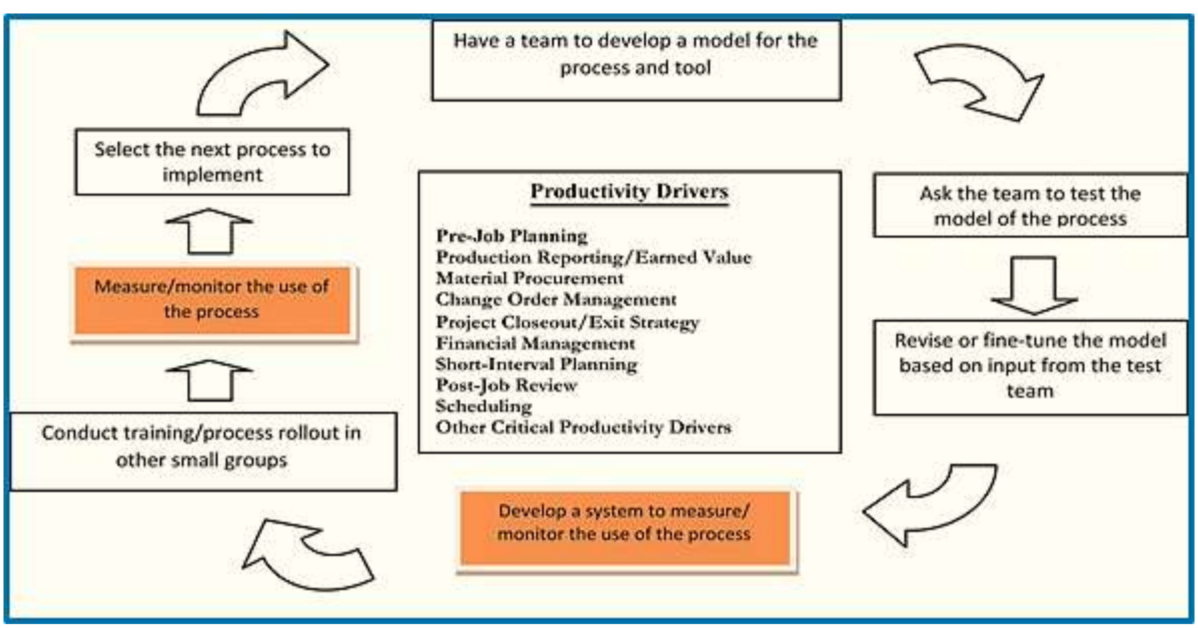
This chapter of **Project Management Guidebook, Part 2 – Application Tools** is very important to the readers of this tutorial. The basic assumption, here, is the knowledge of business management tools based on **production processes**, **quality methods** and scientific management approaches. The articles contained in this chapter show that the management of any endeavor (like a software engineering or management) should be the same in any activity or organization.

Management can be defined as all the activities and tasks undertaken by one or more managers for the purpose of planning and controlling the activities of a work group, in order to achieve an objective or complete an activity that could not be achieved by persons acting independently. Management, as defined by well-known authors in the field of management, contains the following components:

Activity	Definition or Explanation
Planning	Predetermining a course of action for accomplishing organizational objective
Organizing	Arranging the relationships among work units for accomplishment of objective and the granting of responsibility and authority to obtain those objectives
Staffing	Selecting and training people for positions in the organization
Directing	Creating an atmosphere that will assist and motivate people to achieve desire end results
Controlling	Establishing, measuring, and evaluating performance of activities toward planned objectives

All Project Managers should be prepared to carry out the functions of planning, organizing, staffing, leading, and controlling, although the time spent in each function will differ and the skills required by managers at different organizational levels vary. Still, all managers are engaged in getting things done through people. The managerial activities, grouped into the managerial functions are carried out by all managers, but the practices and methods must be adapted to the particular tasks, enterprises, and situations.

Furthermore, the person in a managerial role must be a very well prepared technically and academically to directing people in sales, production, engineering, quality or finance department. A very well **prepared Project Manager** (Engineer or a Technician) should be flexible to plan, control, realize the quality management tools and know the basis of EPPC – Engineering, Procurement, Planning and Construction.



II. PLANNING TECHNIQUES:

Planning techniques are the essential ways for any construction for the purpose of monitoring results. Among them are budgeting, cost accounting, network planning and control techniques to develop the rate-of-return-on-investment control, within various devices of organizational development. The objectives may approach to a Quality System, which normally reflects a theory, but is one of many means of helping managers to undertake activities, most effectively reflecting quality. The most known tools are:

1. Program Evaluation and Review Technique (PERT):

The **Program Evaluation and Review Technique**, commonly abbreviated PERT, is a **planning tool** used in project management, designed to analyze and represent the tasks involved in completing a given project. The Navy's Special Projects Office (Polaris-Submarine weapon system and Fleet Ballistic Missile), developed a statistical technique for measuring and forecasting progress in research and development programs, called Program Evaluation and Review Technique (**PERT**) is applied as a decision-making tool designed to save time in achieving end-objectives, for which time is a critical factor.

First developed by the United States Navy in the 1950s, it is commonly used in conjunction with the **Critical Path Method** (CPM). The **PERT** technique represents the major, finite accomplishments (events) essential to achieve objectives, and estimates a range of time necessary to complete each activity, between successive events, of "*most likely time*", "*optimistic time*", and "*pessimistic time*" for each activity. The technique also highlights danger signals requiring management decisions; reveals and defines both criticalness and slack in the flow plan or the network of sequential activities that must be performed to meet objectives.

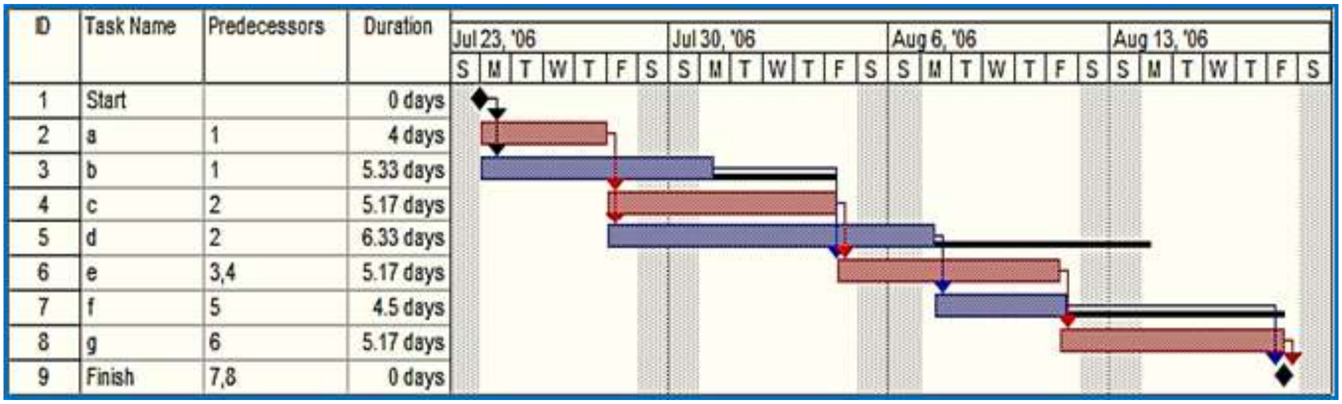
1.1. Implementation:

The first step to scheduling a project **is to determine all the tasks** required, according to the order and time length in which it must be completed. The order may be easy to record for some tasks (e.g. when building a house, the land must be graded before the foundation can be laid), sometimes difficult for planning (there are two areas that need to be graded, but there are only enough bulldozers to do one). Then, the time usually reflects the normal, non-rushed, required to execute a task that can be improved to an additional cost or a reduction in the quality.

In the following example there are seven tasks, labeled ***A*** through ***G***. Some tasks can be done concurrently (A and B) while others cannot be done until their predecessor task is complete (C cannot begin until A is complete). Additionally, each task has **three time estimates**: the **optimistic** time estimate (O), the most likely or **normal** time estimate (M), and the **pessimistic** time estimate (P). The expected time (TE) is computed using the formula (O + N + P) / 3.

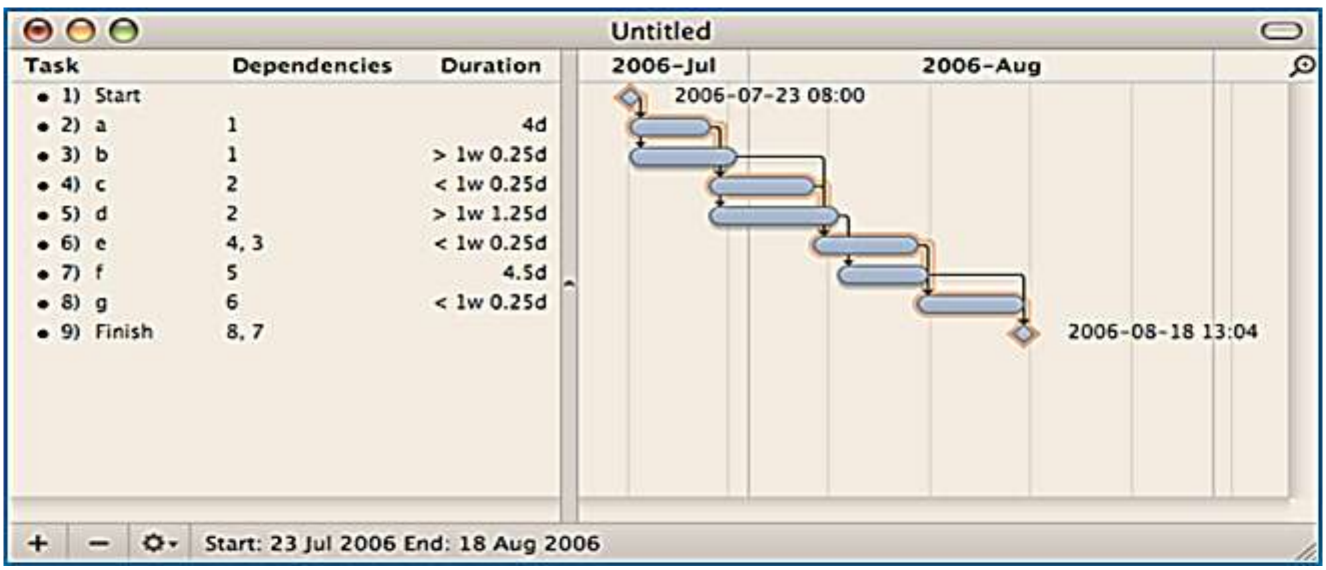
Activity	Predecessor	Time estimates			Expected time
		Optimistic (O)	**Normal** (M)	**Pessimistic** (P)	
A	—	2	4	6	4.00
B	—	3	5	9	5.66
C	A	4	5	7	5.33
D	A	4	6	10	6.66
E	B, C	4	5	7	5.33
F	D	3	4	8	5.00
G	E	3	5	8	5.33

Gantt Chart: Is a type of bar chart, (developed by Henry Gantt in the 1910). Once the Stage 1 is complete, draw a Gantt Chart to show the **start** and **finish** dates of the elements of a network project diagram. Below, there is a Gantt chart that was created using the very well-known **Microsoft Project** (MS Project). Some bars on the Gantt chart are longer when cut through a weekend.



1. The **critical** path is in **red**;
2. The **slack** is the black lines connected to **non-critical** activities;
3. Since Saturday and Sunday are not working days are excluded from the schedule.

Below, a **Gantt Chart** was created using the **OmniPlan**, which is a planning and project management software product from The Omni Group dedicated to Apple Macintosh products.



1. The **critical** path is **highlighted**;
2. The **slack** is not indicated on task 5 (d), though it can be observed on tasks 3 and 7 (b and f),
3. Since weekends are indicated by a thin vertical line, and take up no additional space on the work calendar, bars on the Gantt chart are no longer or shorter, when they do or don't carry over a weekend.

Thus, the designer draws each activity that does not have a predecessor activity (***a and b*** in this example) and connect them with an arrow from start to each node. Next, since both ***c and d*** list a as a predecessor activity, their nodes are drawn with arrows coming from a. Activity ***e*** is listed with ***b and c*** as predecessor activities, so node ***e*** is drawn with arrows coming from both ***b and c***, signifying that ***e*** cannot begin until both ***b and c*** have been completed.

Activity ***f*** has d as a predecessor activity, so an arrow is drawn connecting the activities. Likewise, an arrow is drawn from ***e*** to ***g***. Since there are no activities that come after ***f*** or ***g***, it is recommended (but again not required) to connect them to a node labeled finish.

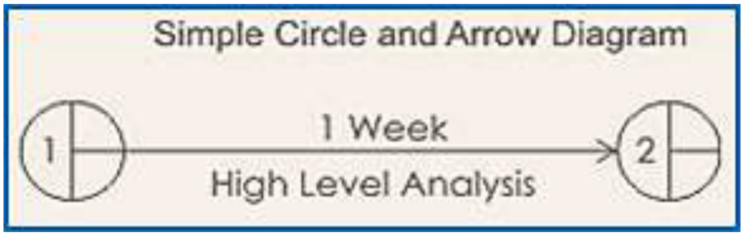
1.2. Drawing a Critical Path Analysis Chart:

List all activities in the plan: For each activity, show the earliest start date, estimated length of time it will take, and whether it is parallel or sequential. If tasks are sequential, show which stage they depend on. For the project example used here, you will end up with the same task list as explained in the article on Gantt Charts. The chart is repeated below:

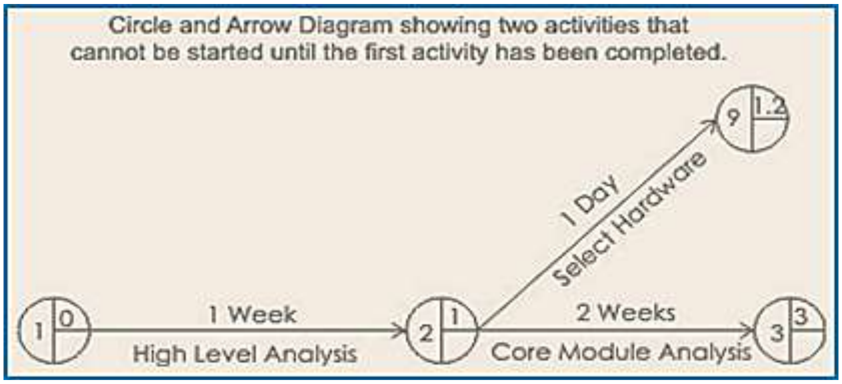
Task List: Planning a New Computer Project:

Task Designation..	Earliest start..	Time..	Task Type..	Dependent on...
A). High level analysis	Week 0	1 week	Sequential	
B). Selection of hardware platform	Week 1	1 day	Sequential	A
C). Installation and commissioning of hardware	Week 1.2	2 weeks	Parallel	B
D). Detailed analysis of core modules	Week 1	2 weeks	Sequential	A
E). Detailed analysis of supporting modules	Week 3	2 weeks	Sequential	D
F). Programming of core modules	Week 3	2 weeks	Sequential	D
G). Programming of supporting modules	Week 5	3 weeks	Sequential	E
H). Quality assurance of core modules	Week 5	1 week	Sequential	F
I). Quality assurance of supporting modules	Week 8	1 week	Sequential	G
J).Core module training	Week 6	1 day	Parallel	C,H
K). Development and QA of accounting reporting	Week 5	1 week	Parallel	E
L). Development and QA of management reporting	Week 5	1 week	Parallel	E
M). Development of Management Information System	Week 6	1 week	Sequential	L
N). Detailed Training	Week 9	1 week	Sequential	I, J, K, M

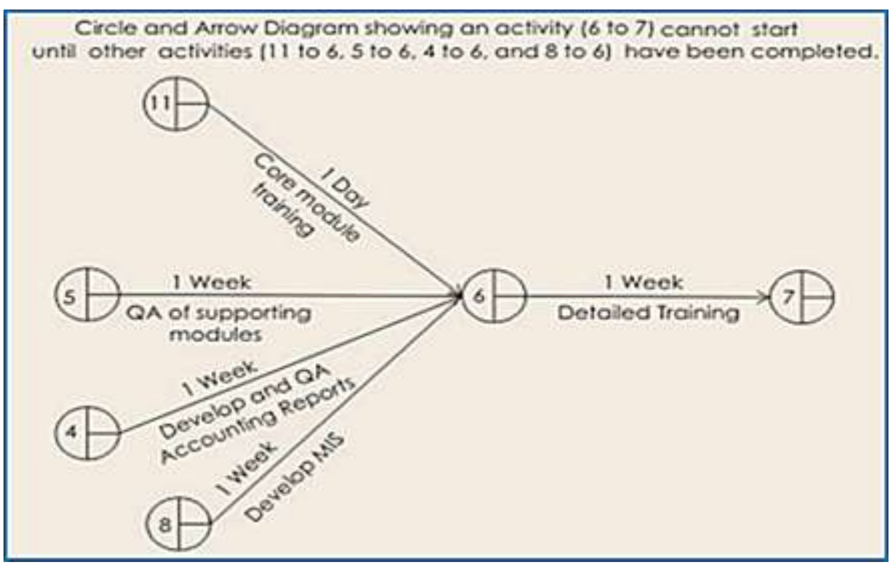
Critical Path Analysis in PERT: The Critical Path Analyses are presented in PERT using circles and arrows diagrams, commonly in different colors. Circles show events within the project, such as the **start and finish** of tasks. The number shown in the left hand half of the circle allows you to identify each one easily. These circles are sometimes known as nodes. An arrow running between two event circles shows the activity needed to complete that task. A description of the task is written underneath the arrow. The length of the task is shown above it. By convention, all arrows run left to right. Arrows are also sometimes called arcs. Plot the activities with a circle or an arrow diagram, as shown below:



This shows the start event (**circle 1**), and the completion of the "*High Level Analysis*" task (**circle 2**). The arrow between them shows the activity of carrying out the "*High Level Analysis*". This activity should take 1 week. Where one activity cannot start until another has been completed, we start the arrow for the dependent activity at the completion event circle of the previous activity. See the example shown below:



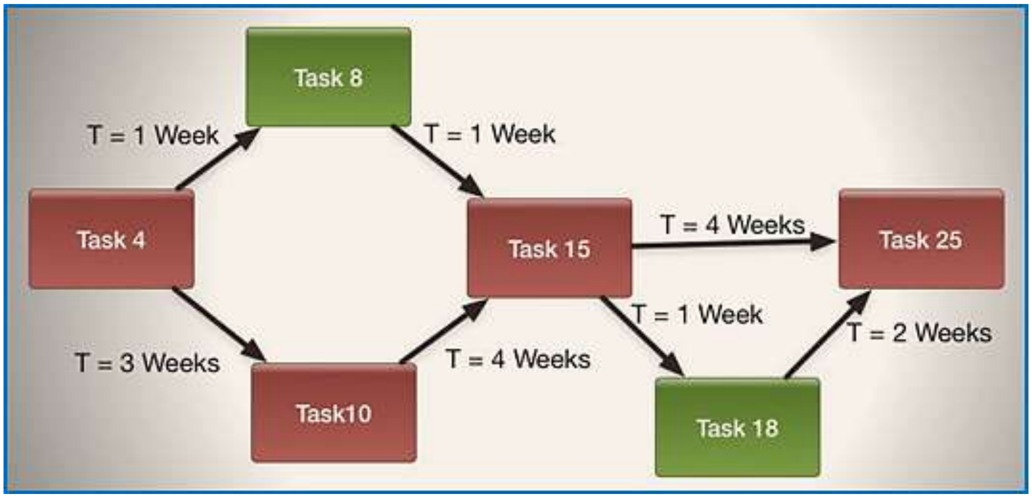
The Critical Path Analysis is referred to activities by the numbers in the circles at each end. For example, the task *"Core Module Analysis"* would be called activity 2 to 3. The *"Select Hardware"* would be activity 2 to 9. Activities are not drawn to scale. In the diagram above, activities are 1 week long, 2 weeks long, and 1 day long. Arrows in this case are all the same length. In the example above, a second number is in the top, right hand quadrant of each circle. It is conventional to start at 0. Here activity 6 to 7 cannot start until the other four activities (11 to 6, 5 to 6, 4 to 6, and 8 to 6) have been completed.



Note: In some situations, shortening the original critical path of a project can lead to a different series of activities becoming the critical path. For example, if activity **4 to 5 were reduced to 1 week**, activities 4 to 8 and 8 to 6 would come onto the critical path. In practice Project Managers use software tools like

Microsoft Project to create Gantt Charts to make them easier to draw, but make modification of plans by providing facilities for monitoring the planning progress.

The image below is an example of a **PERT** chart, showing the critical tasks or milestones and the time required to complete them. The Critical Path is in **red**, and the parallel tasks are simply those required to finish one of the critical tasks. This particular project will take 11 weeks to complete at a minimum. You will find that by using a visual tool such as a **PERT** chart, you will be able to see areas of concern before they become issues, and keep your project on track.



2. Project Planning:

In **Microsoft Project**, a project can have all information regarding tasks and resources. The information is fed into a "**black box**" or algorithm, to provide a schedule in the form of a Gantt Chart, Network Diagram Chart, or Resource Graph. In summary, the seven or eight parameters to enter result in a schedule displayed on various views and forms.

- Define the project;
- Plan the project;
- Implement the stages;
- Monitoring, controlling and adjusting;
- Whole evaluation of the schedule.

2.1. The Stages of Project Planning:

Planning of all the activities, resources, and estimation of materials and time scales. Some of this planning may have to be done at an appropriate level for **cost estimation before the project** can be agreed. Once the decision of "***to go ahead***" is taken, **the skills** of the Project Manager are used **to define the details of the planning stage**. When this is completed and agreed with the customer (or customers) it will become the "Plan" or the base line, where the project progress can be measured.

Note: After setting out the goal and the objectives with the specifications and limitations where the undertaking must be completed, the process of the project planning is divided into specific stages, which can be defined as follows. Management task attributes include some or all of the following:

- ✓ Objectives, time constraints and milestones;
- ✓ Estimated Duration: Tasks that are dependent of other tasks;

- ✓ Optimistic estimate and itemized task budget;
- ✓ Pessimistic estimate and resources required to complete the task;
- ✓ The ability to manage the progression of the tasks, resources, start times and finish times;
- ✓ The production of appropriate progress reports;
- ✓ The ability to define the Goal, Objective, Specifications and Limitations of a project;
- ✓ The ability to define the individual tasks in sufficient detail and sequence to meet the objective with the minimum of problems, and within the defined time scale.

