



جامعة الجميع الذكية
EVERYONE'S SMART UNIVERSITY

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Advanced project Management

Unit IV: Scheduling and Resource Allocation - PERT & CPM Networks - Crashing — Project Uncertainty and Risk Management — Simulation — Gantt Charts — Expediting a project — Resource loading and leveling.

PROJECT SCHEDULING

It is one of the key components in the project control system. It refers to when it is to be done and how much is to be done. The purpose of scheduling is to obtain commitment, communicate the commitments to concerned and ensure coordination through self-regulating first efforts. The project schedule is simply the project plan in an altered format. It is a convenient form for monitoring and controlling project activities. Actually, the schedule itself can be prepared in several formats. The most common formats— Gantt charts and PERT/CPM networks

Purpose: The ongoing scheduling and monitoring process enables one to:

1. Successively detail out the schedule to provide equivalence with reality.
2. Adopt the schedule to the changed realities
3. Provide intervention when stability of the work system is being threatened and revitalize the system.

Kinds of Schedules

Two kinds of schedules are project schedule and task schedule. Project managers and upper management use a project schedule (or project master schedule) to plan and review the entire project. The project schedule shows the major project activities, but not much detail about each. It is at first developed during project initiation and is continually refined thereafter. Managers develop the project master schedule in a top-down fashion, first scheduling the tasks identified from the WBS or in the scope statement. Later, the schedule is refined in a bottom-up fashion, taking into account the more-detailed task schedules developed by functional managers. When the project is performed in phases, the schedule for each phase must be in sufficient detail to enable management to authorize work for the phase to commence.

A task schedule shows the specific activities necessary to complete an activity or work package. It is created for people working on a specific task and enables lower level managers and supervisors to focus on the task and not be distracted by other tasks with which they have no interaction. Task schedules are prepared by functional managers or subcontractors, but incorporate interface and milestone events as specified by the project manager and shown on the project master schedule. Project and task schedules can be prepared and displayed in many ways including with Gantt charts and project networks.

Developing Project Network Using PERT and CPM

- Developing the Project Network

Network analysis is a generic name for a number of associated project planning and control procedures that are all based on the concept of network. The project network is the tool used for planning, scheduling, and monitoring project progress. The network is developed from the information collected for the WBS and is a graphic flow chart of the project job plan. The network depicts the project activities that must be completed, the logical sequences, the inter dependencies of the activities to be completed, and in most cases the times for the activities to start and finish along with the longest path(s) through

the network—the critical path. The network is the framework for the project information system that will be used by the project managers to make decisions concerning project time, cost, and performance,

- Objectives of Project Network

1. Basis for scheduling labour and equipment;
2. Enhances communication that brings together all managers and groups in meeting the time, cost, and performance objectives of the project
3. Provides an estimate of the time the project will take (duration); gives the times when activities can start or finish and when they can be delayed
4. Provides the starting point for budgeting the cash flow (when money needs to be received and spent on various elements) of the project.
5. Identifies which activities are "critical" and, therefore, should not be delayed if the project is to be completed as planned.
6. Highlights which activities to consider if the project needs to be compressed to meet a deadline.

Project networks are developed from the WBS. The project network is a visual flow diagram of the sequence, interrelationships, and dependencies of all the activities that must be accomplished to complete the project

Constructing a Project Network

Terminology

Every field has its jargon that allows colleagues to communicate comfortably with each other about the techniques they use. Project managers are no exception. Here are some terms used in building project networks.

Activity: For project managers, an activity is an element of the project that requires time. It may or may not require resources. Typically an activity consumes time—either while people work or while people wait. Examples of the latter are time waiting for contracts to be signed, materials to arrive, drug approval by the government, budget clearance, etc. Activities usually represent one or more tasks from a work package. Descriptions of activities should use verb/noun format: for example, develop product specifications.

Merge activity: This is an activity that has more than one activity immediately preceding it (more than one dependency arrow flowing to it).