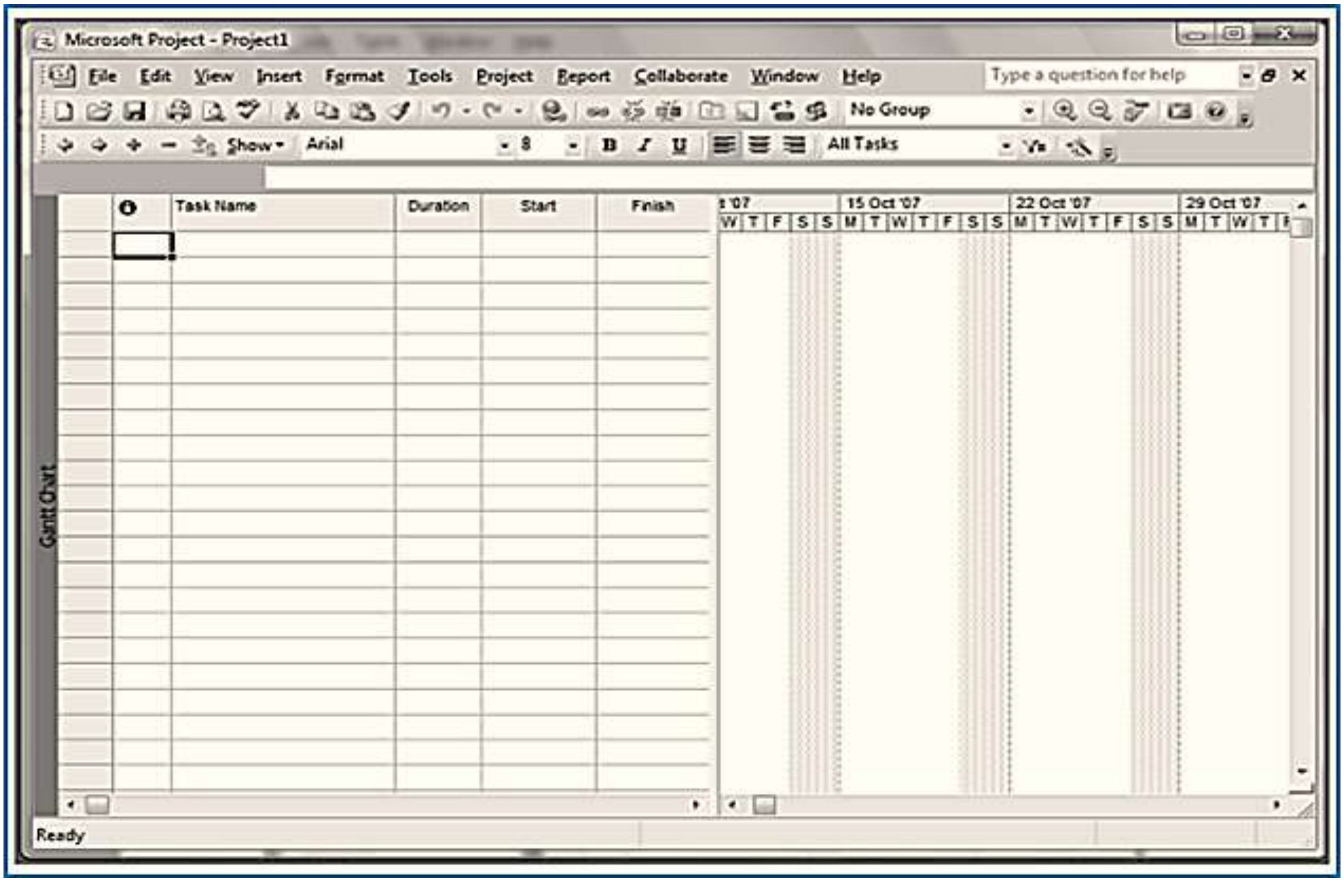
2.2. Understanding Microsoft Project:

Project is a planned undertaking. The skills of management are gathered from a wide range of experiences, where a major undertaking has to be completed, whose skills are not only brought into focus but must be applied in a much more structured format. The Project Manager must **understand** jargons, techniques, methods and become familiar with the "***tools of the trade***", relevant to project management.

2.3. MS Project Basic Tutorial:

A Project Manager that **does not know MS Project** or any other management software and interactive quality tools **is not prepared** to effectively manage important projects and work with Project Management. Below is described the usefulness of the Microsoft Project (MS Project) in planning a full project time, whose tools may show how to control all management stages, since the basic earthwork installations, materials, machines, personnel logistics and costs, when is necessary a complete work planning.

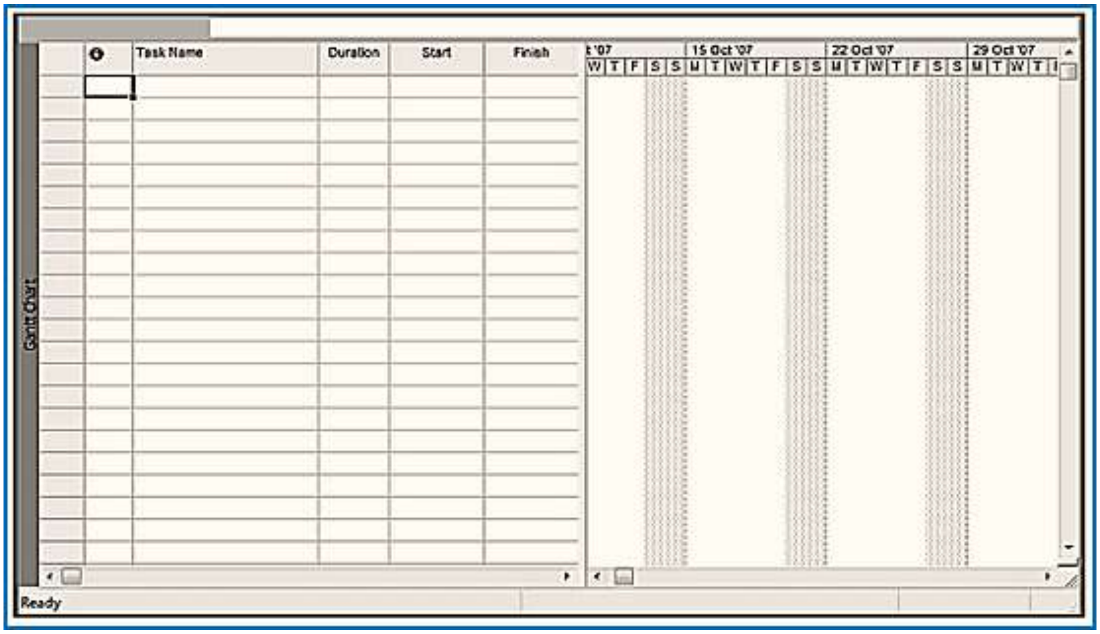
a. The Screen: Double-click on the **MS Project icon**, or click the Start button, select Programs, select the Project icon, click on the Help menu and select Microsoft Project Help or press [F1].



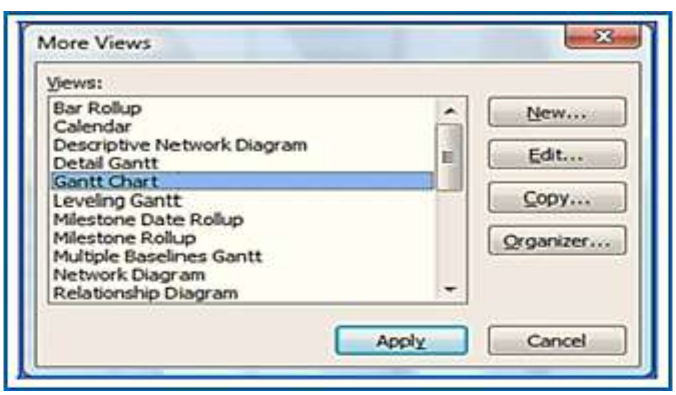
As the complexities of these undertakings increase, the importance of discipline and structure also increase and the Project Manager must look to the tools that can help which is where Microsoft Project comes into the picture. The **Project Help** task will open on the right of the screen enabling you to search for assistance on a specific topic.

The Menus:	**Always displayed, some options depend on the selected view.**
Tool Bars:	Buttons provide quick access to common commands. Bars can be customized.
Task Pane	With options to help when 'Getting Started'. Other task panes are available.
Entry Bar:	The entry point for text with outlining buttons.
Status Bar:	At the bottom of the screen showing the current status.
Scroll Bars:	Using a mouse to scroll the views and to move the boundary between two views.
Working Area:	The area for 1 or 2 views, the size of each can be adjusted.

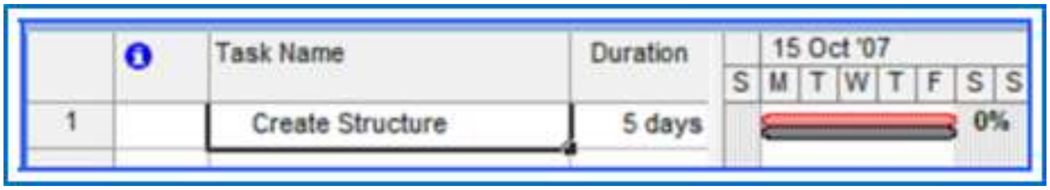
b. Gantt Chart: The default Project view is the **Gantt Chart** view, as displayed below. This view is used extensively in Microsoft Project. The Gantt Chart consists of a Gantt table and a Gantt bar chart. The divider bar separates the two and can be repositioned to display more of the table or more of the chart. The Gantt table consists of **rows and columns**. Just like on a spreadsheet, the intersection of a row and a column is called a cell. The Gantt bar chart graphically displays your schedule on a time line.



c. View Menu: The View bar is located vertically on the left of the default view (if it is active). To activate/deactivate, select View, View Bar. More Views may be selected to see other tools.



d. The Calendar: Is the tracking **Gantt View**: When you initially set up a project with tasks and dates, and saves the project with a baseline, the Tracking Gantt view displays those tasks as shown below. The baseline bars and the scheduled or actual bars are synchronized. Due the tasks are linked, the slipping of task 2 will cause a ripple effect, making its successor tasks slip by 2 days as well.



e. Tool Bars: The icons provide quick access to some of the commands available from the pull down menus. The default arrangement of the toolbars is the Standard and Formatting bars active.

	Create a New blank file.		Link the selected tasks with a Finish-to-Start relationship
	Open an existing File.		Unlink the selected tasks.
	Save the current file		Split the selected tasks
	Print the active View		Open the Task Information dialog box.
	Print Preview the active view		Attach a note to the current task.
	Spell-check the selection.		Task drivers
	Cut the highlighted section to the Clipboard		Add Resources.
	Copy the highlighted section to the Clipboard		Group Information.
	Paste from the Clipboard.		Zoom in.
	Format Painter.		Zoom out.
	Undo the previous action.		Go to selected task.
	Redo the previous action		Copy a static Picture so it can be used in another application.
	Insert a hyperlink Launch the Web toolbar.		Display the Office Assistant

f. Select File - Open:

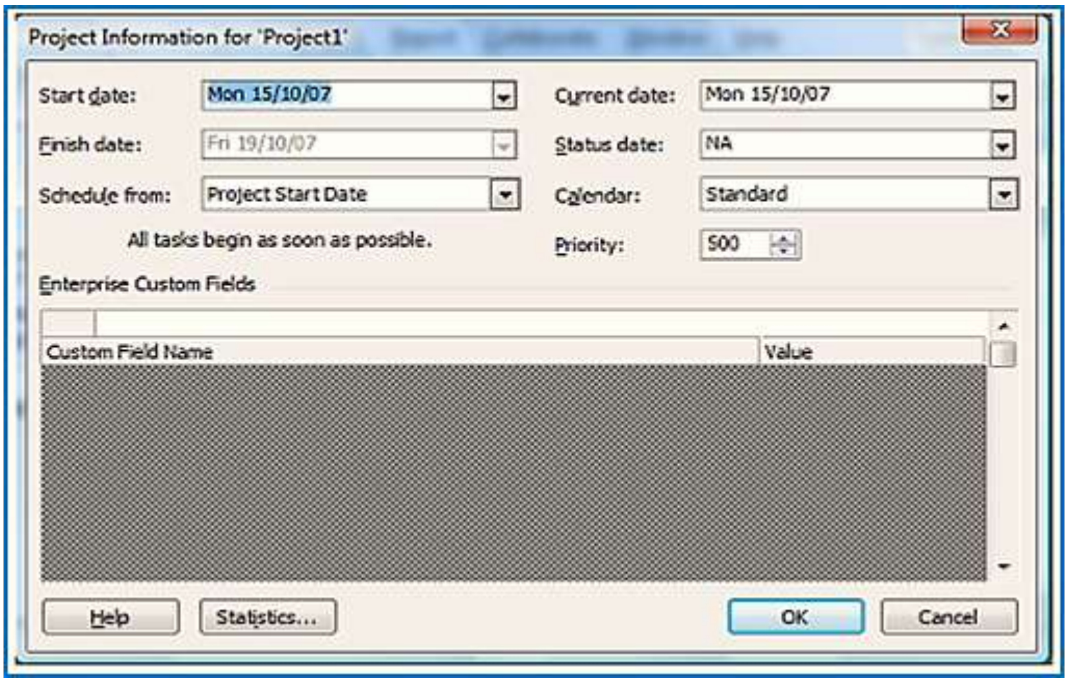
- Press [Ctrl-Home] and [Alt-Home] to go to the start of the project;
- Use the scroll tools to see the project progress;
- Use the mouse to change the size of the various windows;
- Alter the time scale with View, Zoom.

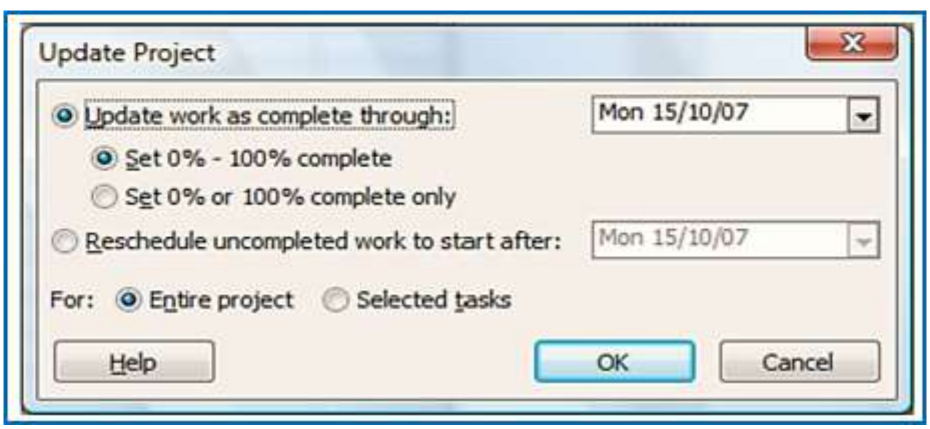
g. Click on the View menu:

- Choose each of the top five and note the different screens;
- Select View, Gantt Chart to return to the original view;
- Move the mouse to the central vertical bar. It will change to a double line with a double arrow;
- Click and hold the left button and drag left to see more of the Gantt Chart;
- Repeat but drag right to see more of the Entry Table.

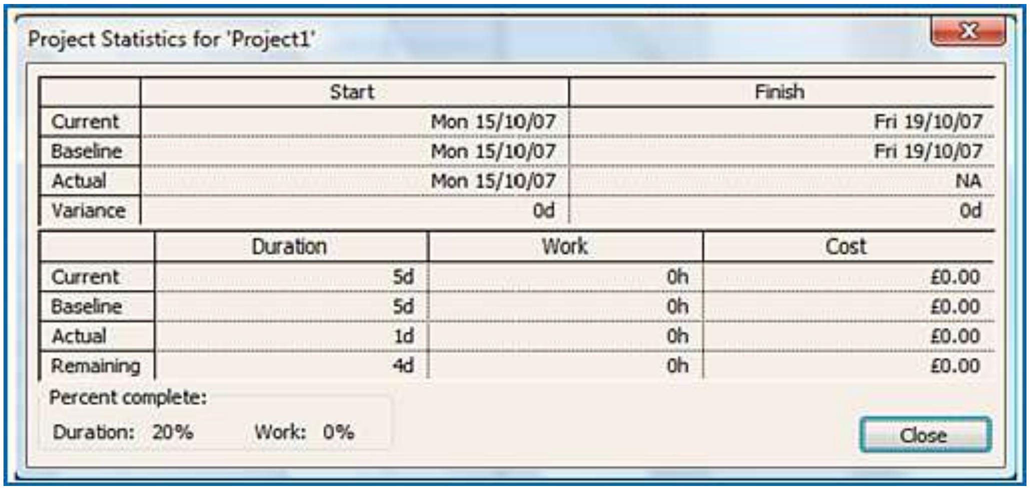
h. Change the Project start date:

- Select Project, Project Information from the menus.
- Change the project Start Date.
- Click OK and examine the views again.
- Select Tools, Tracking, Update Project to see project progress so far.

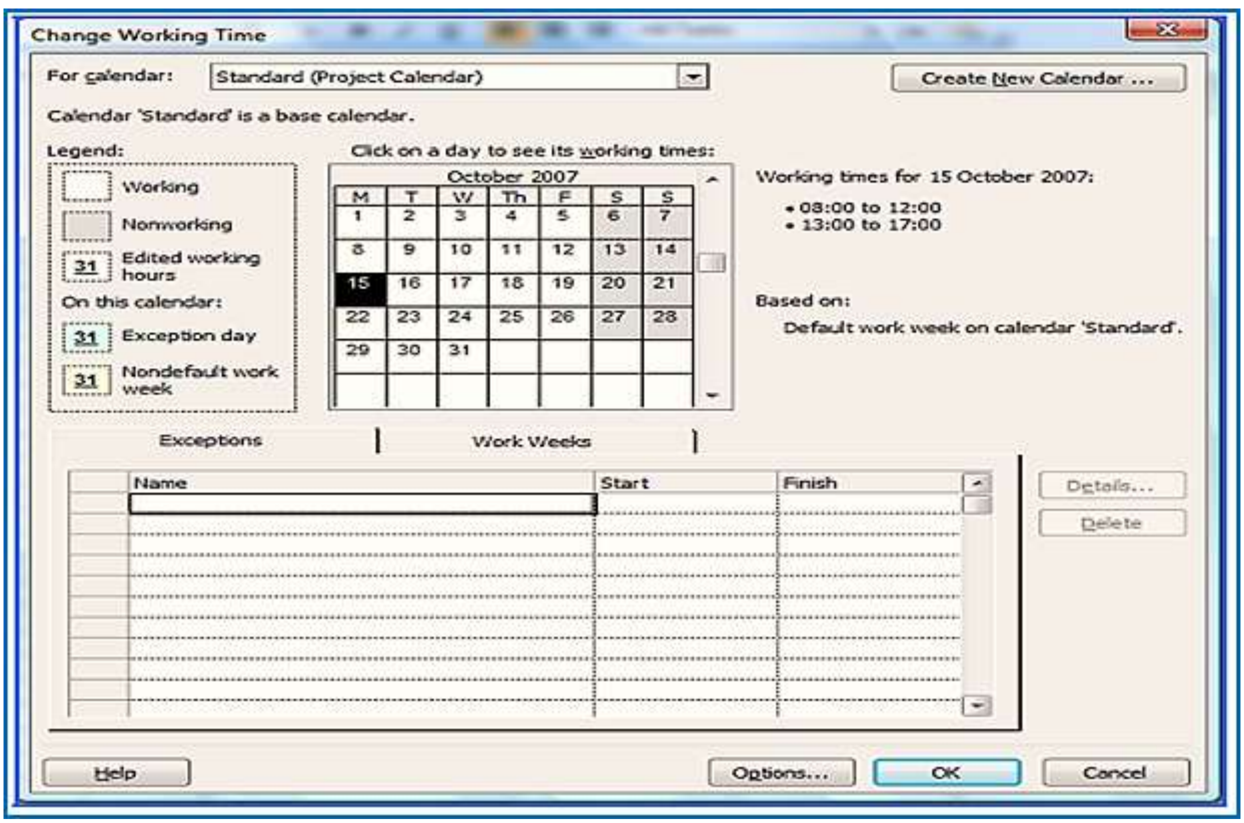




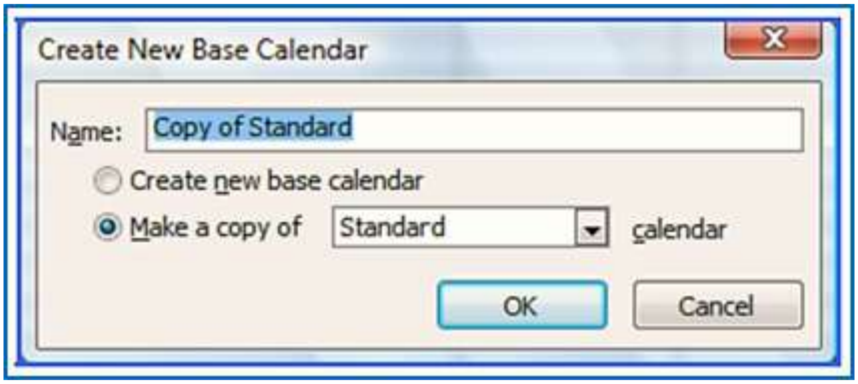
i. Project Statistics Dialog Box: The Statistics button opens the dialog box to display information on project start and finish dates, duration, work, and cost. It also provides comparative statistics you can use to measure the progress of your project.



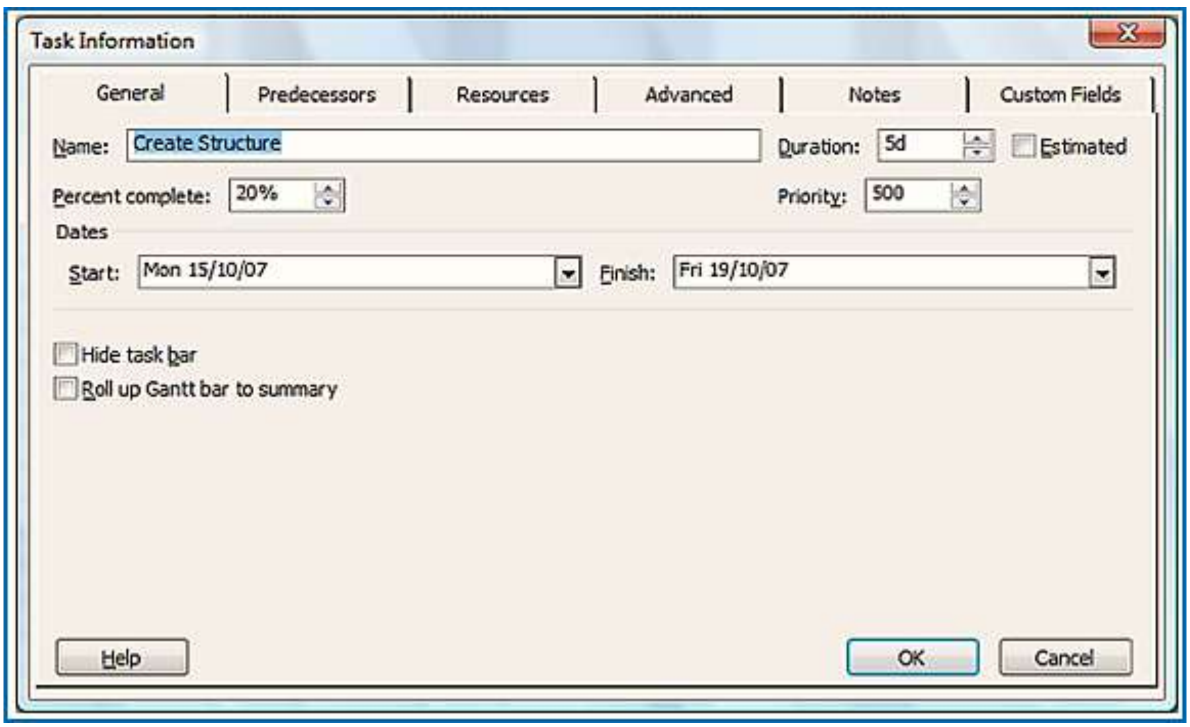
j. Default Working Calendar: Is used by MS Project to calculate all timescales and resource costs. It defaults to a working day of **8 hours** with the working hours **08:00 to 12:00 and 13:00 to 17:00**. A calendar can be created with own particular times. When a project is not a standard 8 hours day, you must indicate in the MS Project what the standard day is. Each resource you add will be based on the calendar when you start. The base is **standard 8 hours** day is satisfactory. A full day's work is considered as **two work time shifts**, one in the morning and one in the afternoon. The "**From and To"** text boxes in the Working Time area can specify up to **three work time shifts**. Selecting Default restores the selected days and working hours to their default settings.