Parallel activities: These are activities that can take place at the same time, if the manager wishes. However, the manager may choose to have parallel activities not occur simultaneously.

Path: A sequence of connected, dependent activities.

Critical path: When this term is used, it means the path(s) with the longest duration through the network; if an activity on the path is delayed, the project is delayed the same amount of time.

Event: This term is used to represent a point in time when an activity is started or completed. It does not consume time.

Burst activity: This activity has more than one activity immediately following it (more than one dependency arrow flowing from it).

Network Analysis Techniques

A convenient analytical and visual technique of PERT and CPM prove extremely valuable in assisting the managers in managing the projects.

PERT stands for Project Evaluation and Review Technique and developed during 1950's. The technique was developed and used in conjunction with the planning and designing of the Polaris missile project.

CPM stands for Critical Path Method which was developed by DuPont Company and applied first to the construction projects in the chemical industry.

Though both PERT and CPM techniques have similarity in terms of concepts, the basic difference is that the CPM has single time estimate and PERT has three time estimates for activities and uses probability theory to find the chance of reaching the scheduled time.

The PERT/CPM Procedure

There are six stages common to both PERT and CPM:

1. Define the project and specify all activities or tasks.
2. Develop the relationships amongst activities. Decide upon precedences.
3. Draw network to connect all activities.
4. Assign time and/or costs to each activity.
5. Calculate the longest time path through the network: this is the "critical path"
6. Use network to plan, monitor and control the project.

Finding the critical path (step 5) is a major in controlling a project. Activities on the critical path represent tasks which, if performed behind schedule, will delay the whole project. Managers can derive flexibility by identifying the non-critical activities and replanning, rescheduling and reallocating resources such as manpower and finances within identified boundaries.

PERT and CPM differ slightly in their terminology and in network construction. However their objectives are the same and, furthermore, their project analysis techniques are very similar. The major difference is that PERT employs three time estimates for each activity. Probabilities are attached to each of these times which, in turn, is used for computing expected values and potential variations for activity times. CPM, on the other hand, assumes activity times are known and fixed, so only one time estimate is given and used for each activity.

Components of PERT/CPM Network

PERT / CPM networks contain two major components:

- Activities

- Events

Activity: An activity represents an action and consumption of resources (time, money, energy) required to complete a portion of a project. Activity is represented by an arrow.

Event: An event (or node) will always occur at the beginning and end of an activity. The event has no resources and is represented by a circle. The i th event and j th event are the tail event and head event respectively

Merge and Burst Events: One or more activities can start and end simultaneously at an event.

Preceding and Succeeding Activities: Activities performed before given events are known as preceding activities, and activities performed after given events are known as succeeding activities.

Dummy Activity: An imaginary activity which does not consume any resource and time is called a dummy activity. Dummy activities are simply used to represent a connection between events in order to maintain logic in the network. It is represented by a dotted line in a network.

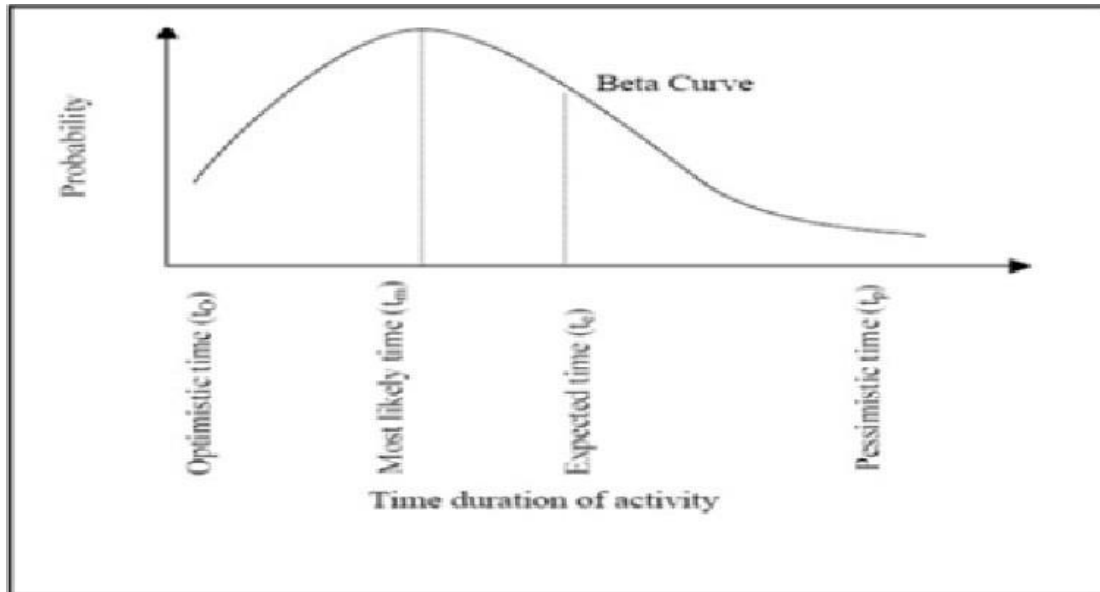
Critical Path Analysis

The critical path for any network is the longest path through the entire network. Since all activities must be completed to complete the entire project, the length of the critical path is also the shortest time allowable for completion of the project. Thus, if the project is to be completed in that shortest time, all activities on the critical path must be started as soon as possible. These activities are called critical activities.

If the project has to be completed ahead of the schedule, then the time required for at least one of the critical activity must be reduced. Further, any delay in completing the critical activities will increase the project duration. The activity, which does not lie on the critical path, is called non-critical activity. These non-critical activities may have some slack time. The slack is the amount of time by which the start of an activity may be delayed without affecting the overall completion time of the project. But a critical activity has no slack. To reduce the overall project time, it would require more resources (at extra cost) to reduce the time taken by the critical activities to complete.

Project Evaluation Review Technique (PERT)

In the critical path method, the time estimates are assumed to be known with certainty. In certain projects like research and development, new product introductions, it is difficult to estimate the time of various activities. Hence, PERT is used in such projects with a probabilistic method using three time estimates for an activity, rather than a single estimate, as shown in the following figure.



Optimistic time (t_o): It is the shortest time taken to complete the activity. It means that if everything goes well then there is more chance of completing the activity within this time. **Most likely time (t_m):** It is the normal time taken to complete an activity, if the activity were frequently repeated under the same conditions.

Pessimistic time (t_p): It is the longest time that an activity would take to complete. It is the worst time estimate that an activity would take if unexpected problems are faced.

Explain different methods used in project Scheduling. Ans.

1 (Gantt Chart:

Basic Gantt chart is an easy way to document schedules. It is a horizontal- bar schedule showing activity start, duration, and completion. It shows the connection between events and the calendar, and provides a graphical analog of the activity duration.

The Gantt schedule can illustrate the relationship between work activities having duration, events without duration that indicate a significant completion, and milestones that represent major achievements or decision points. Various annotations can be used to communicate the progress of the project effort compared to the baseline plan, as well to depict in a graphical way areas where there are modified expectations from the baseline plan.

A Gantt chart is a simple technique that can be used to attach a time scale and sequence to a project. A Gantt Chart is a form of horizontal bar chart and horizontal bars are drawn against a time scale for each project activity, the length of which represents the time taken to complete. To construct a Gantt chart the following steps are necessary

1) Use the horizontal axis to represent time 2) Use the vertical axis to represent activities

3) Represent each activity by a horizontal bar of appropriate length

4(Take activity procedures into account by starting each activity bar to an appropriate point along the time axis after its preceding activities. Normally the start point for an activity is the earliest time that it could start after its preceding activities had finished.

It is possible to enhance the Gantt Chart in several ways. For instance the number of staff required to do a task can be entered into the bar on the diagram.