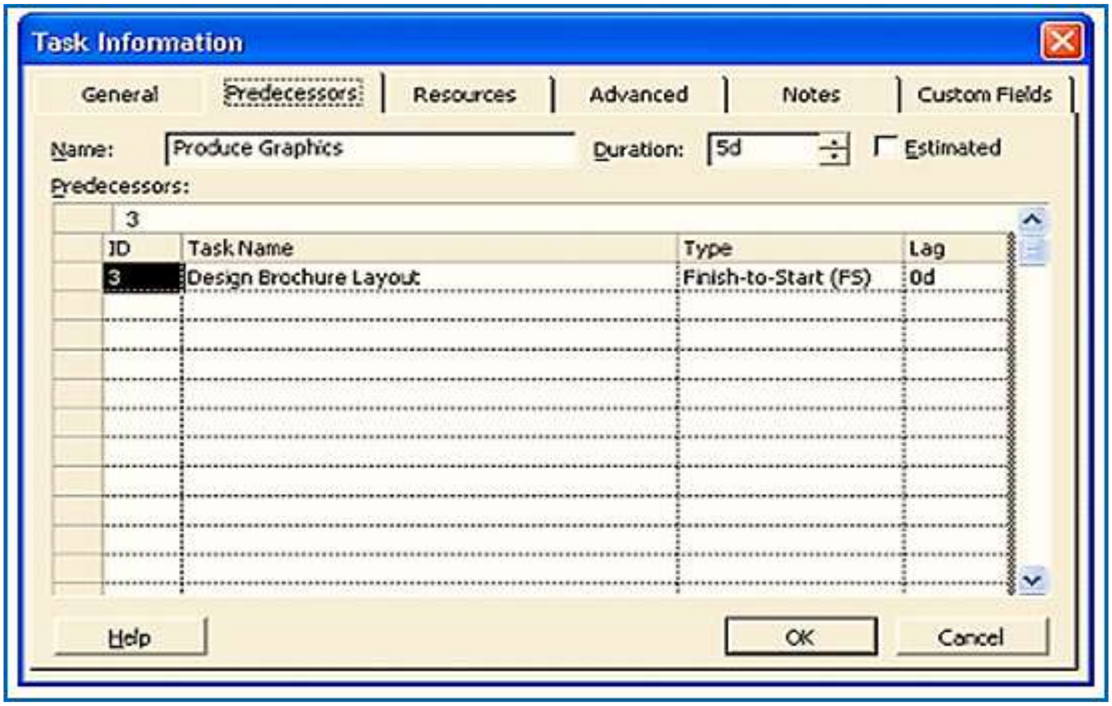
k. Creating a New Calendar: From the **Tools** menu, choose **Change Working Time**, choose **New**, in the name text box, type the **New Calendar's Name**, select either the **Create New Base Calendar** or make copy of **Calendar** option **button**, choose **OK**. If required, select the desired month by clicking the up/down arrow on the vertical scroll bar of the calendar, select specific dates for which you want to make a change or select all days of the week by selecting the column headings, specify the changes to be applied to the selected days, i.e., working, nonworking, default, or hours.



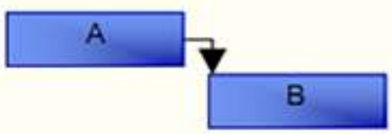
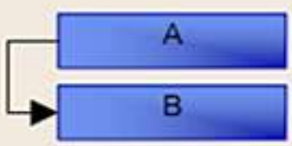
l. Entering Tasks: This is the main activity in setting up a new project. The tasks which have been identified at the Design Stage must be entered. Normal Task entry will be by using the standard Task Sheet. The Gantt View shows the Gantt Chart in the right part of the window with the Task Sheet in the left part.

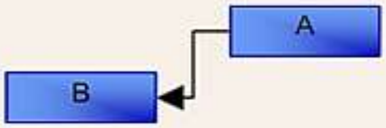


ID:	Task Identification Number.
Name:	The Name of the Task.
Duration:	The time the Task will take including the time units.
Start Date:	This is the current Scheduled Start date for the Task. Not the Planned or Actual Start.
Finish Date:	The Scheduled Finish date.
Predecessors:	The ID numbers for the preceding Tasks that are linked to this Task.
Resources:	The names of the resources performing or used in the Task.

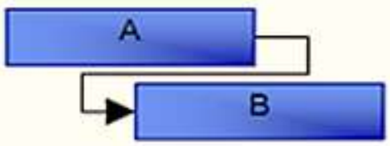
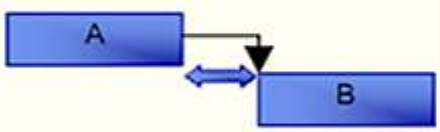


m. Linking Tasks: The system is able to display the time aspects. Each Task must be defined in terms dependent on previous tasks. It is also possible to define in what way these dependencies exist.

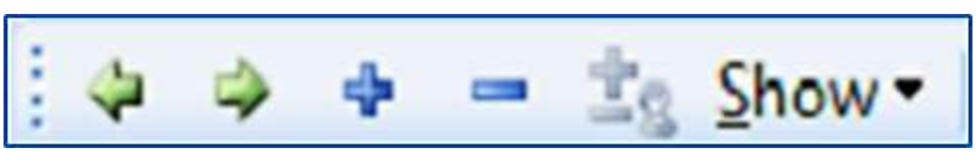
Link type	Example	Description
Finish-to-start (FS)		The dependent task (B) cannot begin until the task that it depends (A) on is complete. For example, if you have two tasks, "Dig foundation" and "Pour concrete," the "Pour concrete" task cannot begin until the "Dig foundation" task is complete.
Start-to-start (SS)		The dependent task (B) cannot begin until the task that it depends (A) on begins. The dependent task can begin anytime after the task that it depends on begins. The SS link type does not require that both tasks begin simultaneously. For example, if you have two tasks, "Pour concrete" and "Level concrete," the "Level concrete" task cannot begin until the "Pour concrete" task begins.
Finish-to-finish (FF)		The dependent task (B) cannot be completed until the task that it depends on (A) is completed. The dependent task can be completed anytime after the task that it depends on is completed. The FF link type does not require that both tasks be completed simultaneously. For example, if you have two tasks, "Add wiring" and "Inspect electrical," the "Inspect electrical" task cannot be completed until the "Add wiring" task is completed.

Start-to-finish (SF)		The dependent task (B) cannot be completed until the task that it depends on (A) begins. The dependent task can be completed anytime after the task that it depends on begins. The SF link type does not require that the dependent task be completed concurrent with the beginning of the task on which it depends. For example, the roof trusses for your construction project are built offsite. Two of the tasks in your project are "Truss delivery" and "Assemble roof." The "Assemble roof" task cannot be completed until the "Truss delivery" task begins.

We can also fine tune these relationships by specifying **Lag or Lead** times as required:

Type	Example	Description
Lead		**Lead time** is an overlap between two tasks that are linked by a dependency. For example, if a task can start when its predecessor is half finished, you can establish a finish-to-start dependency and specify a lead time of 50% for the successor task. You enter the lead time as a negative value
Lag		**Lag time** is a delay between two tasks that are linked by a dependency. For example, if there must be a two-day delay between the finish of one task and the start of another, you can establish a finish-to-start dependency and specify two days of lag time for the successor task. You enter the lag time as a positive value.

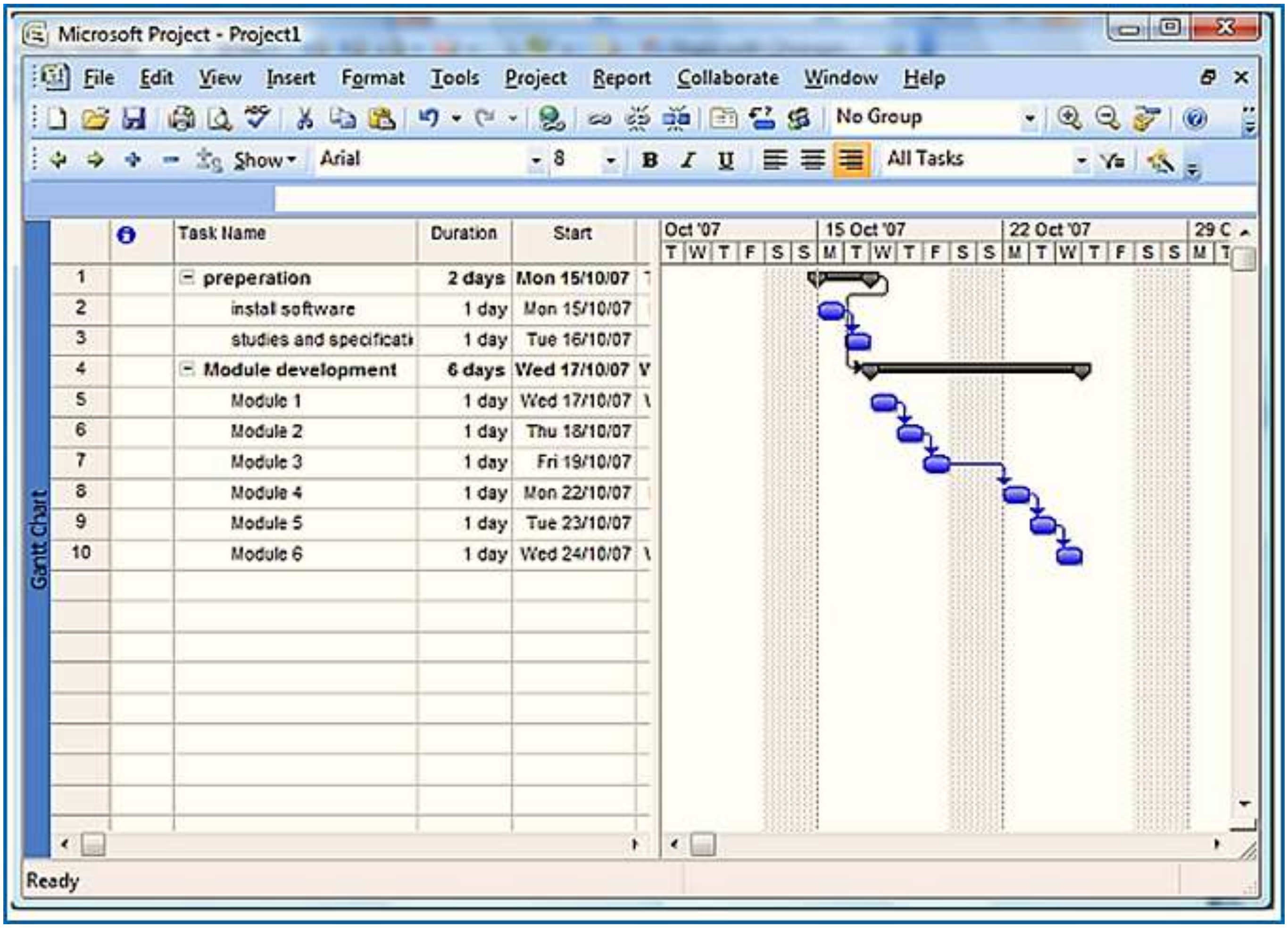
n. Defining the Summary Tasks: By setting different levels of tasks and grouping under a summary task. This can be useful where the project has a considerable number of tasks; management can be made easier by only viewing and reporting on the summary tasks.



Example - Create Summary Tasks and Link Tasks:

- Select the sub tasks “Install Software” and then “Studies and Specification”;

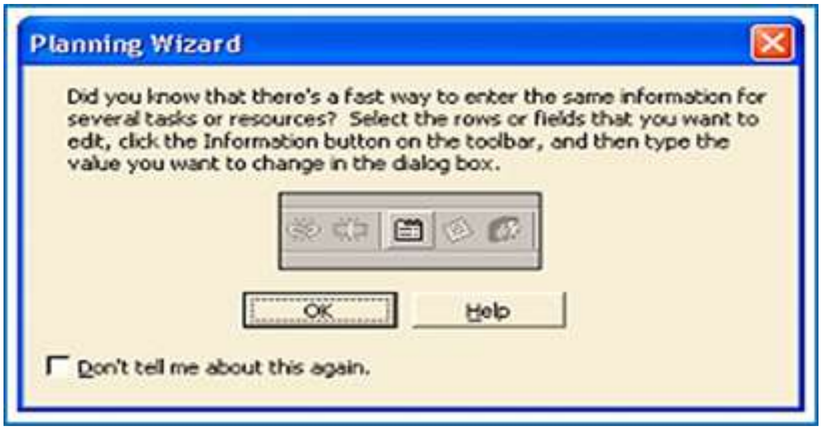
- Indent the tasks to make them sub tasks;
- While they are still selected link them (chain button or Edit menu);
- Make Sections 1 to 10 sub tasks and link them.



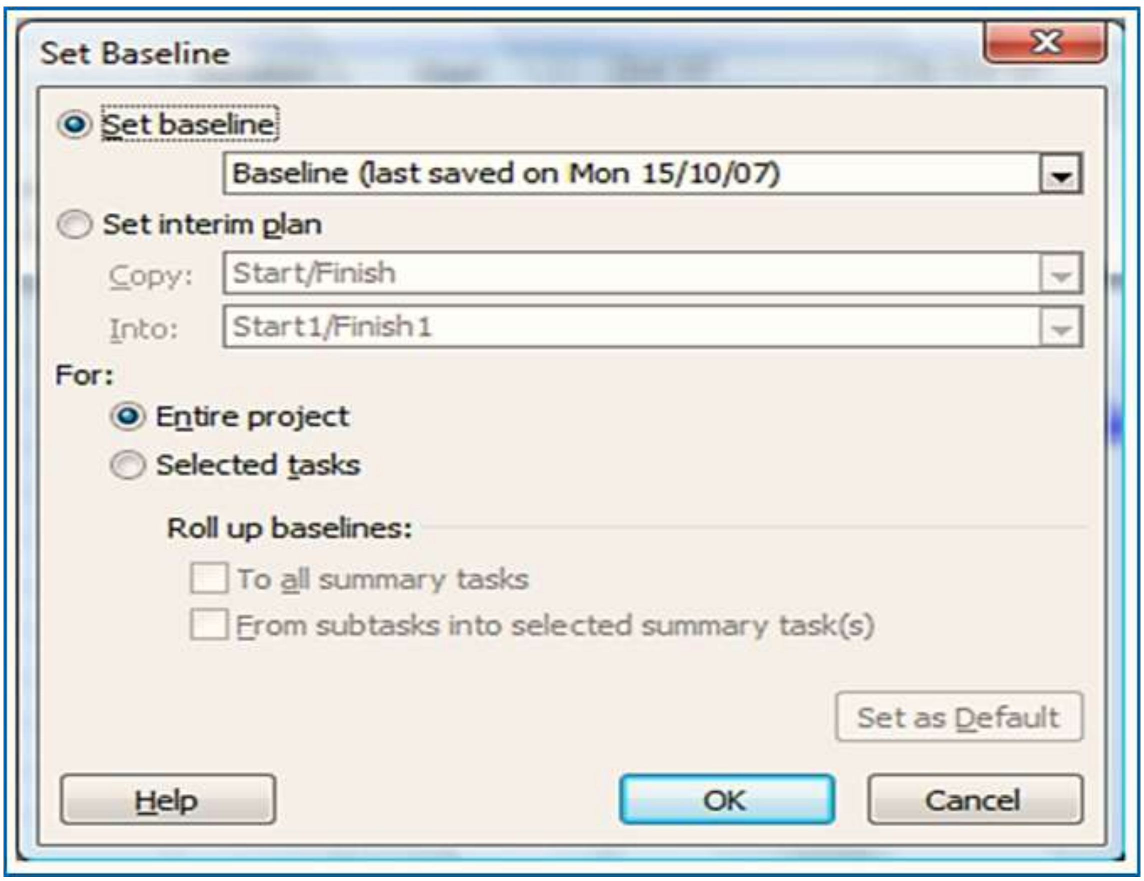
o. Formatting Toolbar: There are five buttons on the far left of the which can be used on a single task or group of highlighted tasks.

	Promote the selection to the next higher level
	Demote the selection to the next lower level
	Expands a summary task to show its subordinate tasks
	Collapse a summary task to hide the subordinate tasks
	Hide assignments
Show ▾	Show all subtasks, or those of a particular outline level.

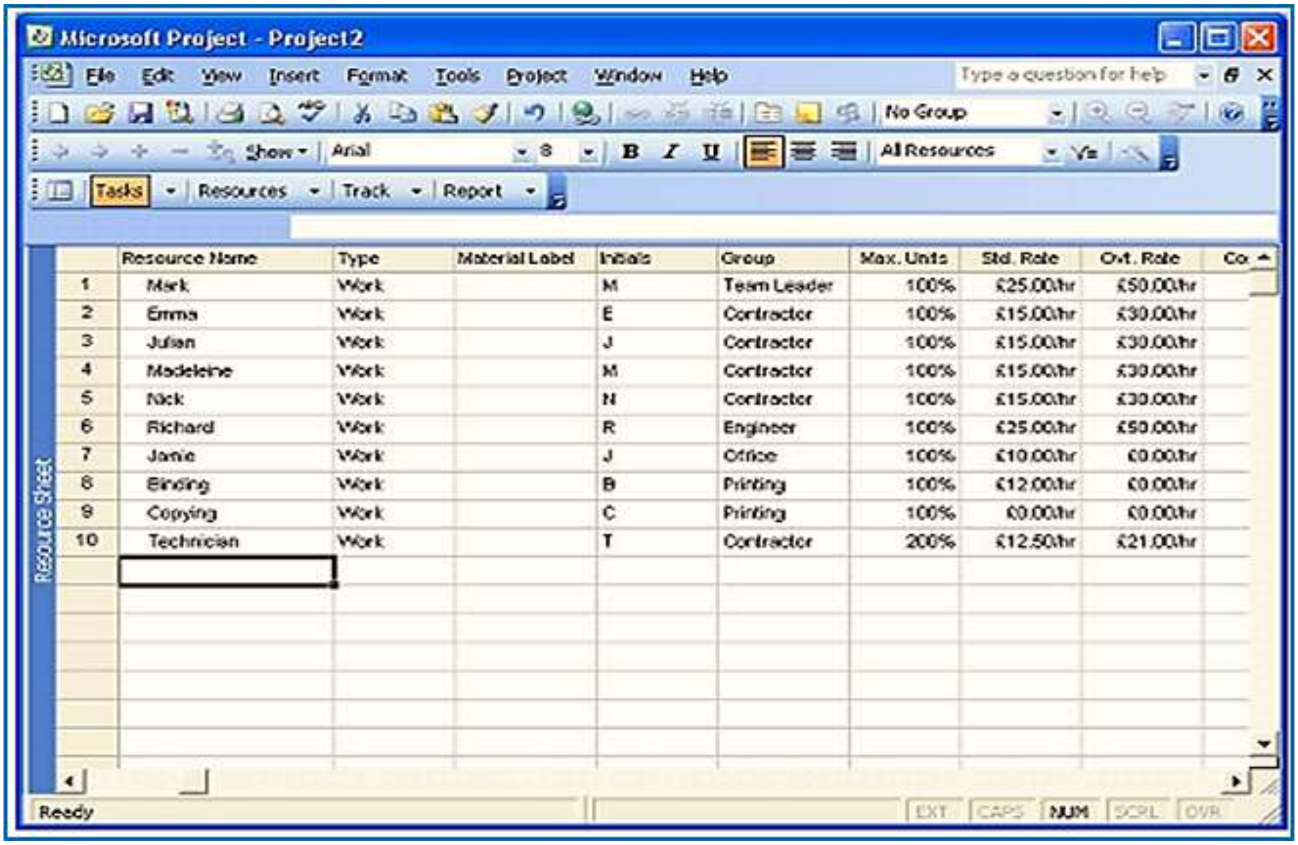
p. Change Time Duration: The default duration is **1 day**. To change this, simply overtype with the new value. For example, change the duration for each Module to **2d**. When the Planning Wizard box appears ***read the information*** then click on the **OK** button, select all the remaining tasks, open the task information box, set the duration to **2d.**



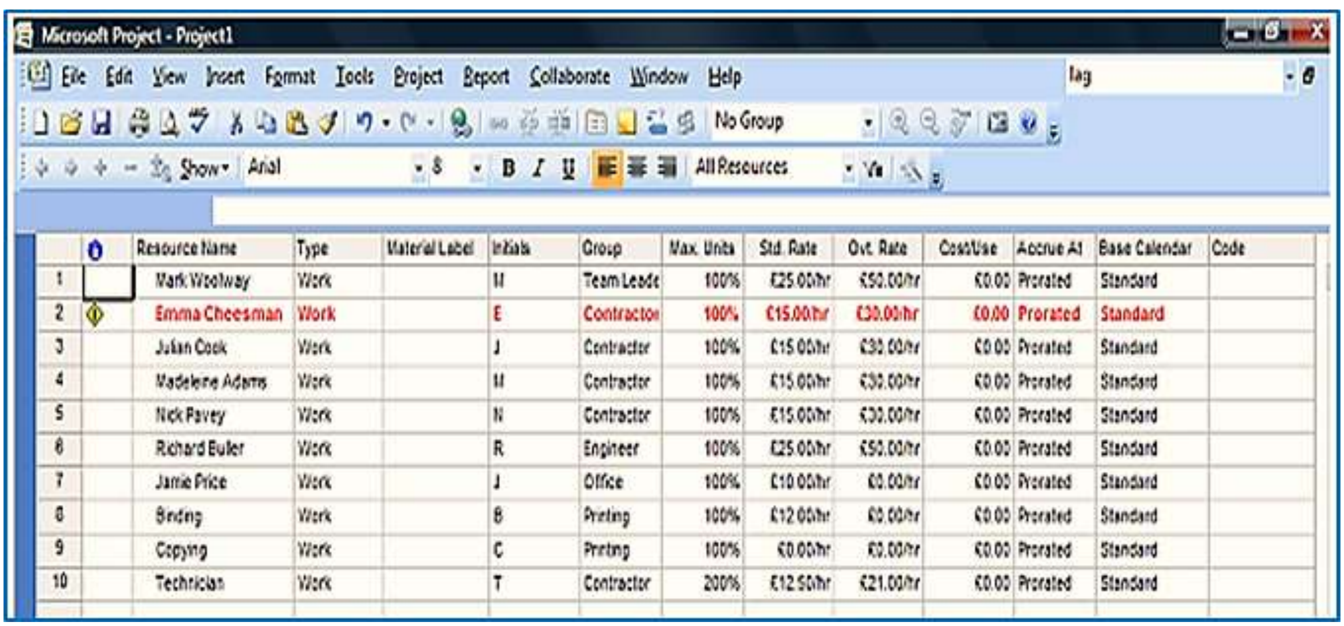
q. Save a Baseline: Select Tools, Tracking, Save Baseline from the menus, Click on the Save baseline button, Click on the OK button.