Gantt charts, also commonly known as milestone plans, are a low cost means of assisting the project manager at the initial stages of scheduling. They ensure that:

1. all activities are planned for,
2. the sequence of activities is accounted for,
3. the activity time estimates are recorded; and
4. the overall project time is recorded.

They are therefore a simple, rough and ready means of planning a project and assessing progress and are sufficient for most simple projects. However, where projects become complex, it becomes difficult to see relationships between activities by using a Gantt Chart. For more complex projects Network Analysis techniques are used.

Gantt charts also provide a summary of the project as a whole and can be used as a rough and ready means of assessing progress at the project control phase. At any date, the project manager can draw a dateline through the Gantt chart and see which activities are on-time, which are behind schedule and generally record project status against plan.

Gantt charts, named after Henry L Gantt, one of the pioneers of scientific management, are a useful means of representing a schedule of activities comprising a project and enable the operations manager to know exactly what activities should be performed at a given time and, more importantly, to monitor daily progress of a project so that corrective action may be taken when necessary.

To construct a Gantt chart, the various activities are listed on a vertical axis and the horizontal axis is used to represent time. Activity dependencies are taken into account by starting a horizontal bar to represent the next activity at an appropriate point after its preceding activities, i.e. those activities which must take place before the next activity can start, have taken place. Normally this would be at the earliest time that it could start after its preceding activities had finished.

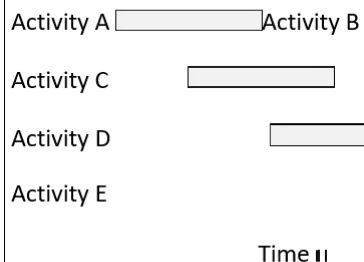
Suppose a project comprises five activities: A, B, C, D, and E. A and B have no preceding activities, but activity C requires that activity B must be completed before it can begin. Activity D cannot start until both activities A and B are complete. Activity E requires activities A and C to be completed before it can start. If the activity times are A: 9 days; B: 3 days; C: 9 days; D: 5 days; and E: 4 days,

determine the shortest time necessary to complete this project.

identify those activities which are critical in terms of completing the project in the shortest possible time.

Solution:

The figure below indicates the form that a Gantt chart would take from the above information.



The above chart shows that activities A and B have no preceding activities and so can start right away. Activity C requires Activity B to have been completed before it can begin. The chart is then completed using such precedence relationships as listed in the question, with each horizontal bar being proportional in length to the activity time that it represents.

Looking at the chart it is apparent that the project ends when activity E has been completed.

Working back in time from activity E the "steps" which are crucial or critical in order to ensure that the project duration does not extend beyond the planned length are: E, C and B. The shortest time in which the project could be completed from the given information is therefore 16 days. The set of activities B, C and E which together determine the project duration are referred to as the critical path through the chart.

MERITS:

1. It is simple to understand
2. It can be used to show progress
3. It can be used for manpower planning

1. It cannot show inter-relationship among activities on large complete projects.
2. There may be physical limit to the size of the bar chart.
3. It cannot easily cope with frequent changes or updating.

2(Resource Leveling: Projects will often be confronted by time and organizational constraints that limit their ability to obtain human resources. Sometimes staff can be supplemented through

temporary help from technical service agencies. When staffing requirements are identified and constraints are understood, work plans can sometimes be adjusted to fit requirements to available resources. Resource scheduling is one of the greatest challenges for projects without access to large organizational or job-market resource pools. Project planning should address such issues as redundancy of critical resources, resource capacity, bench strength in vital areas, and contingency plans to handle departures of key personnel.

3(Crashing: Efforts to accelerate a project schedule are commonly grouped under the term 'crashing' the schedule. Maybe this term was coined to suggest that there is always some price for driving a project to completion sooner than normal. There are a number of ways to improve the schedule when your boss says, I need it sooner!