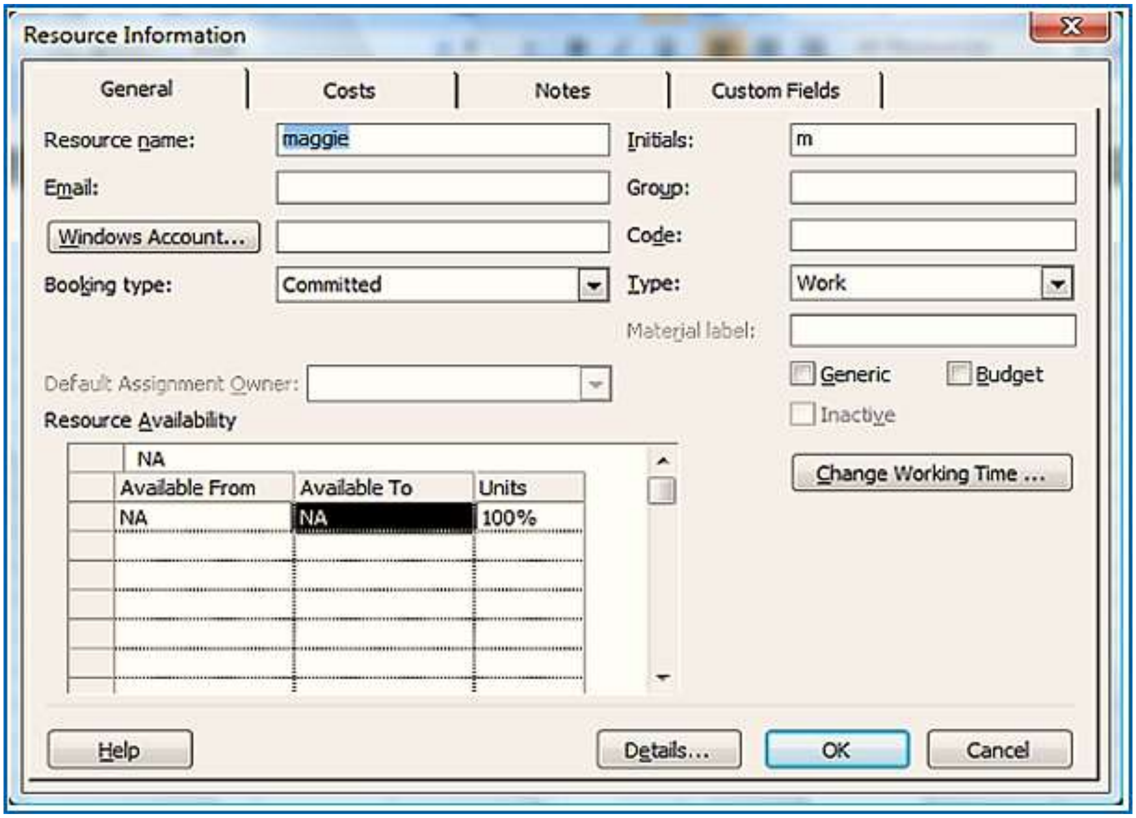
r. Resource Sheet: to build a large pool of resources, for example, **200 employees**. If there are only a **few resources working** on the project, however, you might enter them "**on the fly**" using the Resource Assignment dialog box. The Resource Sheet contains an array of required fields for entering resources, as the example illustrated below:



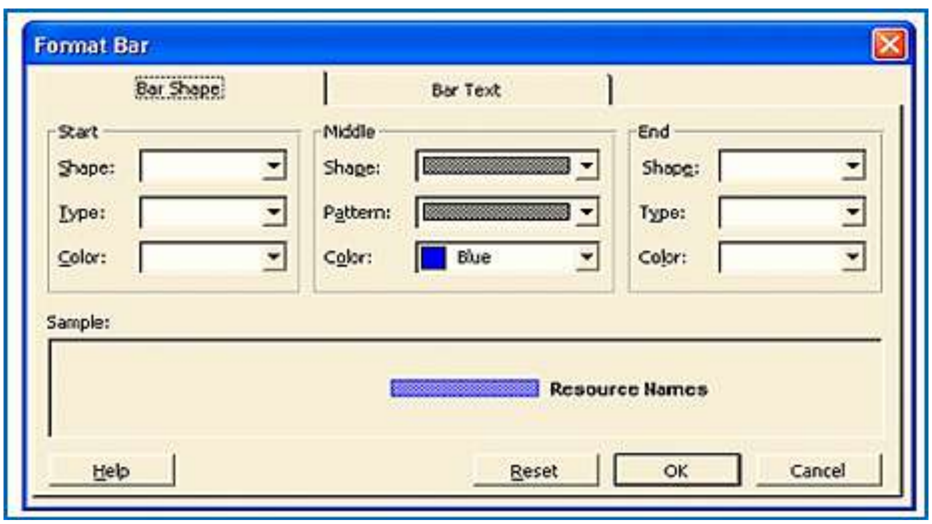
- The **Resource Graph** will only show one resource at a time and automatically switch to the resource allocated to the task highlighted in the top. One great value of this view is that it shows when a resource is over-allocated. For example, see below, **where Emma** is over-resourced.



- **Viewing the Details of a Single Resource:** It is possible to examine the full details of a single resource, place the pointer on the resource and call up the **edit form** by pressing the **Resource Information** button on the tool bar or, simply double-click a resource, as shown below:



s. Changing the Colors of Bars: The palette of colors can be accessed from the Format, Bar command or by double clicking on the Gantt Chart. This dialog box can be used to maximize the information provided by the format of the bars on the Gantt Chart. The appearance of the existing bars can be changed and additional bars can be used. The full use of colour is also possible.

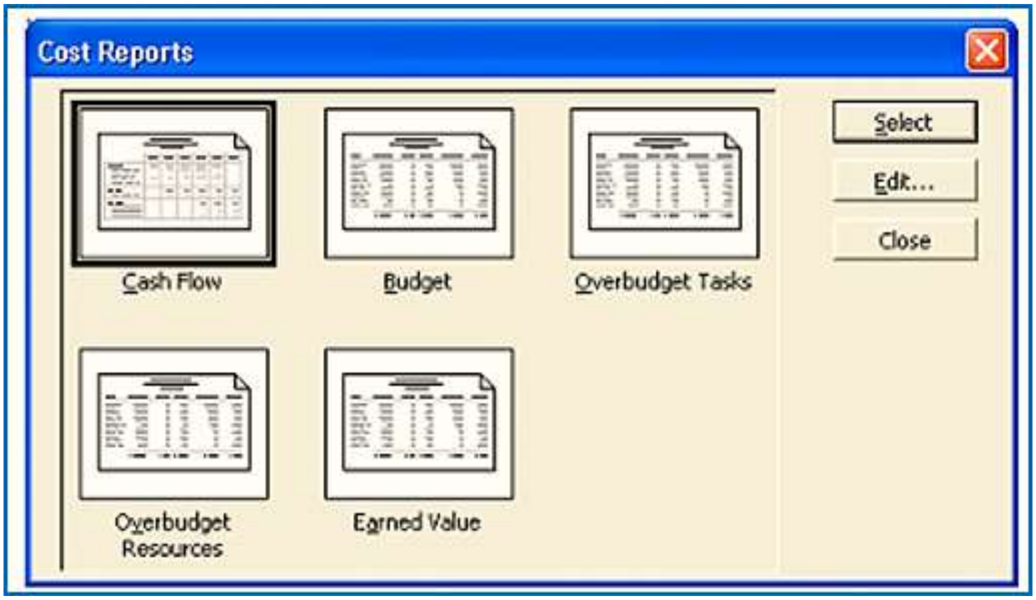


t. Editing Tasks: One method of editing tasks is to **change** on the **Gantt Chart** using the mouse and **dragging the changes** into place. Positioning the pointer at the beginning of a bar will change the pointer to a **%** sign and if the left button is pressed and the symbol dragged to the right a box will appear showing the amount of "*percentage complete*" that has been added. This information will then be updated throughout the system.

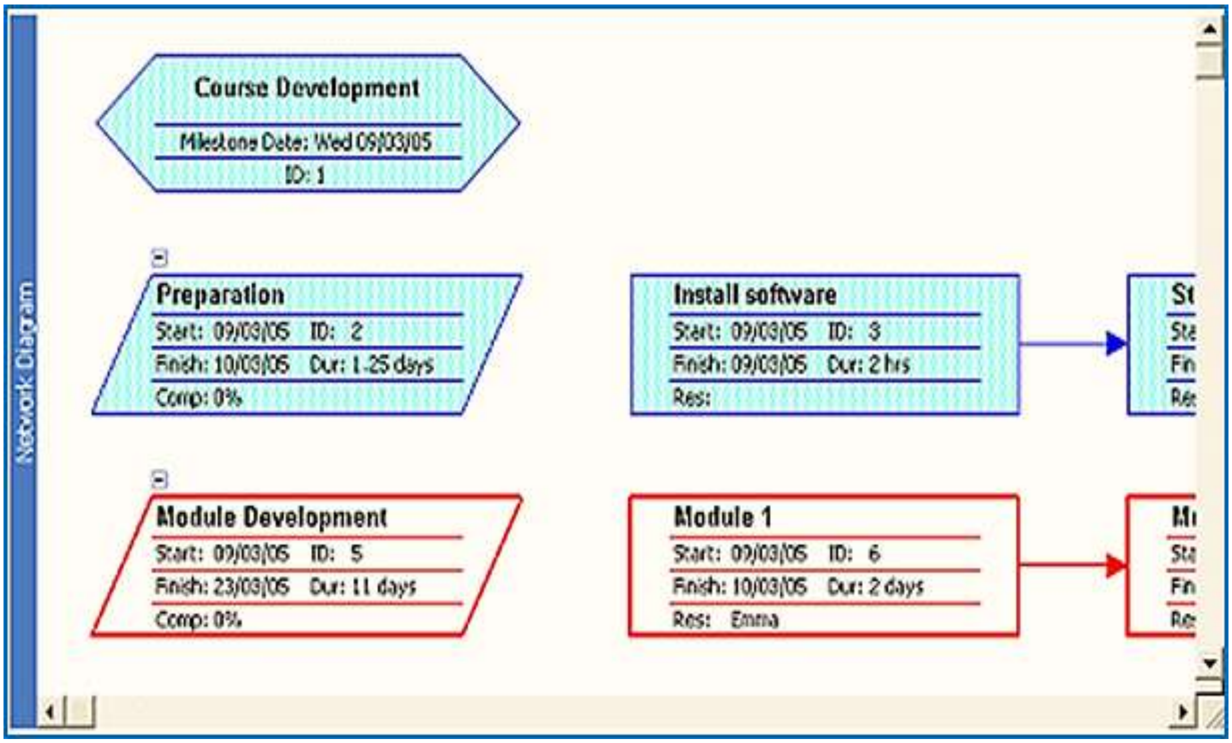
u. Reports Setup: MS Project has a number of pre-defined reports based on six principal types which can be used directly, or changed as required. Alternatively, completely new reports can be created. The system is picture driven and simple to use. Access is from the View, Reports command. A dialog box appears in which the following type of report can be chosen:

- **Overview**: Summarizes the most significant project information, including numbers of tasks and resources, task and schedule status, costs, start and finish dates, and so on.
- **Current Activities**: Displays information about top-level tasks for the entire project. Includes summary tasks and task notes.
- **Costs**: Shows critical tasks for the entire project. Includes summary and successor tasks and task notes.
- **Assignments**: Shows project milestones. Includes summary tasks and task notes.
- **Workload**: Shows working and nonworking times for resources for the entire project duration.
- **Custom**: Use an existing report to create a new one.

v. Creating or Editing Reports: Below is the sub set of reports based on costs. Most of your reports will be available from the pre-selected ones. The Custom choice will allow you to design a very specific report if required. Using this feature will hopefully now be familiar to you as the principle is not dissimilar to and easier than editing tables and filters.



x. Editing Task Details: Are the task fields that can be edited on the **Network Diagram Chart** by editing the fields from the entry bar, as shown below. **Similar to Gantt Chart**, when a field is selected, the contents of the field appear in the entry bar box. Click the **Enter** button to accept changes or click the **Cancel** button to retain the original entry.

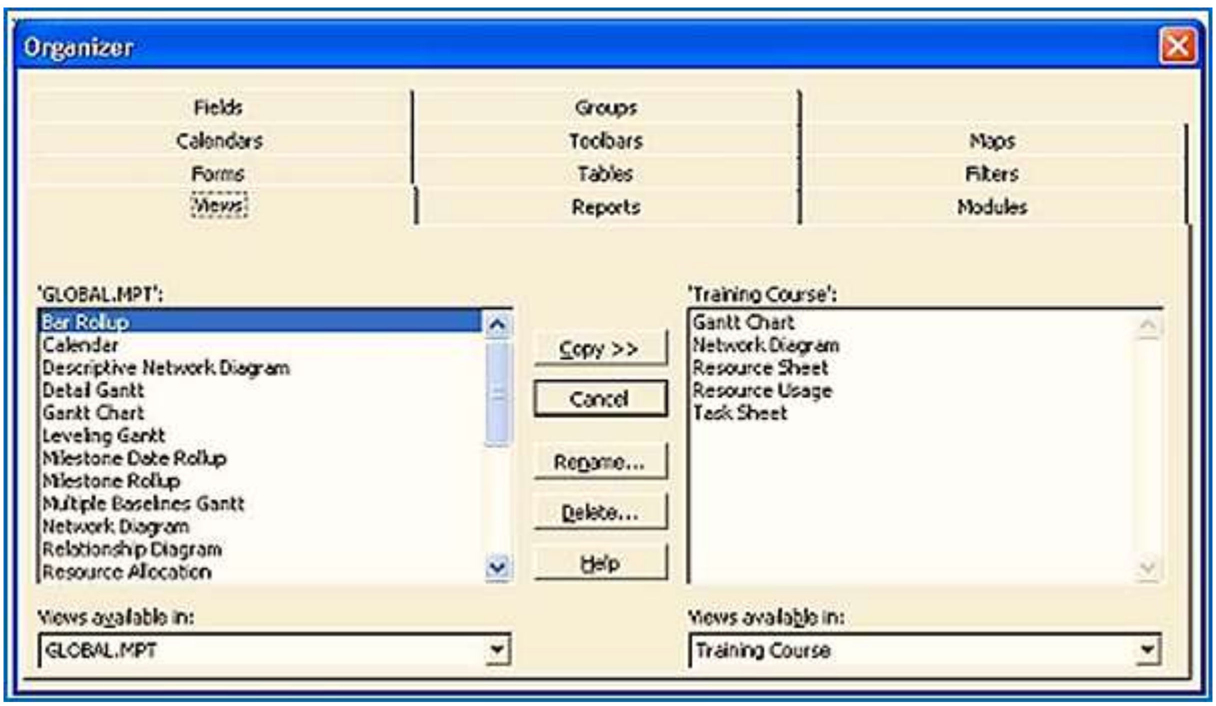


y. Project Meeting or Recurring Task Information: When a task occurs on a regular basis, MS Project allows to insert a task meeting as a Recurring Task, then, select a blank task row; select insert, recurring task; add the task "Project Meeting" and schedule as daily;

- For example, after the start date include the time **16:30**. This will show the meeting occurring at **4:30** pm. Then, other options can be available.

z. The Organizer: Is a tabbed dialog box in which you can copy custom views, tables, filters, calendars, reports, forms, toolbars, maps, and **Microsoft Visual Basic** for applications sections (macro containers) to other documents and to other users. Typically, any changes you make to views, tables, filters, calendars, reports, and forms are local; that is, they take place only in the active project file.

When opened, a new project file shows the original Microsoft Project defaults for those elements, which are saved in the global file. However, any changes you make to toolbars, menus, and import/export map are global; that is, the changes are made to the global file and apply to all project files on your computer. Using the Organizer, you can copy customized elements from your global file to another project that is open on your computer. You can also use the Organizer to delete any of these elements.



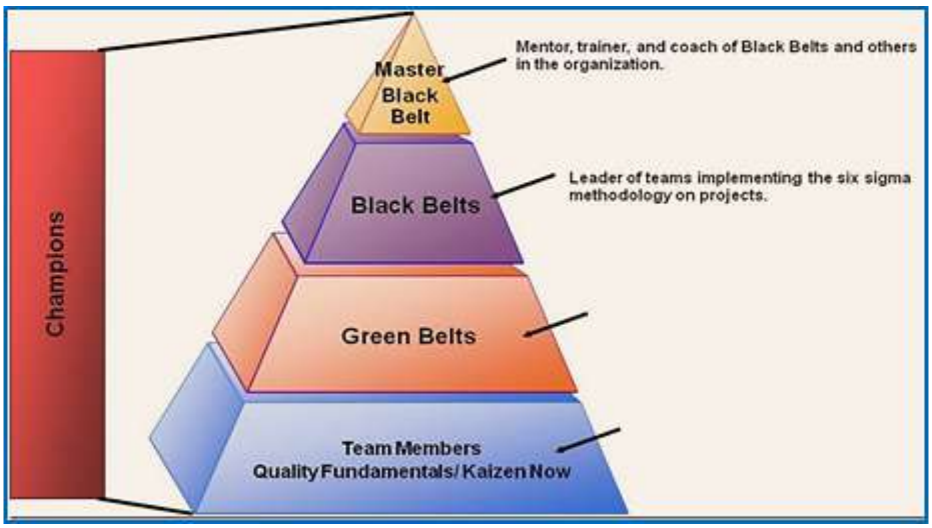
III. PRODUCTION MANAGEMENT TOOLS:

The Production management tools are used to easily manage multiple environments. Quality assurance teams use these types of tools to apply in test cases, defects and project tasks. Production management tools improve logistics, engineering, production processes and allow quick access to data analysis, simplifying internal structure with high levels of automation and easy communication across multiple teams.

1. Six Sigma:

Is a set of tools and strategies for process and production improvement that can be introduced in any organization. The term "*Six Sigma*" comes from a field of process statistics, originally developed by Motorola in 1985. The Six Sigma became well known after **Jack Welch** (CEO in General Electric) made it a central focus of his business strategy in 1995, and today it is used in different sectors of industry. Six Sigma also follows project methodologies inspired by Deming's - **Plan-Do-Check-Act Cycle (PDCA)**.

Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in manufacturing and business processes. It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people within the organization as defined below:



a. Executive Leadership: Includes the CEO (Chief Executive Officer) and other members of top management, responsible for setting up a vision for Six Sigma implementation. They also empower the other role holders with the freedom and resources to explore new ideas for breakthrough improvements.

b. Champions: Are the personnel that take responsibility for Six Sigma implementation across the organization in an integrated manner. The Executive Leadership draws them from upper management. Champions also act as mentors to Black Belts.

c. Master Black Belts: Identified by champions, act as in-house coaches on Six Sigma to assist the champions and guide Black Belts and Green Belts. Apart from statistical tasks, they spend their time on ensuring consistent application of Six Sigma across various functions and departments. They devote 100% of their time to Six Sigma.

d. Black Belts: Operate under Master Black Belts to apply Six Sigma methodology to specific projects, by also devoting 100% of their time to Six Sigma. They primarily focus on Six Sigma project execution, whereas Champions and Master Black Belts focus on identifying projects/functions for Six Sigma.

e. Green Belts: Are the employees who take up Six Sigma implementation along with their other job responsibilities, operating under the guidance of Black Belts. Some organizations use additional belt colours, such as *Yellow Belts*, for employees that have basic training in Six Sigma tools and generally participate in projects and the "*White Belts*" for those locally trained in the basic concepts, but do not participate in the project team.

The **American Society for Quality**, for example, requires **Black Belt** applicants to pass a written exam and to provide a signed affidavit stating that they have completed two projects, or one project combined with three years' practical experience in the **Body of Knowledge**. The **International Quality Federation** offers an online certification exam that organizations can use for their internal certification programs; it is statistically more demanding than the ASQ certification, but many organizations provide certifications.

Therefore, the functions and general activities of management can be universally applied to managing any organization or activity. The recognition of these concepts is crucial to the propagation and utilization of software engineering projects, for it allows us to apply the wealth of research in management sciences and improvement of engineered installations. The **IASSC** (Professional Association for Six Sigma Certification), is dedicated to growing and enhancing the standards within the Lean Six Sigma Community. IASSC exclusively facilitates and delivers centralized universal Lean Six Sigma Certification Standards testing and organizational Accreditation's.

2. The Five W´s and One H:

The **Five W´s and one H**, or the **Six W´s** are questions whose answers are considered basic in information-gathering, and can also be **applied** in research, assembly, quality systems, production processes, fabrication, project and construction engineering. This method constitutes a formula for getting the complete story on a subject. According to the principle of the **5 W´s**, a report can only be considered complete if it answered some **questions**, starting with an interrogative word:

- **Who** is it about?
- **What** happened?
- **When** did it take place?
- **Where** did it take place?
- **Why** did it happen?

Some authors add a sixth question, "**how**", or a seventh question, "**how much**", to the list:

- **How** did it happen?
- **How** much did it cost?

The most important is that none of these questions can be answered with a simple "*yes*" or "*no*". In 19th century, the American Prof. William C. Wilkinson popularized the "**Three W´s**" – What? Why? What of it? – as a method of Bible study in the 1880, though he did not claim originality.

Later, this became the known "***Five W´s***", though the application today is very different from this origin. The "What? Why? What of it?" is a plan of study of alliterative methods for the teacher emphasized by Professor Wilkinson not as original with himself, but as of venerable authority. "It is, in fact," he says, "an almost immemorial orator's analysis.

First the facts, **next** the proof of the facts, then the **consequences** of the facts, this analysis was also expanded into one known as "*The Five W´s*:" "When? Where? Who? What? Why?" Hereby attention is called, in the study of any lesson: to the date of its incidents; to their place or locality; to the person speaking or spoken to, or to the persons introduced, in the narrative; to the incidents or statements of the text; and, finally, to the applications and uses of the lesson teachings.

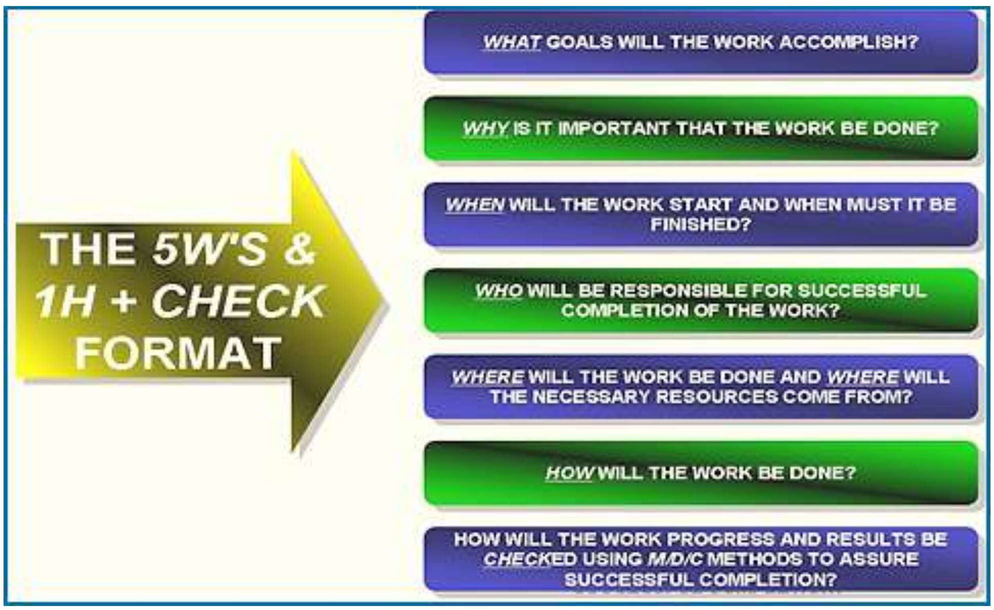
Nevertheless, the "***Five W´s***" **and one** "***H***" were introduced by **Rudyard Kipling** in his "*Just So Stories*" (1902), in a poem accompanying the tale of "***The Elephant's Child***" that opens with:

I keep six honest serving-men;
They taught me all I knew;
*Their names are **What** and **Why** and **When;***
*And **How** and **Where** and **Who**.*

This is why the **"Five W´s and One H"** as a problem solving method is also called as the **"Kipling Method**", which helps to explore the problems by challenging them with these questions. By 1917, the "***Five W´s***" were being taught in high-school **journalism** classes, and by 1940, the "*Five W´s*" were characterized as old-fashioned. However, this old-fashioned method led to the five "***W´s and the one H***", crystallized largely by the Pulitzer's "*new journalism*" and sanctified by the schools, widely giving way and guard to straight news stories and a form of management process.

2.1. 5 W's and 1 H Applied to Six Sigma:

The **5W and 1H** applied to **Six Sigma** explains the approach to be followed by analyzing the process, project or a problem for improvement. Four of the W's (who, what, where, when) and one H is used to comprehend for details, analyze inferences and judgment to get to the fundamental facts and a guide to statements. The last **W** (why) is often asked five times so, some user can drill to get the core of a problem. The example below, shows how to apply the **5 W´s and One H"** including a checking question:



2.2. "What" in Six Sigma:

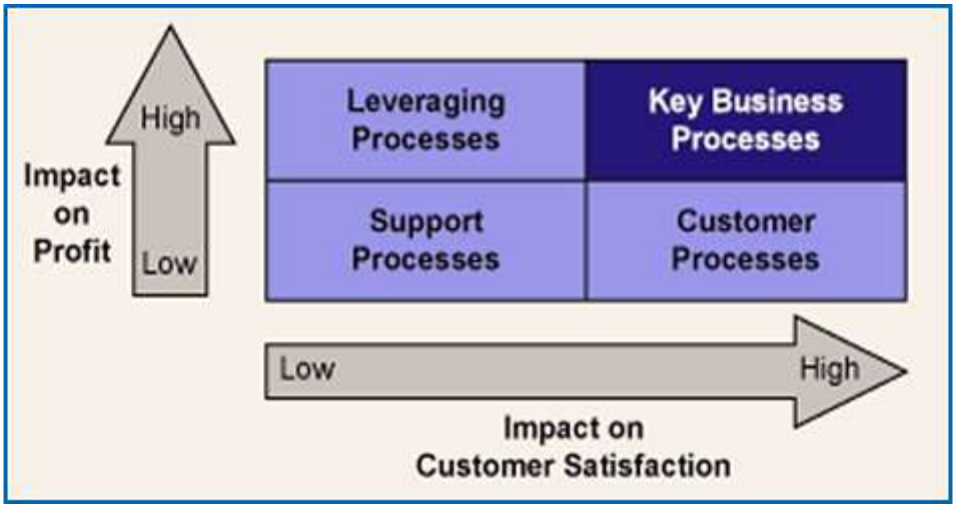
The "**what**" in Six Sigma is a concept and a level of quality applied to variations in any process. Sigma, (the Greek letter "σ") is the symbol in statistics used for standard deviation, a measure of variation in the distribution of values. Processes that operate with "**six sigma quality**" over the short term, are assumed to produce long-term defect levels, below 3.4 defects per million opportunities.

2.3. "Why" in Six Sigma:

How to achieve the goals is accomplished in "**why**" context. Six Sigma requires practitioners to consider both the "voice of the customer" and the "voice of the process," it reduces the gap between the two voices. That leads to more satisfied customers, and that is what makes the Six Sigma initiative a profitable business proposition. Not only does the Six Sigma organization save costs, but it also has great opportunity to increase sales.

2.4. "Who" is Involved with Six Sigma:

Six Sigma eventually involves everyone in the organization, starting from the top management to the operator/staff level. It requires a companywide understanding of the processes, a commitment toward achieving the set goals and an involvement in projects that accompany those goals. The top levels of management appoint Sponsors, who are members of the leadership team who are responsible for selecting Six Sigma projects and are ultimately accountable for project results.



Key Business Processes

Under the Sponsors are the Champions, who typically have day-to-day responsibility for the business process being improved and their role is to ensure the Six Sigma project team has the resources required to successfully execute the project. Next are the **Master Black Belts**, who **teach** and mentor the Black Belts, who have been trained to manage Six Sigma projects and serve as leaders of project teams, con-isting of Green Belts and other employees.

2.5. "Where" to Apply Six Sigma:

Six Sigma is applied to all business processes. To start with, it can be applied to key business processes which have the highest visible impact on the customers and shareholders. All business processes impacting customer satisfaction and profit growth of the organization need to undergo Six Sigma methodology implementation.

2.6. "When" to Apply Six Sigma:

In well-functioning Six Sigma deployments, **everyone** in the organization is involved in reducing defects, reducing cycle times and increasing customer satisfaction. As long as an organization has a strong desire to improve the business performance by identifying each and every key business processes for improvement, the starting point of Six Sigma does not matter. Organizations can implement Six Sigma:

- When they find out that the customer satisfaction level is eroding.
- When they want to retain a leadership position through quality in the market.
- When there is a clear indication of losing market share due to quality.
- When their processes have not changed for a long time.

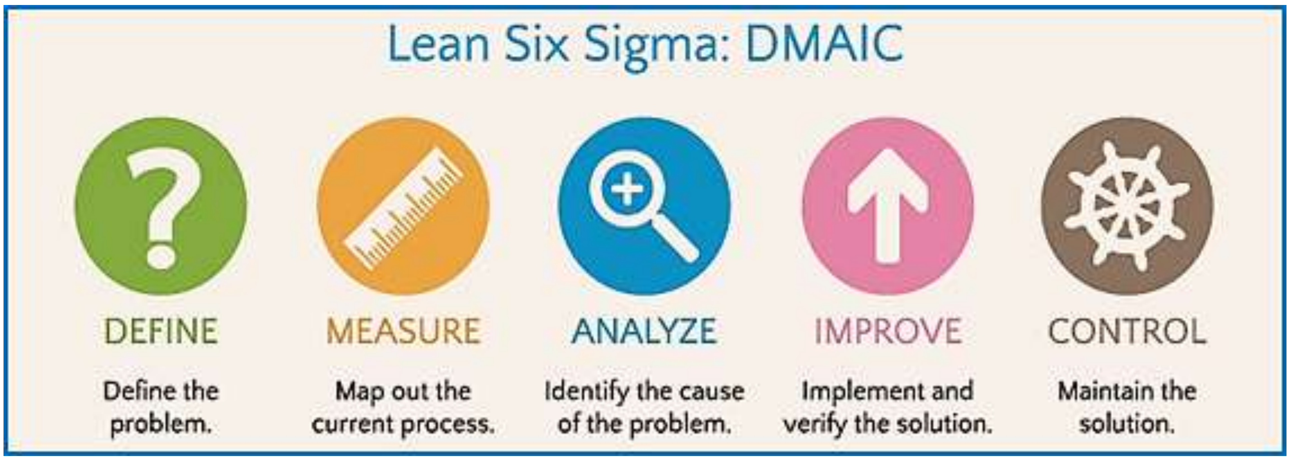
- When the quality of a product is largely dependent on human inspection skills instead of being built-in to the production process.
- When they think their processes have all reached an improvement plateau.
- When they are required to improve performance in all areas of their business process.
- When they decide they want to survive and grow in today's competitive market.

2.7. "How" to Apply Six Sigma:

Depending upon the requirement of the organization and the type of organization different strategies are followed for Six Sigma implementation. The three main strategies followed in Six Sigma are:

- ✓ **Process Management:** An ongoing cross-functional ownership and measurement of core support processes.

- ✓ **Process Improvement:** Focused on problem solving, aimed at eliminating the vital few root causes. It is most common to use the **DMAIC** roadmap as explained below:

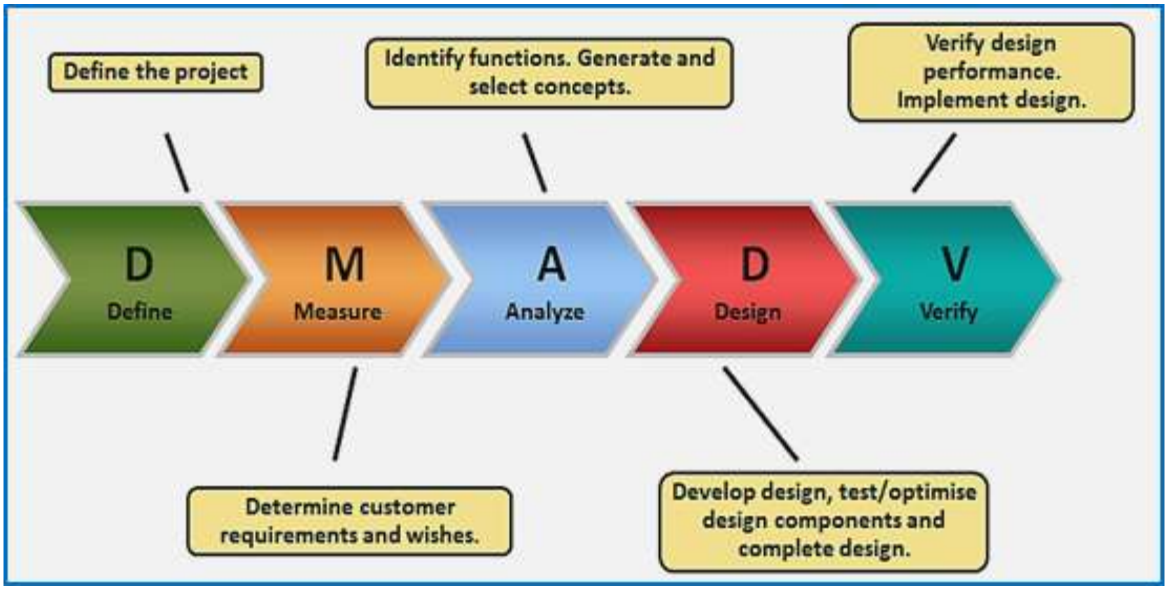


- **Define** - Select customer's critical-to-quality characteristics (CTQs). Define the process improvement goals that are consistent with customer demands and enterprise strategy.
- **Measure -** Create a measurement system and validate the system. Measure the current process and collect relevant data for future comparison.
- **Analyze -** Identify the sources of variation from the performance objectives. Analyze to verify relationship and causality of factors. Determine what the relationship is and attempt to ensure that all factors have been considered using one or more of the tools in the Six Sigma toolkit.
- **Improve -** Discover process relationships and establish new and improved procedures. Improve or optimize the process based upon the analysis.
- **Control -** Sustain the gain by implementing process controls, to ensure that any variances are corrected before they result in defects and continuously measure the control mechanisms.

Process Design/Redesign: Is the creation of a **new process** to achieve exponential improvement and/or meet the changing demands of customers, technology and competition. It must handle totally dysfunctional processes and reengineer them. It is also known as Design for Six Sigma (DFSS). **DMADV** is the most common roadmap as defined below :

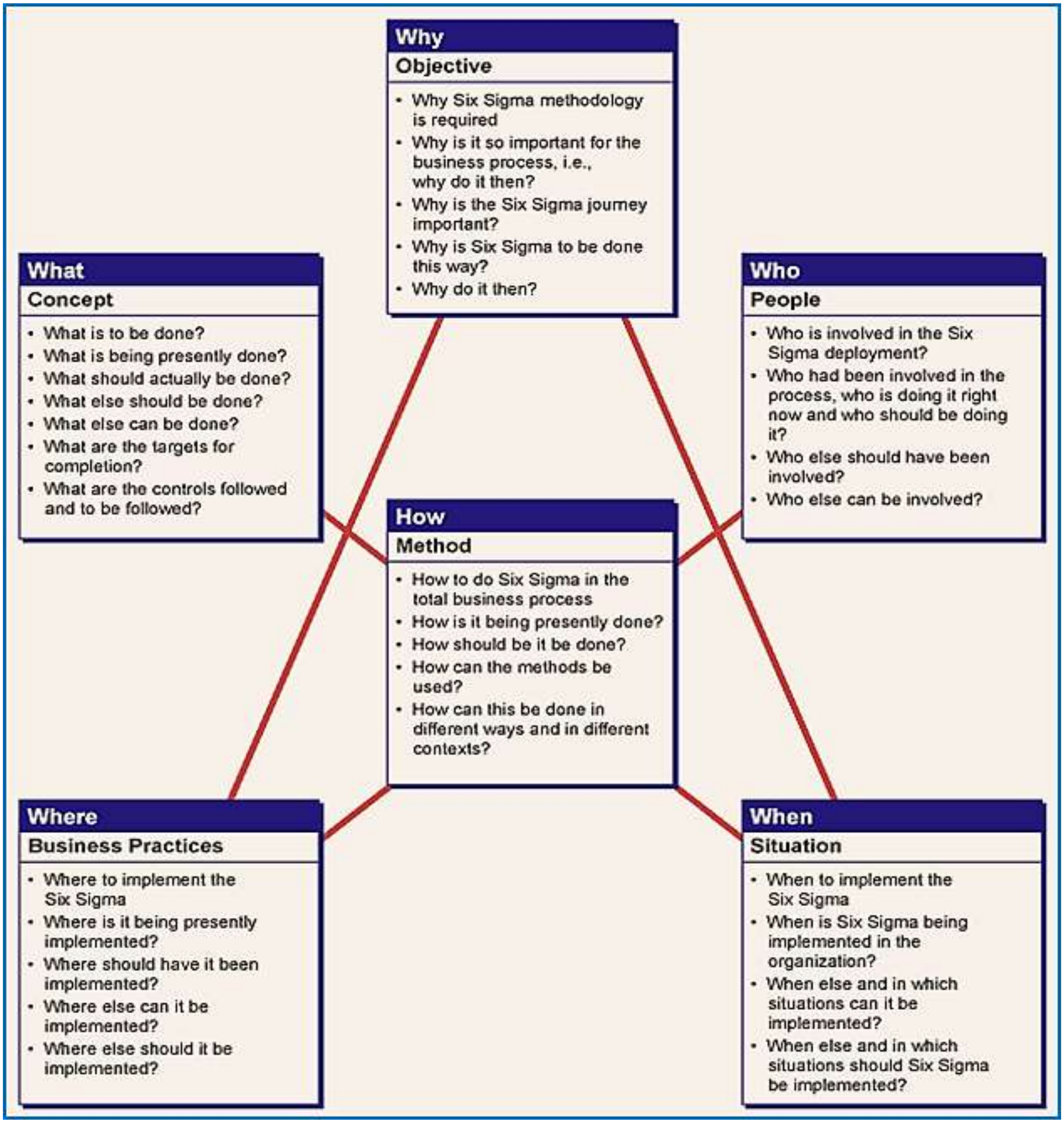
- **Define -** Define the goals of the design activity that are consistent with customer demands and enterprise strategy.
- **Measure -** Measure and identify CTQs, product capabilities, production process capability and risk assessments.

- **Analyze -** Analyze to develop and design alternatives, create high-level design and evaluate design capability to select the best design.
- **Design -** Design details, optimize the design, and plan for design verification. This phase may require simulations.
- **Verify -** Verify the design, set up pilot runs, implement production process and handover to process owners.



The Six Sigma system generally **focuses** on a long and sustained success for every improvement projects, improving each and every process in the organization. That gives organizations a way to continue improving year after year and even provides a system that rewards “out of the box” thinking, which can accelerate the rate of improvement. In the Six Sigma methodology, anything that dissatisfies the customer is a defect, and so understanding the customer and customer requirements is the most important issue in establishing a Six Sigma culture.

Six Sigma is a **problem-solving management methodology** that can be applied to any type of business process to identify and eliminate the root causes of defects, ultimately improving the key business processes and saving cost for the organization. In this regard, the main goal of Six Sigma is that any quality improvements in an organization need to be economically viable.

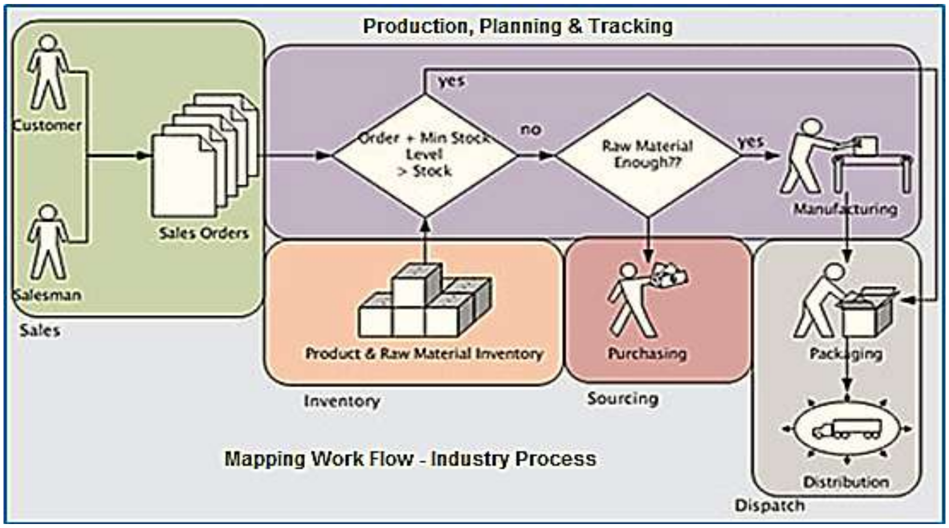


Since when a data-driven approach to problem solving appears in a production process, Six Sigma builds **robustness** in daily management. This starts a set of chain reaction in strategic, tactical and operational improvements, which compels the organization to set a stretch target for every business performance and set goals for everyone in the organization.

Six Sigma **creates** a culture in an organization aimed at learning to build processes that delivers the business output with flawless quality. Six Sigma also focuses on measuring and controlling the variation at each stage of business process. That sometimes creates a mistaken notion that Six Sigma is a set of statistical tools and a mere strategy for their use. The reality is Six Sigma is a blending of the wisdom of an organization with a methodology and an extensive toolkit to improve both the efficiency and effectiveness of the organization in meeting its the customer requirements.

3. Production Planning and Control (PPC):

Planned production is an important feature either in small and big industries. The companies possessing the ability to look ahead, organize and coordinate plenty of driving force, and capacity to lead, supervise and coordinate work simulating associates, by means of a programme of human relation and organization of employees, to be able to get the best out of an industrial unit.



Obs.: With the help of the Production Planning and Control (PPC**)** the company can schedule his tasks and production runs and thereby, ensure that his productive capacity does not remain idle and there is no undue queuing up of tasks, via proper allocation of tasks to the production facilities. No order goes unattended and no machine remains idle.

3.1. Optimum Utilization of Capacity:

Production, Planning and Control (PPC): Involve generally the manufacturing process. Especially it consists of the planning of routing, scheduling, dispatching inspection, and coordination, control of materials, methods machines, tools and operating times. The ultimate objective is the organization of the supply and movement of materials and labour, machines utilization and related activities, in order to bring about the desired manufacturing results in terms of quality, quantity, time and place.

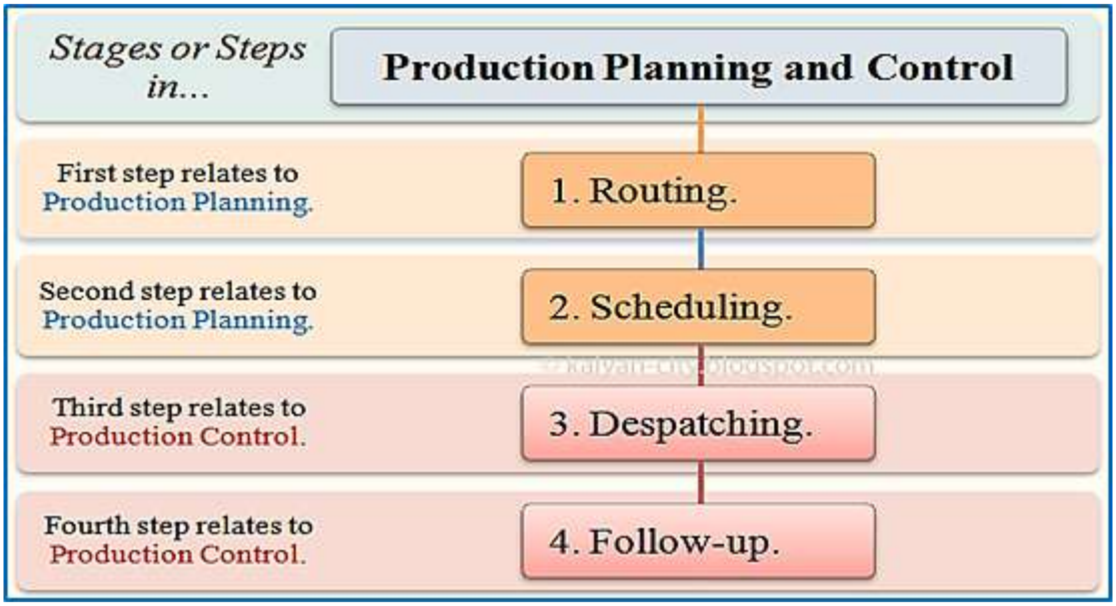
- **Inventory control**: Proper PPC will help the company to resort to just-in-time systems and thereby reduce the overall inventory. It will enable him to ensure that the right supplies are available at the right time.