1. Add people to the schedule. Additional staff must be added early in a project or they will slow it down while learning the ropes. If you add people, you may also need to add staff for supervision and coordination, so staffs are fully applied.

2. Improve productivity and work longer hours. A good team atmosphere with management support can help make this happen. Without positive nourishment of this process, you could lose your team to attrition.

3. Review schedule dependencies and look for opportunities to overlap tasks or make serial tasks concurrent or parallel activities. This requires greater coordination and sometimes involves increased risks which need to be managed carefully.

4. Review the project scope and remove or delay features or functionality from the project critical path.

5. Consider innovative approaches such as a different development methodology, alternative technologies, or out-sourcing options.

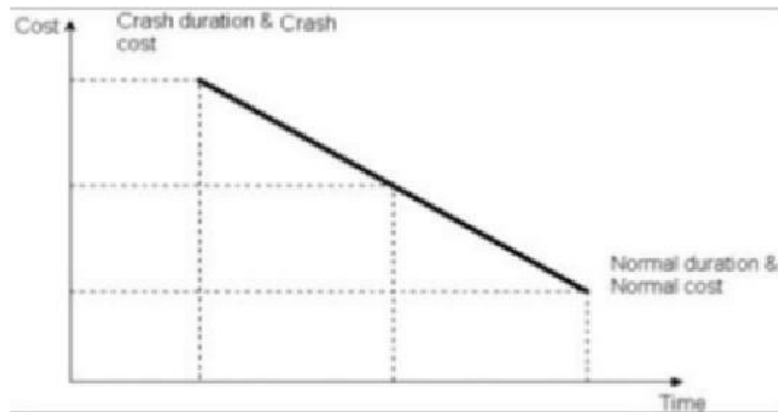
Crashing and Resource Leveling of Projects

Crashing of Project Network

Crashing refers to a particular variety of project schedule compression which is performed for the purposes of decreasing total period of time (also known as the total project schedule duration). The diminishing of the project duration typically take place after a careful and thorough analysis of all possible project duration nummization alternatives in which any and all methods to attain the maximum schedule duration for the least additional cost. The objective of crashing a network is to determine the optimum project schedule. Crashing may also be required to expedite the execution of a project, irrespective of the increase in cost. Each phase of the project consumes some resources and hence has cost associated with it. In most of the cost will vary to some extent with the amount of time consumed by the design of each phase. The total cost of project, which is aggregate of the activities costs will also depends upon the project duration, can be cut down to some extent. The aim is always to strike a balance between the cost and time and to obtain an optimum project schedule. An optimum minimum cost project schedule implies lowest possible cost and the associated time for the project management.

Activity Time-Cost Relationship

A simple representation of the possible relationship between the duration of an activity and its direct costs appears in the following figure. Shortening the duration on an activity will normally increase its direct cost. A duration which implies minimum direct cost is called the normal duration and the minimum possible time to complete an activity is called crash duration, but at a maximum cost. The linear relationship shown above between these two points implies that any intermediate duration could also be chosen.



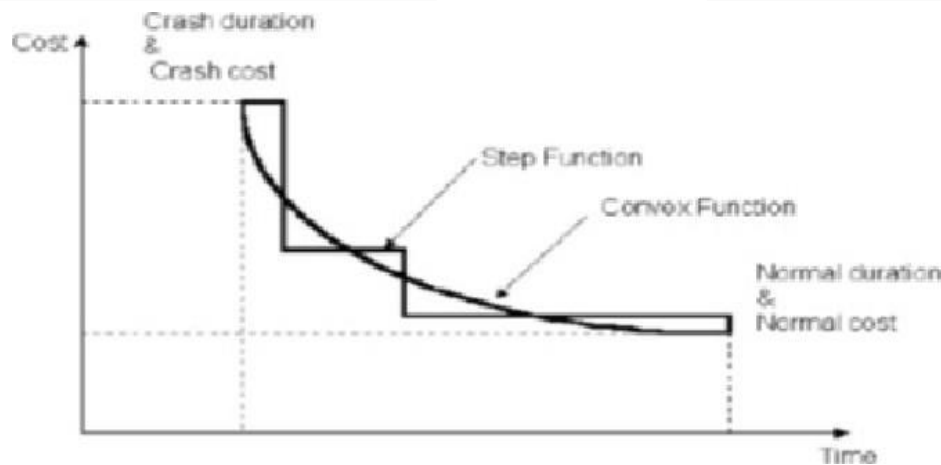
Linear time and cost trade-off for an activity