- **Economy in production time**: PPC will help the company to reduce the cycle time and increase the turnover via proper scheduling.

- **Ensure quality**: A good PPC will provide for adherence to the quality standards so that quality of output is ensured. PPC is of immense value in capacity utilization and inventory control. More importantly it improves his response time and quality. An effective PPC contributes to time, quality and cost parameters of entrepreneurial success.

3.2. Steps for Production, Planning and Control:

Production planning may be defined as the technique of foreseeing every step in a long series of separate operations, each step to be taken at the right time and in the right place and each operation to be performed in maximum efficiency. It helps entrepreneur to work out the quantity of material manpower, machine and money requires for producing predetermined level of output in given period of time.



a. Routing: Gives a very systematic method of converting raw-materials into finished goods. It leads to smooth and efficient work. It leads to optimum utilization of resources; namely, men, machines, materials, etc. It leads to division of labor. It ensures a continuous flow of materials without any backtracking. It saves time and space. It makes the work easy for the production engineers and foremen. It has a great influence on design of factory's building and installed machines. Routing is the first step in production planning and control and fixes in advance:

- The quantity and quality of the product;
- The men, machines, materials, etc. to be used;
- The type, number and sequence of manufacturing operations;
- The place of production.

b. Scheduling: It means working out of time that should be required to perform each operation and also the time necessary to perform the entire series as routed, making allowances for all factors concerned. It mainly concerns with time element and priorities of a job. The pattern of scheduling differs from one job to another which is explained as below:

Production Schedule: The main aim is to schedule an amount of work, which can easily be handled by workers and equipment without interference, as it takes into account following factors.

- Physical plant facilities of the type required to process the material being scheduled;
- Personnel who possess the desired skills and experience;
- Good operation of the equipment and perform the type of work involved;
- Necessary materials and purchased parts.

Master Schedule: Means a weekly or monthly break-down of the production requirement for each product inside a definite time period commonly designated as **master schedule**. A master schedule is followed by the **scheduling** which fixes total time required to do a piece of work with a given machine or shows the time required to do each detailed operation of a given job with a given machine or process.

Manufacturing Schedule: It is prepared on the basis of type of manufacturing process involved. It is very useful where single or few products are manufactured repeatedly at regular intervals. Thus it would show the required quality of each product and sequence in which the same to be operated.

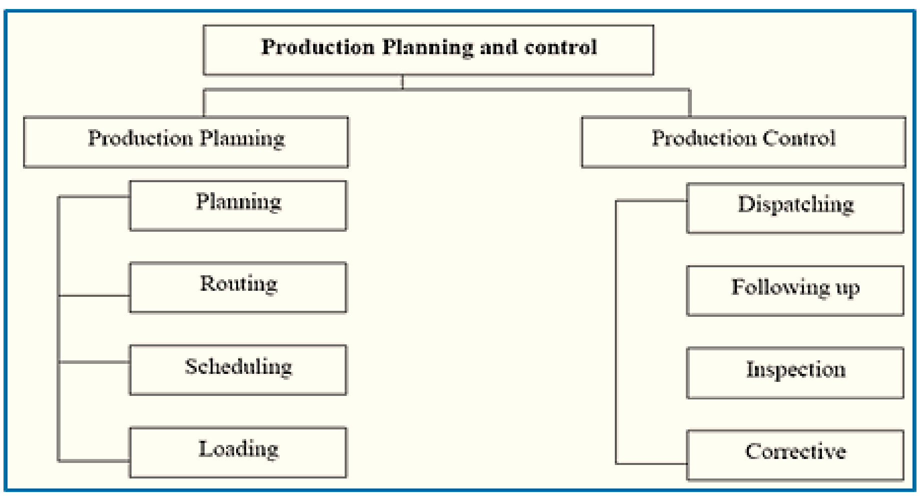
Job Schedule: Job scheduling acquires greater importance in job order manufacturing. This will enable the speedy execution of job at each center point. The Gantt Charts are most commonly used in medium and small industries to determine the job schedule and also to foresee how fast a job can be done.

Loading Schedule: The next step is the execution of the loading schedule, which includes the assignment of the work by operators, machines and work places. So the loading schedule determines who will do the cargo work and also determines when the products loading will be done.

c. Dispatching: The product dispatching is the next step in PPC and involves issue of production orders for starting the operations. Necessary authority and quality conformation is given for:

- Movement of materials to different workstations;
- Movement of tools and fixtures necessary for each operation;
- Beginning of work on each operation;
- Recording of time and cost involved in each operation;
- Work logistics from one operation point to another in accordance with the routing schedule;
- Inspecting or supervision of work.

d. Follow up: Follow-up or expediting is the last step in PPC and acts as a controlling device. Follow-up finds out and removes the defects, delays, limitations, bottlenecks, loopholes, etc. It measures the actual performance, compares the expected performances, keep work records, delays and bottlenecks. This step means that the productive operations should take place in accordance with production plans and ensuring the correct work flow. It also spots the delays or deviations from the production plans.

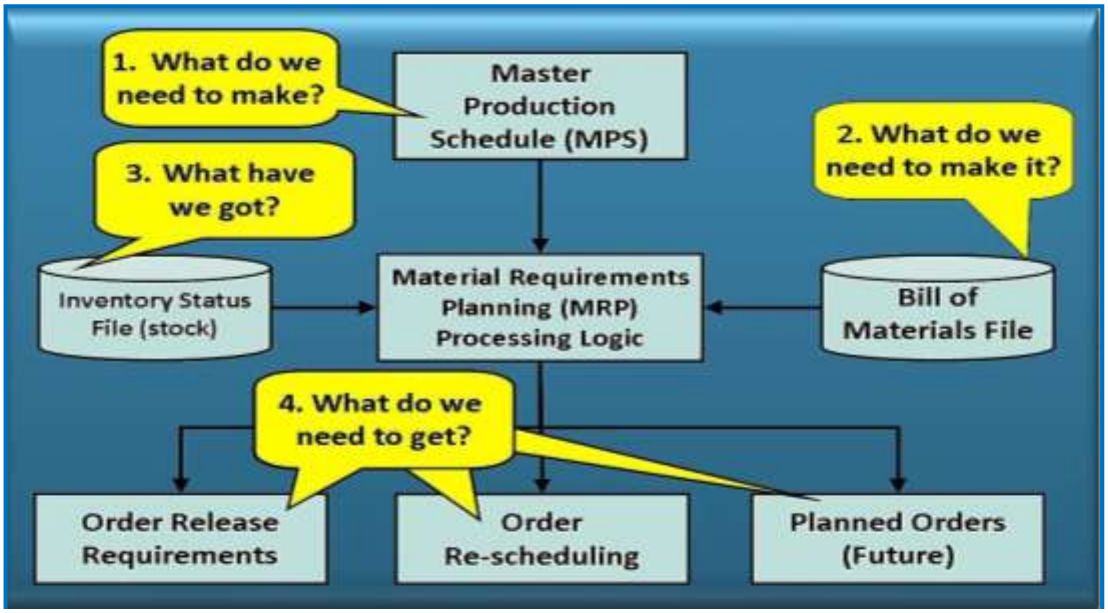


e. Inspection & Quality: Inspection in manufacturing includes measuring, examining, testing, or gauging one or more characteristics of a product or process and comparing the results with specified requirements to determine whether is the requirements are met for each characteristic. Quality is related to process inspection/verification as an essential part of quality control in manufacturing.

f. Corrective Measures: Corrective action may involve any of those activities of adjusting the route, rescheduling of work changing the workloads, repairs and maintenance of machinery or equipment, control over inventories of the cause of deviation is the poor performance of the employees. Certain personnel decisions like training, transfer, demotion etc. may have to be taken.

4. Enterprise Resource Planning (ERP):

ERP is a software architecture that facilitates the flow of information among the different functions within an enterprise. Similarly, ERP facilitates the communication sharing across organizational units, geographical locations and enables decision-makers to have an enterprise-wide view of the information they need in a timely, reliable and in a consistent fashion.



ERP facilitates internal and external management of information across an entire organization-embracing finance/accounting, manufacturing, sales, services, customer relationship, production schedule, materials, management and procurement. ERP also facilitates the communication flow between all business functions, starting inside the organization, connecting managers and outside stakeholders.

The ERP system software is a multi-billion dollar industry that produces components that support a variety of business functions. IT investments have become the largest category of capital expenditure in United States-based businesses over the past decade. Enterprise systems are complex software packaages that offer the potential of integrating data and processes across functions in an enterprise.

Organizations consider the ERP system as a backbone, and a vital organizational tool because it integrates varied organizational systems, and enables flawless workflow. However, an ERP system is radically different from traditional systems development. ERP systems can run on a variety of computer hardware and network configurations, typically employing a database as a repository for information.

4.1. Origin of "ERP":

In 1990, the Gartner Group first employed the acronym ERP as an extension of **Material Requirements Planning (MRP)**, later Manufacturing Resource Planning and Computer-Integrated Manufacturing. Without supplanting these terms, ERP came to represent a larger whole, reflecting the evolution of application integration beyond manufacturing.

Not all ERP packages were developed from a manufacturing core. Vendors variously began with accounting, maintenance, and human resources. By the mid-1990, the ERP systems addressed all core functions of an enterprise. Beyond corporations, governments and non–profit organizations also began to use the ERP systems.

4.2. Expansion:

The ERP systems experienced rapid growth in the 1990s because the year 2000 problem and introduction of the euro disrupted legacy systems. ERP systems initially focused on automating *back of office functions* that did not directly attend customers and the general public. The Customer Relationship Management (CRM), dealt directly with customers or e-business systems, such as e-commerce, e-government, e-telecom, and e-finance, and the Supplier Relationship Management (SRM) became integrated later, when the Internet simplified communicating with external parties.

The "ERP II" was coined in the early 2000s. It describes web–based software that provides employees and partners (such as suppliers and customers) with real–time access to ERP systems. The ERP II role expands traditional ERP's resource optimization and transaction processing. The ERP II is more flexible than the first generation ERP. Rather than confine ERP system capabilities within the organization, it goes beyond the corporate walls to interact with other systems.

4.3. Two-tier Enterprise Resource Planning:

The two-tier ERP software and hardware lets companies run the equivalent of two ERP systems at once: one at the corporate level and one at the division or subsidiary level. For example, a manufacturing company uses an ERP system to manage across the organization. This company uses independent global or regional distribution, production or sales centers, and service providers to support the main company's customers. Each independent center or subsidiary may have their own business model, worflows, and business processes.

5. Material Requirement Planning - MRP I:

Is a software specifically developed for the production industry, with the objective of keeping adequate stocks and the production lines in great activity. The use mathematical techniques related to industrial process engineering, knowledge through a default demand, make the future planning of raw materials and production steps. The MRP I system is intended to simultaneously meet three objectives:

- Ensure materials and products are available for production and delivery to customers;
- Maintain the lowest possible level of inventory;
- Plan manufacturing activities, delivery schedules and purchasing activities.

5.1. Manufacturing Resource Planning - MRP II:

The **MRP II** is the optimization of **MRP I**, where was added several allocations, tool resources and activity-based costing product structure, where the defined stocks of raw materials and other resources are used for the production stages. Generally, the MRP II refers to a system with **integrated financials**. An MRP II system can include finite or infinite capacity planning. But, to be considered a true MRP II, the system must also include the **financial tools**.

In the MRP II concept, fluctuations in forecast data are taken into account by including simulation of the master production schedule, thus creating a long-term control. A more general feature is its extension to purchasing, to marketing and to finance (integration of all the function of the company), where ERP has been the next step.

5.2. MRP I and MRP II Relationship:

Material Requirements Planning (MRP I) and Manufacturing Resource Planning (MRP II) are predecessors of Enterprise Resource Planning (ERP), a business information integration system. Both MRP and MRPII are still widely used, independent and as modules of more comprehensive ERP systems, but the original version began with the development of MRP and MRPII in manufacturing. The development of these manufacturing and integration methods and tools made the ERP systems possible.

5.3. Manufacturing Resource Planning - MRP III:

The MRP III process begins with an Accurate Demand Forecast, which drives to the remainder of the business. Thus, using the best possible demand forecast, a **Master Schedule** is developed. The total number of **master scheduled items** will be minimized, so that the MRP III system can appropriately generate build schedules for components and "accessories" automatically, derived directly from the Demand Forecast with little or no changes.

The Master Schedule and the MRP III system originate individual components, assembly requirements, recommend new purchase orders, just like a "*standard MRP*", generate a recommended purchase order and also automatically re-schedules a non-master scheduled assemblies, based on the availability of components/resources and material requirements, like an MRP II system.

The MRP III system also bases its operating parameters on the principles of Bandwidth Management, dynamically **adjusting parameters** and "*ideal inventory*" according to the historic data, measuring performance to a set of statistically derived "*control bands*", rather than fixed parameters. A process, such as the MRP III, would help to eliminate certain kinds of errors that currently plague manufacturing businesses on a nearly universal level.

5.4. Problems with MRP Systems:

The major problem with MRP systems is the integration of the data. If there are any errors in the inventory data, the Bill of Materials (commonly referred to as "BOM") or the master production schedule, the output data will be running **incorrect**. Most vendors of this type of system recommend at least 99% data integration, for the system to give useful results.

6. Resource Management Plan (RMP):

This system is an efficient and effective deployment of an organization's necessities and also for management needs. Such resources may include financial resources, inventory, human skills, production resources, or information technology. It is in the realm of project management, processes, techniques and philosophies and the best approach for allocating resources.

In this system are included resource allocations, as well as, processes espoused by organizations like the Project Management Institute (PMI) through their **Project Management Body of** (PMBOK) methodology of project management. Resource management is a key element to activity resource estimating and project human resource management.

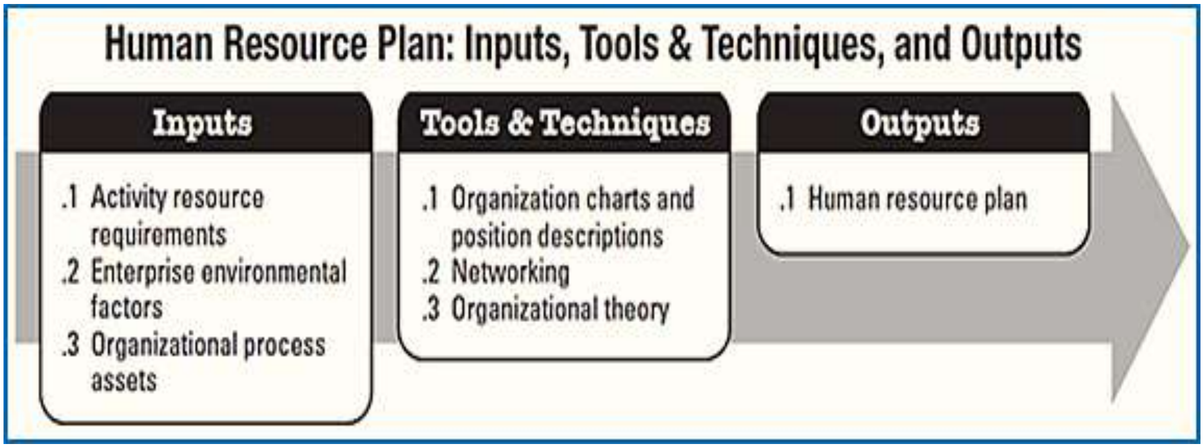
Both are essential components of a comprehensive project management plan to execute and monitor a project successfully. As is the case, there are resource management software tools available that automatically assist the system in resource allocations to production and its portfolios, including supply and procurement demands.

6.1. Human Resource Management (HRM):

Is the application of allocating human resources among various projects or business units, maximizing the utilization of available personnel resources to achieve business goals; and performing the activities that are necessary in the maintenance of that workforce through identification of staffing requirements, planning and oversight of payroll and benefits, education and professional development, and administering their work-life needs. It is the efficient and effective deployment of an organization's personnel working data, as well in training and skills required by the work.

6.2. Resource Management Techniques:

One resource management technique is the resource leveling. It aims at smoothing the personnel resources on hand, reducing both excess inventories and shortages. The required data are: the demands for various resources, as well as, the configurations required in those demands, and the supply of the resources, which must be forecast by time period into the future as far as is reasonable.



Natural Resource Management (NRM): Examples of this form of management are **air resource** management, **soil conservation**, **forestry**, **wildlife** management and **water resource** management. The goal is to achieve 100% utilization but that is very unlikely, when weighted by important metrics and subject to constraints, for example: meeting a minimum service level, but otherwise minimizing cost. The principle is to invest in resources as stored capabilities, then unleash the resources according to the project time and the demand.

7. Kanban:

It means literally signboard or billboard. It is a scheduling system for lean manufacturing and just-in-time (JIT) system. Kanban is a system to **control the logistical chain** of a production, and each material acquisition points to a defined point of assembly of a product on the shop floor. Kanban was developed by **Taiichi Ohno**, **at Toyota**, to improve and maintain a high level of production. Kanban is one method through JIT is achieved. Kanban became an effective tool in support of running a production system as a whole, and it proved to be an excellent way for promoting improvement.

7.1. Operation:

The normal production scheduling is based on the "*pushing*" system, which is the demand-forecast to receive a "*push*" item. Kanban, by contrast, is part of an approach where the "*pull*" comes from the demand. The supply or production is determined according to the actual demand of the internal customers. In contexts where supply time is lengthy and demand is difficult to forecast, often, the best one can do is to respond quickly to observed demand.

The Kanban system accomplishes standard items used as a demand, which immediately travels through the supply productive chains. This ensures **intermediate stocks**, better managed items and usually smaller. Toyota, for example, has six simple rules, and close monitoring of these rules is a **never-ending task**, thereby ensuring that the Kanban personnel only does what is required for.

7.2. Toyota's Six Rules:

- Do not send defective products to the subsequent process;
- The subsequent process comes to withdraw only what is needed;
- Produce only the exact quantity that was withdrawn by the subsequent process;
- Level the production;
- Kanban is a means of fine tuning;
- Stabilize and rationalize the process.

7.3. Kanban Cards:

The ***Kanban cards*** are key components and signal the need to move materials within a manufacturing facility or move materials from an outside supplier to the production facility. The Kanban cards are, in effect, messages to show that there can be a depletion of products, parts, or inventories that, when received, the Kanban personnel must trigger the replenishment of manufacturing products. The demand for more production is **signaled by Kanban cards*,*** which create a complete cycle system, what today, is common in modern lean production facilities that find a practical widespread usage of this system.

7.4. Three-bin System:

An example of a **simple Kanban** system is the implementation of a "**Three-bin System**" for the supplied parts, where there is no in-house manufacturing. **The first bin** is on the **factory floor** (considered the initial demand point), **the second bin** is in the **factory storage** (considered the inventory control point), and the **third bin** is outside at the **supplier's** business. The bins usually have a removable card containing the product details and other relevant information, known as the classic ***Kanban cards***.

Note: In Oracle ERP, the Kanban system is used for **signaling demand to vendors** through e-mail notifications. When stock of a particular component is depleted by the quantity assigned on Kanban cards, a "**Kanban trigger**" is created (which may be manual or automatic), a purchase order is released with predefined quantity for the vendor defined on the card, and the supplier is expected to dispatch the materials always within a specified time.

8. Kaizen:

Kaizen means "**improvement**" or "**change to better**" and refers to a philosophy or practice that focus upon a **continuous improvement of processes** in manufacturing, engineering, and business management. Applied to production workplaces, Kaizen may go beyond activities that continually improve all functions and also involves the employees, from the CEO to the assembly line. It also applies to processes, such as purchasing and logistics, which cross organizational boundaries into the supply chains.

The Kaizen main philosophy **aims to eliminate waste** in production (see lean manufacturing) and was first implemented in several Japanese businesses after the Second World War, influenced by William E. Deming and American quality management teachers, who visited the country. It has since spread throughout North America and is now being implemented in many other companies around the world.

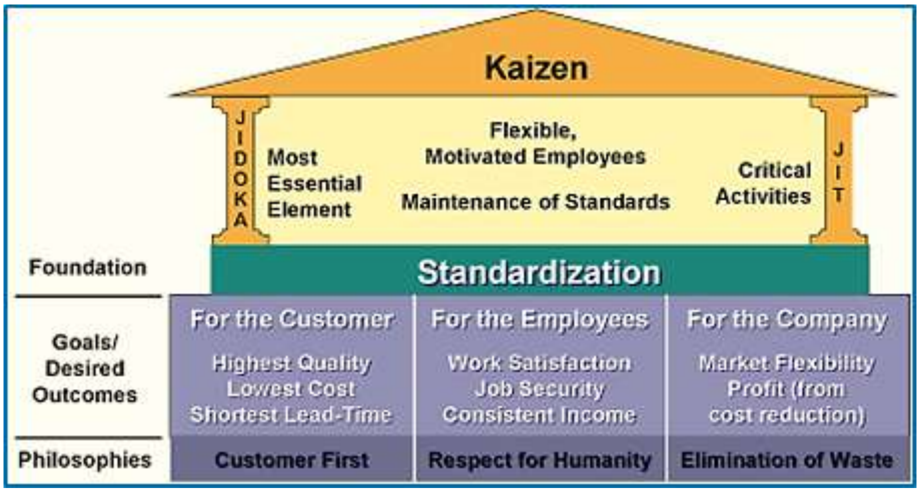
8.1. Kaizen Operation:

Kaizen is a daily process, which goes beyond simple productivity improvement. It is also a process that, when done correctly, **humanizes the workplace**, eliminates hard work, and teaches people how to perform experiments on their work using **scientific methods** and how to learn to spot and **eliminate waste** in business processes. Generally, the process suggests a humanized approach to workers and to increasing productivity: "*The idea is to nurture the company's human resources as much as it is, to praise* *and encourage participation in Kaizen activities*". Successful implementation requires "*the participation of all workers and supervision*" in the improvement of processes.

8.2. Implementation:

The Toyota production is better known for its Kaizen Systems, where all line personnel are expected to stop their moving production line in case of any abnormality and, along with their supervisors, suggest an improvement to resolve the abnormality, which may initiate a Kaizen. The cycle of the Kaizen activity can be defined as:

- Standardize an operation and activities;
- Measure the operation (find cycle time and amount of in-process inventory);
- Gauge measurements against requirements;
- Innovate to meet requirements and increase productivity;
- Standardize the new, improved operations;
- Continue cycles *ad infinitum.*



9. Just-in-Time (JIT):

JIT or Just-in-Time system, means making "***only what is needed, when it is needed, and in the amount needed***". For example, to efficiently produce a large number of automobiles, which can consist of around **30,000 parts** or more, it is necessary to create a detailed production plan, which includes supply parts by stock and procurement. Supplying "*what is needed, when it is needed, and in the amount needed*" according to a production plan can eliminate waste, inconsistencies, and unreasonable requirements, resulting in improved productivity.

The **Just-in-Time** system is a production strategy that strives to improve a business return on investment by reducing in-process inventories, highly associated with carrying costs. To meet the JIT objectives, the process relies on signals or Kanban, between different points in the process, which tells the production when to make the next part. This means that stock levels of raw materials, components, work in progress and finished goods **can be kept** to a **minimum**.

9.1. JIT Operation:

Just-in-Time is a "*demand system*" of production, the way that actual orders provide a signal for when a product or part should be manufactured. This "*demand-pull*" enables a firm to produce **only** what **is required**, in the correct quantity and at the correct time. All supplies are delivered right to the production line only when are necessary. For example, a car manufacturing plant may receive exactly the right

number of tyres only for one day's production, and the **supplier** would be expected to **deliver** them to the correct loading point, on the production line, within a very narrow time.

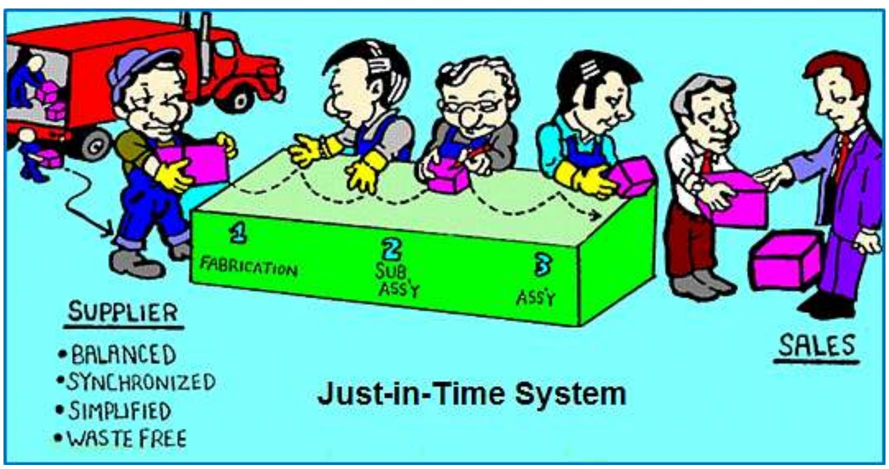
Kiichiro Toyoda, the founder of Toyota Motor Corporation, at the beginning, directed the engine casting work and discovered many problems in their manufacture. The Toyota's journey with JIT may have started back in 1934 when it moved from textiles to produce its first car. In 1936, when Toyota won its first truck contract with the Japanese government, the productive processes hit new problems and he developed the "*Kaizen*" improvement teams.

a. Advantages of JIT:

- ✓ Lower stock holding means a reduction in storage space which saves rent and insurance costs;
- ✓ As stock is only obtained when it is needed, less working capital is tied up in stock;
- ✓ There is less likelihood of stock perishing, becoming obsolete or out of date;
- ✓ Avoids the build-up of unsold finished product that can occur with sudden changes in demand;
- ✓ Less time is spent on checking and re-working the product of others as the emphasis is on getting the work right first time.

b. Disadvantages of JIT:

- ✓ There is little room for mistakes as minimal stock is kept for re-working faulty product;
- ✓ Production is very reliant on suppliers and if stock is not delivered on time, the whole production schedule can be delayed;
- ✓ There is no spare finished product available to meet unexpected orders, because all products are made to meet actual orders, however, JIT is a very responsive method of production.



10. Lean Manufacturing:

Lean manufacturing, **lean enterprise**, or **lean production**, often simply, "**lean**", is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer. Essentially, lean is centered on ***preserving product value*** with less work and less waste. Lean may have started at the turn of the 20th century in a textile factory with looms that stopped production when a thread broke. Thus, this has become the seed of automation and process controls.

10.1. Lean Implementation:

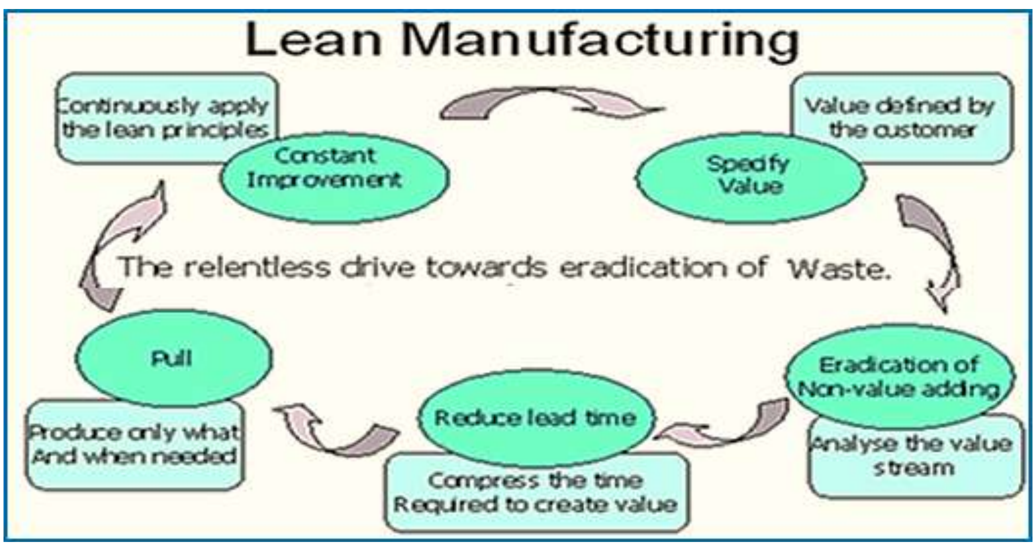
There are many examples of the Lean Manufacturing implementation without a sustained benefit, and these are often blamed on weak understanding of the method, throughout the whole organization. Lean philosophy aims to make the work simple enough to **understand, do, and manage**. This term was first coined by John Krafcik in his 1988 article, "*Triumph of the Lean Production System*", based on his master's thesis at the MIT Sloan School of Management. Lean is the set of "*tools*" that assist in the identification and steady elimination of waste. As waste is eliminated, then quality in a production process improves, while operation stop, time and costs are reduced.

10.2. Waste in Production:

To achieve these **goals** at once, the Toyota's mentoring process, (called *Senpai* and *Kohai* - Senior and Junior), is one of a better way to foster Lean thinking up and down the organizational structure. The elimination of **waste** is the main goal of the Lean Manufacturing, and Toyota defined **three** broad types of waste, designated as: ***Muda*, *Muri* and *Mura***, as described below:

- ✓ ***Muri*:** Is all the unreasonable work that management imposes on workers and machines because of poor organization, such as carrying heavy weights, moving things around, dangerous tasks, even working significantly faster than usual. It is pushing a person or a machine beyond its natural limits.
- ✓ ***Mura***: Is equal to “*making plan*” and “increasing plan”, when the "*numbers*" are low, which causes production to lift an extra capacity from the process, which causes routines and standards to be modified or stretched.
- ✓ ***Muda***: Is the equal to the original seven systems that are:

  - **Over Production**: Production ahead of demand;
  - **Unnecessary Stock**: Work in process and finished product not being processed;
  - **Inefficient Transport**: Not actually required to perform the processing;
  - **Unnecessary Motion**: People or equipment moving more than is required;
  - **Waiting Times**: Waiting for the next production step;
  - **Rejects & Defects**: The effort involved in inspecting for and fixing defects;
  - **Inappropriate Processing**: Resulting from poor tool or product design creating activity.



IV. QUALITY MANAGEMENT TOOLS:

The acts of overseeing all activities and tasks needed to maintain a desired level of excellence, includes create and implementing quality planning and assurance, as well as, quality control and quality improvements. In resume, the most used quality management tools are:

1. Total Quality Management (TQM):

The TQM is a philosophy and system for continuously improving the services and/or products offered to customers. Now that the technologies of communication have replaced national economic systems with a global economy, nations and businesses that do not practice TQM, can become globally non-competitive rather rapidly. The concept of quality first emerged out of the Industrial Revolution. In the late 19th century pioneers such as **Frederick Winslow Taylor** and **Henry Ford** recognized the limitations of the methods being used in mass production at the time and the subsequent varying quality of output.

Taylor established Quality Departments to oversee the quality of production and Ford emphasized the standardization of components to ensure a standard product of his cars. The quality system, known worldwide, was defined by William Edwards Deming (1900-1993), known as the "**father of the quality**" in Japan and then in the United States. Application of the SCP (Statistical Control Process) production methods came later, as a result after World War, also advanced with Deming, who was a statistician, after whom the Deming Prize for quality is actually named.

The "*Total Quality*" was also defended by Joseph M. Juran, who focused more on quality management. The first edition of the Juran's Quality Control Handbook was published in 1951. He also developed the "**Juran's trilogy**", an approach to a functional management composed of **three** managerial processes: **quality planning, quality control and quality improvement**. Quality management method relies on the cooperation of all members of any organization, which centers on Quality and on the long-term success, through the satisfaction of the Customers, as well as, the benefit of all its members and society.

1.1. Quality Management System (QMS):

The Quality Management System (QMS) can be expressed as an organizational structure, procedures, processes and resources needed to implement quality management, as **ISO 9000**. Early systems emphasized many outcomes of an industrial production line, using simple statistics and random sampling. Currently, QMS has tended to converge with **sustainability and transparency initiatives**, as both investor and customer satisfaction and perceived quality is increasingly tied to these factors. The ISO 19011 audit regime applies to both, and deals with quality and sustainability and personnel integration.

1.2. TQM and QMS Relationship:

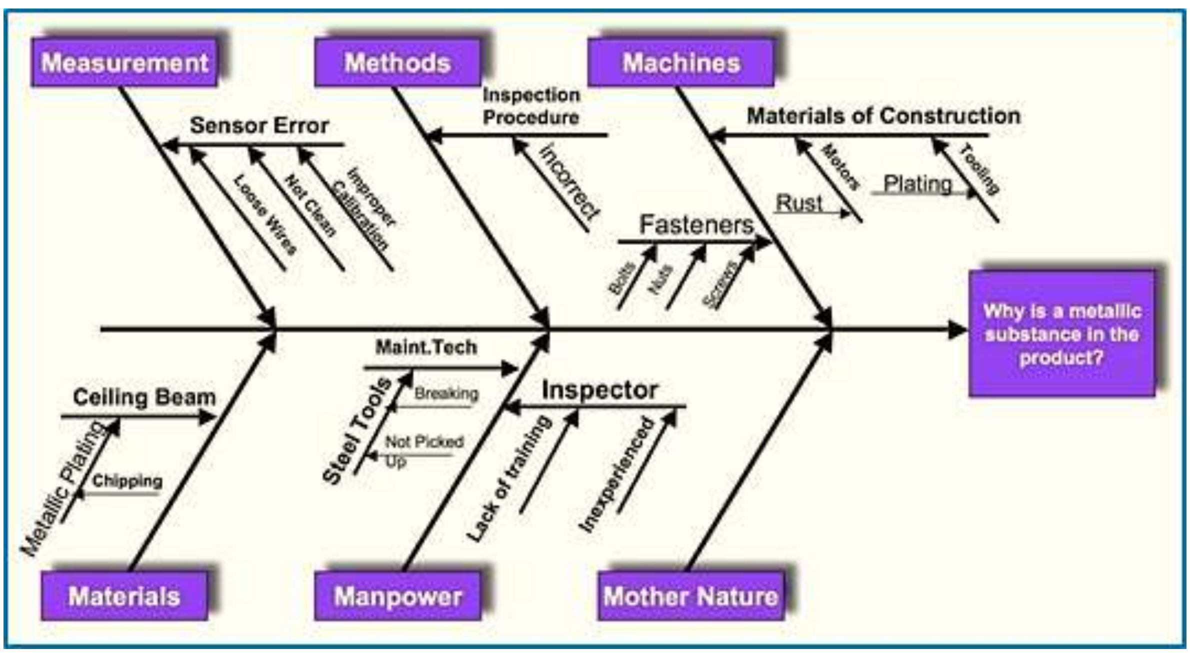
Total Quality Management: Is not a set of requirements, it is an **attitude**, a way of working together for improving everything within the organization, much bigger than just a set of requirements. The TQM philosophy would break down barriers within a company, at functional level, and encourage people to support each other for the good of the organization.

Quality Management System: Is potentially "**the way you do things**" and normally reflects the ISO 9000 as the basis for the management system. The ISO 9001 **is a set of requirements**, nothing more, but provides a platform for standardization, commonly focused by customers to rely on products and services. QMS provides a framework for continual improvement, while TQM is a business strategy based on education, which tends to drive the customer to evaluate the processes within a company.

2. Ishikawa Diagrams:

Also called **fishbone**, **herringbone**, **cause-and-effect** or **Fishikawa,** are models of statistic **causal diagrams** created by **Kaoru Ishikawa** (1968) that show the causes of a specific event. Cause-and-effect or Ishikawa diagrams were popularized by in 1960s and pioneered the quality management processes in the Kawasaki shipyards. This process became one of the founding fathers of modern management.

The basic concept was first used in the 1920s, and is considered one of the seven basic tools of quality control. It is known as a fishbone diagram because of its shape, similar to the side view of a fish skeleton. Common uses of the Ishikawa diagram are product design and quality defect prevention, to identify potential factors causing an overall effect. Each cause or reason for imperfection is a source of variation.



2.1. Cause-and-Effect Diagrams:

Cause-and-effect diagrams can reveal key relationships among various variables, and the possible causes provide additional insight into process behavior. Causes can be observed from groups of brainstorming sessions that can label the categories, designated as fishbone, due the diagram seems to be fish bones. Causes and effects are usually grouped into major categories to identify these sources of variation. The categories typically include:

- **People**: Anyone involved with the process;
- **Methods**: How the process is performed and the specific requirements for doing it, such as policies, procedures, rules, regulations and laws;
- **Machines**: Any equipment, computers, tools, etc. required to accomplish the job;
- **Materials**: Raw materials, parts, pens, paper, etc. used to produce the final product;
- **Measurements**: Data generated from the process that are used to evaluate its quality;
- **Environment**: The conditions, such as location, time, temperature, and culture in which the process operates.

The purpose of a cause and effect analysis is to identify causes, factors, or sources applied to production variations that lead to specific events, which may result in errors or defects in a product or process. A fishbone diagram is simply a tool to be used along with Brainstorming and the **5 Whys**. Causes can be traced back to root causes using the 5 Whys technique or using the **6 M's**, described below.

2.2. The 6 M´s Used by Toyota:

- **Machines**: Technologies;
- **Methods**: Processes;
- **Materials**: Includes Raw Material, Consumables and Information;
- **Manpower**: Physical work/Mind Power (brain works);
- **Measurements**: Inspection;
- **Mother Nature**: Environment.

The original **6 M´s** used by the **Toyota Production System** was expanded to include a following system referred to as **8 M´s**. This system was not globally recognized, however, it was suggested to return to the roots of the tools and to keep the teaching simple, since most programs do not address the **8 M´s**.

- **7 P´s:** Product; Price; Place; Promotion; People; Personnel; Process;
- **5 S´s:** Surroundings; Suppliers; Systems; Skills; Safety;
- **5 W´s:** Where; What; When; Who; Why.

3. Control Charts:

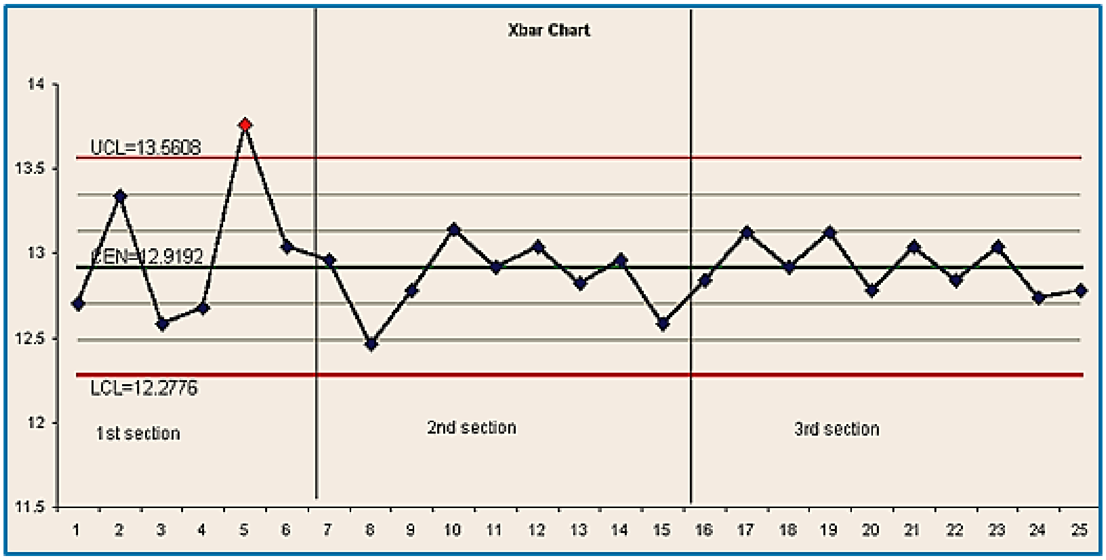
Control chart is also known as **Shewhart charts,** as this system was invented by Walter A. Shewhart while working for Bell Laboratories in the 1920, when the company's engineers had been seeking to improve the reliability of their telephony transmission systems. Then, in 1924 or 1925, the Shewhart's innovation came to the attention of the statistician **W. Edwards Deming**, at that time working at the Hawthorne facility. Deming later worked at the United States Department of Agriculture and became the mathematical advisor to the Census Bureau. Over the next half a century, Deming became the foremost champion and proponent of Shewhart's work.

3.1. Control Charts Definition:

All points of the chart representing a statistic (a mean, range, or proportion) of measurements of a quality. The samples attributes are taken from processes at different times (data). The mean of these points, using all the samples, is then calculated (the mean of the means, mean of the ranges, mean of the proportions). A centre line is drawn at the value of the mean of the points. The standard error [standard deviation/sqrt(n) for the mean] of the points is also calculated using all the samples.

a. Upper and Lower Control Limits: Indicate the threshold, at which the product or the process output quality is considered statistically "*unlikely*", drawn typically with **3 standard errors** from the centre line (sometimes also called "*natural process limits*"). The chart may have other optional features, including:

b. Upper and Lower Warning Limits: Are drawn as separate lines, which show typically two standard errors above and below the centre line, commonly divided into zones, with the addition of rules governing frequencies of observations in each zone. Annotation with events of interest may be determined by the Quality Engineer in charge of the process's quality.



4. Failure Mode and Effect Analysis (FMEA):

FMEA is one of the first systematic techniques for failure analysis, developed by engineers in the 1950 to study problems that might arise from malfunctions of **military operations**. Currently, involves reviewing of many components, assemblies and sub-systems to minimum details, as possible, to identify failure modes, and their causes and effects. An FMEA is often the first step of a system reliability study.

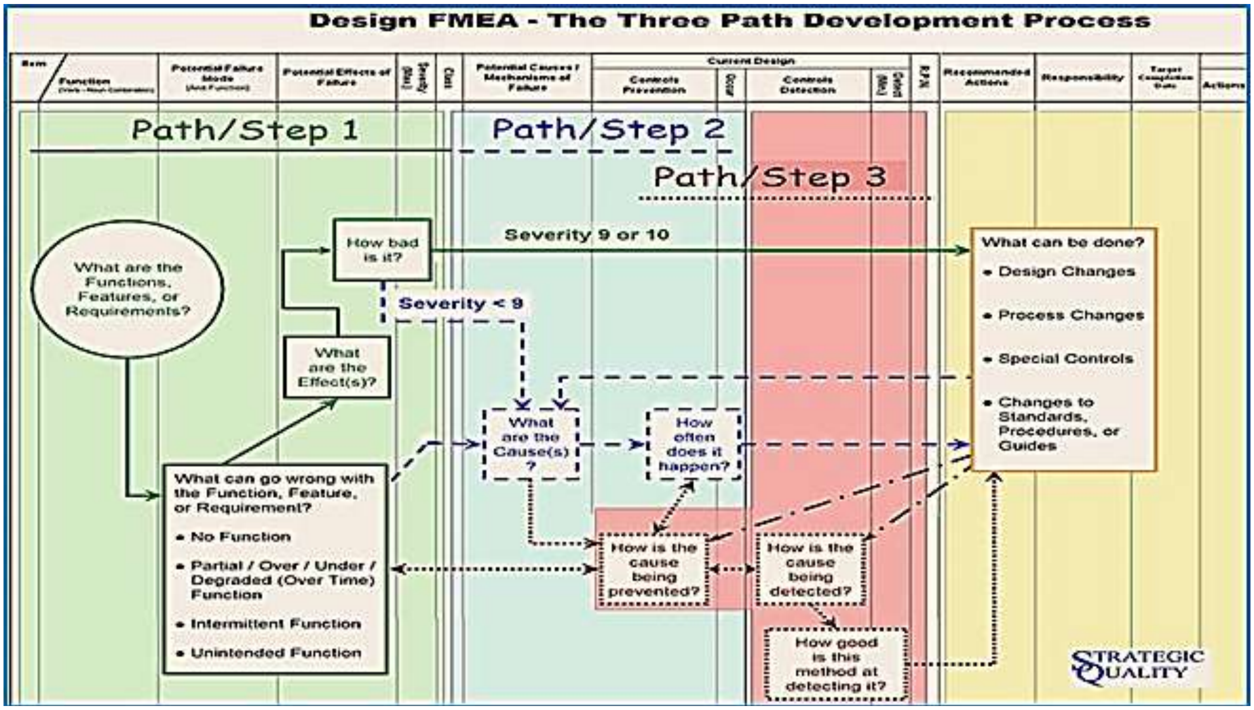
A FMEA is mainly a **qualitative analysis**. For each component, the failure modes and their resulting effects on the rest of the system are recorded in a specific FMEA worksheet, which have several variations. A few different types of analysis exist, like the Functional, Design and Process FMEA. A successful FMEA activity helps to identify potential **failure modes** based on experience with **similar products and processes** or based on common physics of failure logic. This measurement system is widely used in development and manufacturing industries in various phases of the product life cycle.

Effects analysis refers to studying the consequences of those failures on different system levels. Functional analysis is needed as an input to determine correct failure modes, both for functional FMEA or piece-parts (hardware). FMEA is also used to structure Mitigation for Risk reduction based on either failure effect severity reduction or on lowering the probability of failure.

4.1. Critical Analysis - FMECA:

Sometimes the FMEA is also called FMECA to indicate that a **critical analysis** is also performed. An FMEA is an inductive measurement (forward logic), single point of **failure analysis** and is a core task in reliability engineering, safety engineering and quality engineering. The quality engineering is especially concerned with "*some process*" (mainly, manufacturing and assembly).