It is possible that some intermediate point may represent the ideal or optimal trade-off between time and cost for this activity. The slope of the line connecting the normal point (lower point) and the crash point (upper point) is called the cost slope of the activity. The slope of this line can be calculated mathematically by knowing the coordinates of the normal and crash points:

$$\text{Cost slope} = (\text{crash cost} - \text{normal cost}) / (\text{normal duration} - \text{crash duration})$$

As the activity duration is reduced, there is an increase in direct cost. A simple case arises in the use of overtime work and premium wages to be paid for such overtime.

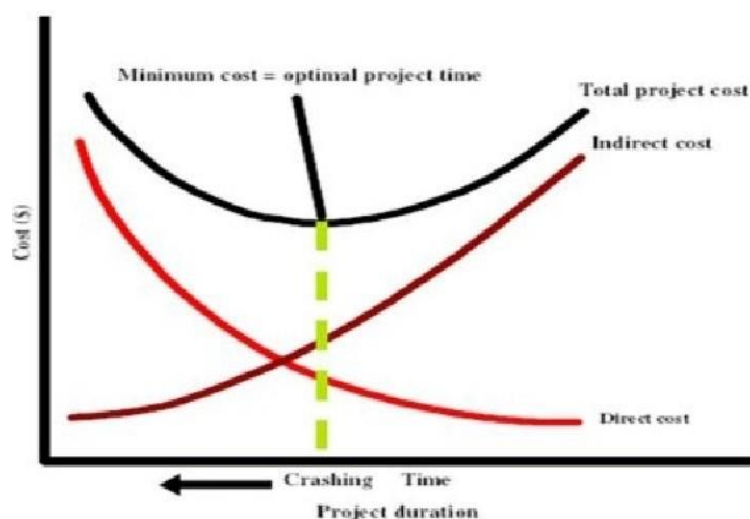
Also overtime work is more prone to accidents and quality problems that must be corrected, so indirect costs may also increase. So, do not expect a linear relationship between duration and direct cost but a convex function as shown in the following figure



Non-linear time and cost trade-off for an activity Project Time-Cost Relationship

Total project costs include both direct costs and indirect costs of performing the activities of the project. If each activity of the project is scheduled for the duration that results in the minimum direct cost (normal duration) then the time to complete the entire project might be too long and substantial penalties associated with the late project completion might be incurred. At the other extreme, a manager might choose to complete the activity in the minimum possible time, called crash duration, but at a maximum cost.

Thus, planners perform what is called time cost trade-off analysis to shorten the project duration. This can be done by selecting some activities on the critical path to shorten their duration. As the direct cost for the project equals the sum of the direct costs of its activities, then the project direct cost will increase by decreasing its duration. On the other hand, the indirect cost will decrease by decreasing the project duration, as the indirect cost are almost a linear function with the project duration. The below figure shows the direct and indirect cost relationships with the project duration. The project total time-cost relationship can be determined by adding up the direct cost and indirect cost values together. The optimum project duration can be determined as the project duration that results in the least project total cost.