Failure probabilities can only be **estimated** or **reduced** by understanding the "*failure mechanisms*". Ideally this probability can be lowered to "***impossible to occur***" by eliminating the "root causes". It is therefore important to include in FMEA an appropriate depth of information on the causes of failure (deductive analysis). Thus, FMECA can be a living document during development of a hardware design, scheduled and completed, concurrently with design. If completed in a timely manner, the FMECA can help guide design decisions. It is useful as a design tool and in decision making processes dependent on the effectiveness and timeliness with which design problems are identified.



4.2. FMEA Terminology:

Failure Mode: The loss of an intended function of a device under stated conditions. Failure mode is the specific manner or the way by which a failure occurs in terms of failure of the item (being part or a subsystem) function under analysis. Poorly defined material or poorly made manufacturing (cause) results in failures (effect). For example: a fully fractured axle, a deformed axle, a fully-open or a fully-closed electrical contact.

Failure Causes: It usually has a source, such as errors in purchasing requirements, design, process, quality control, handling or application of parts, or a sequence of errors that start a process (mechanisms) and consequently lead to causes of failures over a given time. A failure mode can have more causes that are effects of time. For example: fatigue or corrosion of a structural beam, corrosion in an electrical contact, etc.

Failure Effect: Are immediate consequences of a failure on operation, function or functionality, or status of some item. Example: the failure in painting might have been improper initial application of the corrosion protection layer or an incorrect vibration of the paint mixing tank.

5. Risk Levels:

Risk is the combination of probability and severity of the final effect, where probability and severity analysis may include the effect on undetectable failures in products and services. This can influence the probability of failure or the severity of the worst effect of the case. The exact analysis may not be easy in multiple scenarios (with multiple events) due the difficult detectability that plays a crucial role (as for redundant systems). In this case the Quality Analyst should use the ***Fault Tree Analysis*** and/or the ***Event Trees*** to determine the exact probability of risk levels.

6. Statistical Process Control (SPC):

The Statistical Process Control (SPC) tools are widely used in companies because they identify quality problems during the production process and also help identify a change or variation in some product or process quality characteristic. It is necessary to first see what types of variation can be observed when measuring quality. Then identify the specific tools used to measure this variation. Statistical Process Control can be divided into three broad categories.

1. The Statistical Process Control (SPC) means **to inspect** a random sample of the output from a process and deciding whether the process is producing products with characteristics that fall within a predetermined range. The SPC answers the question of whether the process is functioning properly or not.

2. Descriptive **statistics** are used to describe quality characteristics and relationships. Included are statistics such as the mean, standard deviation, the range, and a measure of the distribution of data.

3. Acceptance **sampling** is the process of randomly inspecting a sample of goods and deciding whether to accept the entire lot based on the results. Acceptance sampling determines whether a batch of goods should be accepted or rejected.

For example, if you look at bottles of a soft drink in a grocery store, maybe you notice that two bottles may not be filled to exactly the same level. Some are filled slightly higher and some slightly lower. Similarly, if you look at blueberry muffins in a bakery, you may notice that some are slightly larger than others and some have more blueberries than others. These differences are completely normal. No two products are exactly alike because of slight **differences** in materials, workers, machines, tools, and other factors.

These are called **common, or random, causes of variation.** Common causes of variation are based on random causes that we cannot identify. These types of variation are unavoidable and are due to slight differences in processing. The second type of variation that can be observed involves variations where the causes can be precisely identified and eliminated. These are called **assignable causes of variation.** Examples of this type of variation are poor quality in raw materials, an employee who needs more training, or a machine in need of repair. In each of these examples the problem can be identified and corrected.

6.1. The Arithmetic Mean:

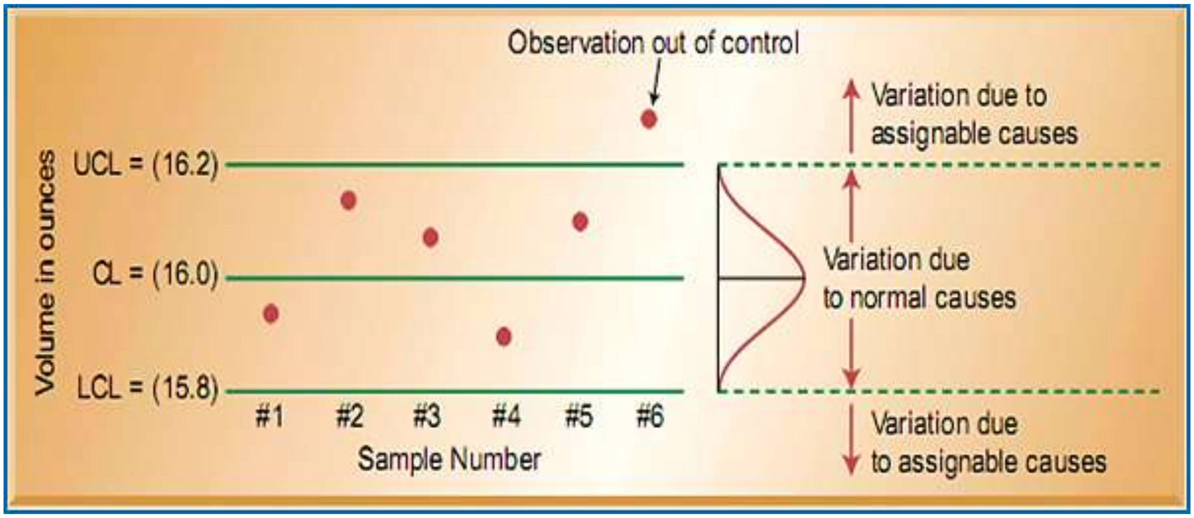
The arithmetic average, or the **mean,** is a statistic that measures the central tendency of a set of data. In the soft drink bottling example, we stated that the average bottle is filled with 16 ounces of liquid. To compute the mean we simply sum all the observations and divide by the total number of observations.

6.2. Control Charts:

A control chart is a graph that shows upper and lower control limits that separate common data from assignable causes of variation and the common range of variation, defined by the use of control limits. A **control chart** (also called process chart or quality control chart) shows whether a sample of data falls within the common or normal range of variation We say that a process is **out of control** when a plot of data reveals that one or more samples fall outside the control limits.

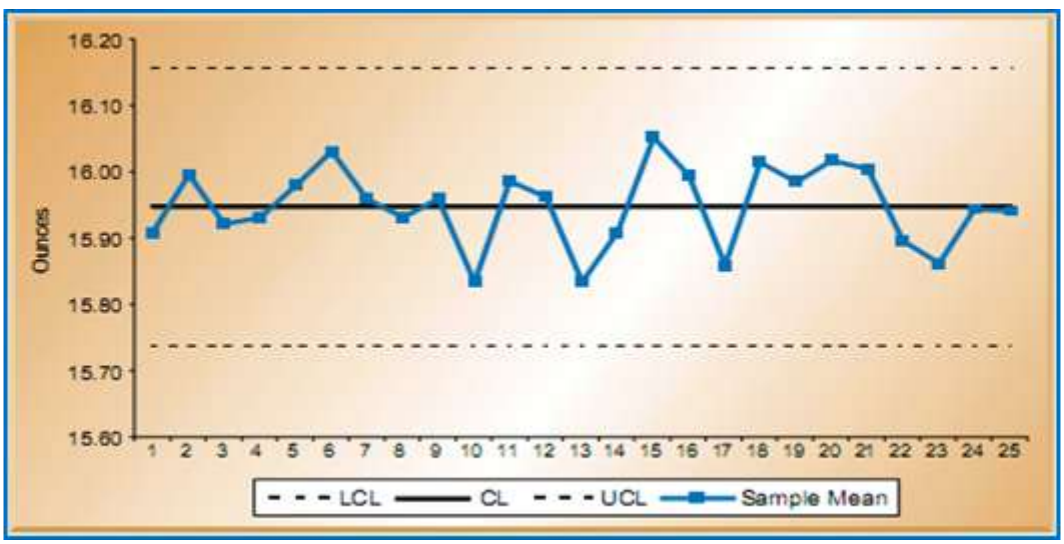
6.3. Types of Control Charts:

Control charts are one of the most commonly used tools in Statistical Process Control (SPC). They can be used to measure any characteristic of a product, such as the weight of a cereal box, the number of chocolates in a box, or the volume of bottled water. The different characteristics that can be measured by control charts can be divided into two groups: **variables** and **attributes.** A *control chart for variables* is used to monitor characteristics that can be measured and have a continuum of values, such as height, weight, or volume. A soft drink bottling operation is an example of a variable measure, since the amount of liquid in the bottles is measured and can take on a number of different values.



6.4. Mean Charts:

A mean control chart is often referred to as an ***X-bar chart.*** It is used to monitor changes in the mean of a process. To construct a mean chart we first need to construct the **center line** of the chart. To do this we take **multiple samples** and compute their means. Usually these samples are small, with about four or five observations. Control charts variables monitor characteristics that can be measured and have a continuous scale, such as **height, weight, volume, or width**. When an item is inspected, the variable being monitored is measured and recorded. For example, if we were producing **candles**, height might be an important variable, so we could take samples of candles and measure their heights.

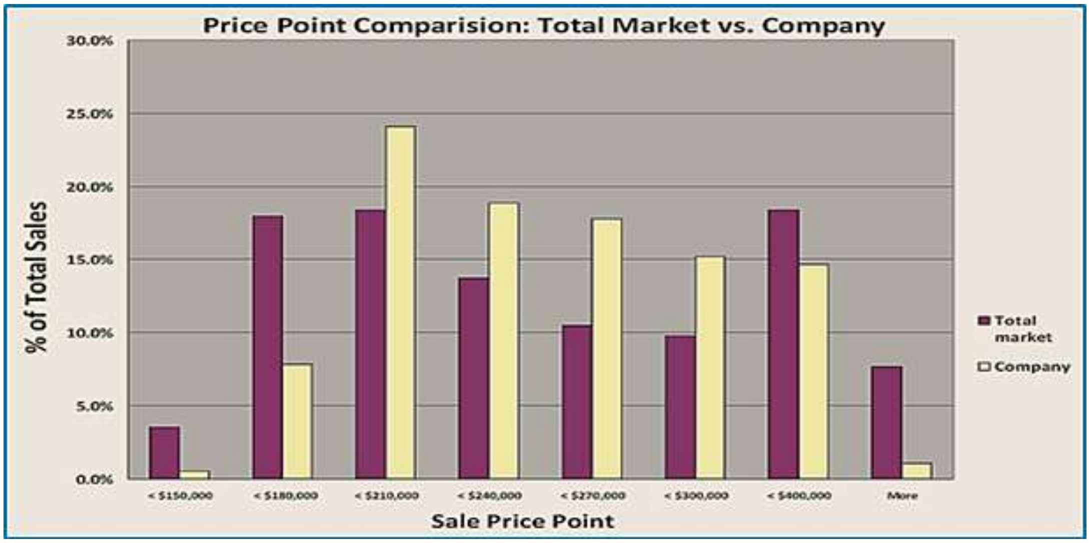


One category of the Statistical Process Quality (SQC) consists of **descriptive statistics tools,** such as the **mean, range, and standard deviation**. These tools are used to describe quality characteristics and relationships. Another category of SQC techniques use the Statistical Process Control (SPC) methods to monitor changes in the production process. To understand SPC methods you must understand the **differences** between common and assignable causes of variation.

7. Histograms:

Histograms are graphical representation of the distribution of data. It is an estimate of the probability distribution of a continuous variable and was first introduced by Karl Pearson, an English mathematician and biostatistician (1857 – 1936). A histogram is a representation of tabulated frequencies, shown as adjacent rectangles, erected over discrete intervals (bins), with an area equal to the frequency of the observations in the interval.

Histograms are used to plot the density of data, and often for density estimation: estimating the probability density function of the underlying variable. An alternative to the histogram is the kernel density (central component of the computer operating system) estimation to smooth samples. This will construct a smooth probability density function, which will in general more accurately reflect the underlying variable. The histogram is one of the seven basic tools of quality control.



The height of a rectangle is also equal to the frequency density of the interval, i.e., the frequency divided by the width of the interval. The total area of the histogram is equal to the number of data. A histogram may also be normalized displaying relative frequencies. It then shows the proportion of cases that fall into each of several categories, with the total area equaling.

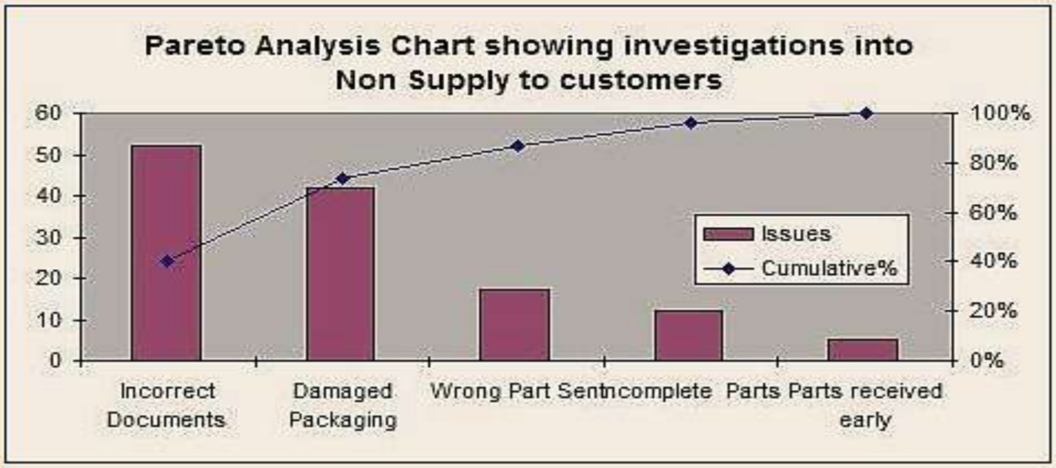
The categories are usually specified as consecutive, non-overlapping intervals of a variable. The categories (intervals) must be adjacent, and often are chosen to be of the same size. The rectangles of a histogram are drawn so that they touch each other to indicate that the original variable is continuous.

8. Pareto Analysis:

Is a **statistical technique** in decision making that is used for selection of a limited number of tasks that produce significant overall effect. It uses the Pareto principle – the idea that by doing 20% of work, 80% of the advantage of doing the entire job can be generated. Or in terms of quality improvement, a large majority of problems (80%) are produced by a few key causes (20%).

The Pareto analysis can be used to identify the root causes of errors. While it is common to refer to Pareto as a "***80/20***" rule, under the assumption that, in all situations, **20%** of causes determine **80%** of problems, this ratio is merely a convenient rule of thumb and is not nor should it be considered immutable law of nature. The application of the Pareto analysis in risk management allows management to focus on those risks that have the most impact on the project.

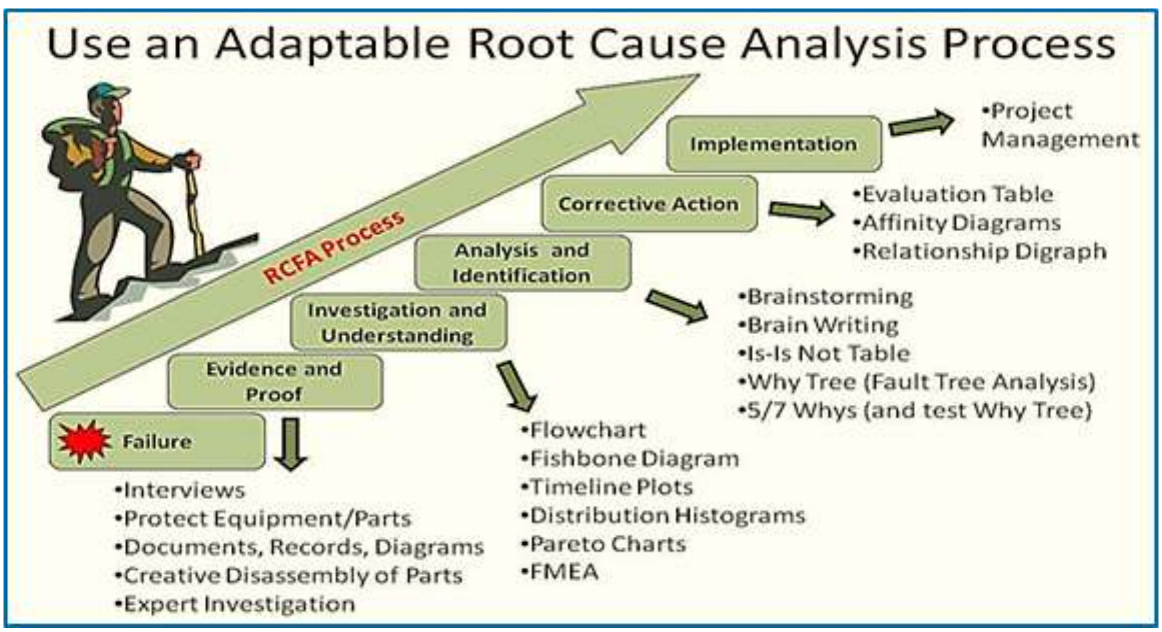
The Pareto analysis is a useful formal technique, where many possible ways of action can be used. In essence, the problem-solver estimates the benefit delivered by each action, then selects a number of the most effective actions to deliver benefit reasonably close to the best possible. The Pareto analysis is a creative way of looking at causes of problems because it helps stimulate thinking and organize thoughts.



	Incorrect Documents	Damaged Packaging	Wrong Part Sent	Incomplete Parts	Parts received early
Issues	52	42	17	12	5
Cumulative%	41%	73%	87%	96%	100%

9. Root Cause Analysis (RCA):

Is a method of problem solving that tries to identify the root causes of faults or root problems that cause operating events. Root cause analysis is not a single, sharply defined methodology; there are many different tools, processes, and philosophies for performing RCA. However, several very-broadly defined approaches or "*schools*" can be identified by their basic approach or field of origin: safety-based, production-based, process-based, failure-based, and systems-based, as defined below:



The RCA practices try to solve problems by attempting to identify and correct the root causes of events, as opposed to simply addressing their symptoms. By focusing correction on root causes, problem recurrence can be prevented. However, the RCA analysts recognize that complete prevention of recurrence by one corrective action is not always possible.

The primary aim of RCA is to identify the factors that resulted in the nature, the magnitude, the location, and the timing of the harmful outcomes (consequences) of one or more past events in order to identify what behaviours, actions, inactions, or conditions need to be changed to prevent recurrence of similar harmful outcomes and to identify the lessons to be learned to promote the achievement of better consequences. "*Success*" is defined as the near-certain prevention of recurrence.

- **Safety-based**: Descends from the fields of accident analysis and occupational safety and health;
- **Production-based**: Has its origins in the field of quality control for industrial manufacturing;
- **Process-based**: Follow-on to production with a scope expanded to business processes;
- **Failure-based**: Rooted in practice of failure analysis employed in engineering and maintenance;
- **Systems-based**: From fields such as systems analysis, change and risk management.

To be effective, the RCA must be performed systematically, usually as part of an investigation, with conclusions and root causes that are identified backed up by documented evidence. The purpose of identifying all solutions to a problem is to prevent recurrence at lowest cost in the simplest way. If there are alternatives that are equally effective, then the simplest or lowest cost approach is preferred. The following table shows an overview of the main methods used:

Total Quality Management (TQM)	Pareto chart
Analysis of variance	Quality Function Deployment (QFD)
Cause & effects diagram (also known as fishbone or Ishikawa diagram)	Root cause analysis
Check sheet	Run charts
Control chart	Scatter diagram
Cost-benefit analysis	SIPOC analysis(Suppliers, Inputs, Process, Outputs, Customers)
CTQ tree	COPIS analysis (Customer centric version/perspective of SIPOC)
Failure mode and effects analysis (FMEA)	Taguchi methods
Histograms	5 Whys

10. Hazop – Hazard & Operability

The "Hazop" or Risk & Operability is the systematic examination of a very complex planned process or operation in order to identify and evaluate problems that may pose risks to personnel, equipment or the company itself. It is carried out by a multidisciplinary team duly experienced in processes and projects, during a series of meetings, usually applied to very complex and dangerous projects and systems. A range of data from the entire facility must be explicitly identified and taken as the basis for the "*safety intent*" for the Hazop study. This technique was initially developed in the 1960s to analyze major chemical process systems, but has since been extended to other areas, including mining operations and other types of complex systems and processes, such as nuclear power plant operation or development of an electronic product.

For example, for a process plan multiple nodes are chosen, so that for each there is a significant risk path that can be specified. In practice, these nodes or points are checked through a drawing or a Pipe and Instrumentation (P&ID) diagram or a Process Flow (PFD) diagram, and each node (or point) of the process must be tabled in a spreadsheet. Each tabled node must be evaluated by a team of projects and processes, as to the magnitude of the hazards that each node or point can pose during operation. However, it should also balance between the "*very large and complex*" (team members should be able to consider all issues within all nodes at once) or the "*very small and simple*". Many trivial nodes are repetitive; however, all points must be independently evaluated and documented.

HAZOP - Chemical Reactor

Guide Word	Deviation	Causes	Consequences	Action
NO	No cooling		Temperature increase in reactor	
REVERSE	Reverse cooling flow	Failure of water source resulting in backward flow		
MORE	More cooling flow			Instruct operators on procedures
AS WELL AS	Reactor product in coils			Check maintenance procedures and schedules
OTHER THAN	Another material besides cooling water	Water source contaminated		

The Hazop from a plant must be fully managed by a Manager with experience in projects and processes and choose the team members. In turn, the Hazop team uses a list of standardized guidelines and process parameters to identify possible deviations from project intent. Hazop is also used as a basis for reviewing batch operational processes and procedures. For each deviation, the team identifies viable causes and likely consequences then decides and confirms by subsequent risk analysis (when necessary), verifies whether design indications are sufficiently safe, or whether action to install additional security is necessary, to reduce risks to an acceptable level.

Parameters and Words: To identify the risks on each node (or point), the team applies (systematically, in order) a set of "guide words" to each node in the process. These are words are general as; Flow, Temperature, Pressure, Composition, etc. It should be noted that the "guide words" should be appropriate to process systems, but not very specific (limiting discussion) or very general (allowing loss of focus) as shown below, as an example.

Guide Word	Meaning
NO OR NOT	Complete negation of the design intent
MORE	Quantitative increase
LESS	Quantitative decrease
AS WELL AS	Qualitative modification/increase

PART OF	Qualitative modification/decrease
REVERSE	Logical opposite of the design intent
OTHER THAN / INSTEAD	Complete substitution
EARLY	Relative to the clock time
LATE	Relative to the clock time
BEFORE	Relating to order or sequence
AFTER	Relating to order or sequence

Note: The last five "*guide words*" are generally applicable to batch or sequential operations. When a guide word is significantly applicable to a parameter, for example, "*no flow*" or "*more temperature*," its combination should be recorded as a potential deviation originating in the intent of the project, but sometimes requiring a revision.

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