Resource Leveling and Resource Allocation

Resource Leveling

Resource Leveling is a project management technique used to examine unbalanced use of resources (usually people or equipment) over time, and for resolving over-allocations or conflicts. When performing project planning activities, the manager will attempt to schedule certain tasks simultaneously. When more resources such as machines or people are needed than are available, or perhaps a specific person is needed in both tasks, the tasks will have to be rescheduled concurrently or even sequentially to manage the constraint. Project planning resource leveling is the process of resolving these conflicts. It can also be used to balance the workload of primary resources over the course of the project, usually at the expense of one of the traditional triple constraints (time, cost, scope). When using specially designed project software, leveling typically means resolving conflicts or over allocations in the project plan by allowing the software to calculate delays and update tasks automatically. Project management software leveling requires delaying tasks until resources are available. In more complex environments, resources could be allocated across multiple, concurrent projects thus requiring the process of resource leveling to be performed at company level. In either definition, leveling could result in a later project finish date if the tasks affected are in the critical path.

Resource Leveling is also useful in the world of maintenance management. Many organizations have maintenance backlogs. These backlogs consist of work orders. In a "planned state" these work orders have estimates such as 2 electricians for 8 hours. These work orders have other attributes such as report date, priority, asset operational requirements, and safety concerns. These same organizations have a need to create weekly schedules. Resource-leveling can take the "work demand" and balance it against the resource pool availability for the given week. The goal is to create this weekly schedule in advance of performing the work. Without resource-leveling the organization (planner, scheduler, supervisor) is most likely performing subjective selection. For the most part, when it comes to maintenance scheduling, there are very few logic ties and therefore no need to calculate critical path and total float.

Resource Allocation

Resource allocation is used to assign the available resources in an economic way. It is part of resource management. In project management, resource allocation is the scheduling of activities and the resources required by those activities while taking into consideration both the resource availability and the project time. In strategic planning, resource allocation is a plan for using available resources, for example human resources, especially in the near term, to achieve goals for the future. It is the process of allocating resources among the various projects or business units. The plan has two parts: Firstly, there is the basic allocation decision and secondly there are contingency mechanisms. The basic allocation decision is the choice of which items to fund in the plan, and what level of funding it should receive, and which to leave unfunded: the resources are allocated to some items, not to others. There are two contingency mechanisms. There is a priority ranking of items excluded from the plan, showing which items to fund if more resources should become available; and there is a priority ranking of some items included in the plan, showing which items should be sacrificed if total funding must be reduced.

Ways to Avoid Time and Cost Overruns

Correct identification of the causes of delays can help the project team to eliminate the same, as per the adage, a problem well formulated is half solved. The most Important reason for delay in cost and time overrun: planning, organization and monitoring; hence, the need to plan the resources adequately and estimate the need scientifically. Right choice of project manager, project oriented organisation, project team and delegation of authority commensurate with responsibility will go a long way to reduce the overruns. Proper project management information system and effective coordination with all concerned will ensure timely project completion. The other reasons that help completing the project without delay are listed hereunder. These are:

- I. Detailed planning and Implementation schedule
2. Sound monitoring
3. Resource planning based on time schedules and anticipated progress
4. Ensuring safety measures while preparing contracts
5. Reward and Incentive schemes for the project staff
6. Selection of appropriate feasible technology
7. Listing engineering parameters and designs
8. Mobilising community participation in planning and Implementation
9. Decentralised decision-making for fast implementation
10. Continuity of the project manager, at least till the start of the plant
- II. Adequate training of the workers, supervisors involved
12. Anticipating omissions, mistakes and preparing the organisation to face crisis
13. Minimising managerial lapses
14. Identifying transport bottlenecks by proper liaison
15. Communication, and following-up with vendors and subcontractors to know the latest status and location of project material
16. Regular follow-up with local, national and international financial agencies
17. Innovative attitude and skills of the project team
18. Adequate project information system
19. Maintaining ecological balance and avoiding environmental pollution
20. Clarity of scope on project objectives
21. Lucid description of team and sub-team tasks
22. Lucid financial cost estimates
23. Milestone charts and project audit reports, and

24. Minutes of the co-ordination committees' meetings with contractors and government agencies