UNIT 6 PLANNING TOOLS

Structure

6.0 OBJECTIVES

After going through this unit, you will be able to:

- explain the importance of Planning and Control;
- describe the importance of planning tools and list the planning tools;
- describe the approach of Bar charts;
- explain the methodology and importance of CPM and PERT Networks;
- describe the precedence network method;

- explain the Time cost-relationship and the concept of Crashing;
- indicate the approaches for Scheduling;
- describe the concept and approach of Line of Balance; and
- explain the role of computers and software in project planning.

6.1 INTRODUCTION

In the previous Unit 5, we examined the importance of planning in the overall perspective of Project Management, from concept to commissioning. Planning provides the road map. It gives direction on how to go ahead and where to go.

Planning does not exist in a vacuum. There are certain tools and techniques to be applied in the planning process. What are they? This section will provide insights into the tools and techniques available to help the planning process.

Projects need to be developed and delivered under certain constraints. Traditionally, these constraints have been listed as "scope," "time," and "cost". These are also referred to as the "Project Management Triangle," where each side represents a constraint. One side of the triangle cannot be changed without affecting the others. A further refinement of the constraints separates product "quality" or "performance" from the scope and turns quality into a fourth constraint.

The project management Triangle is given in Figure 6.1.

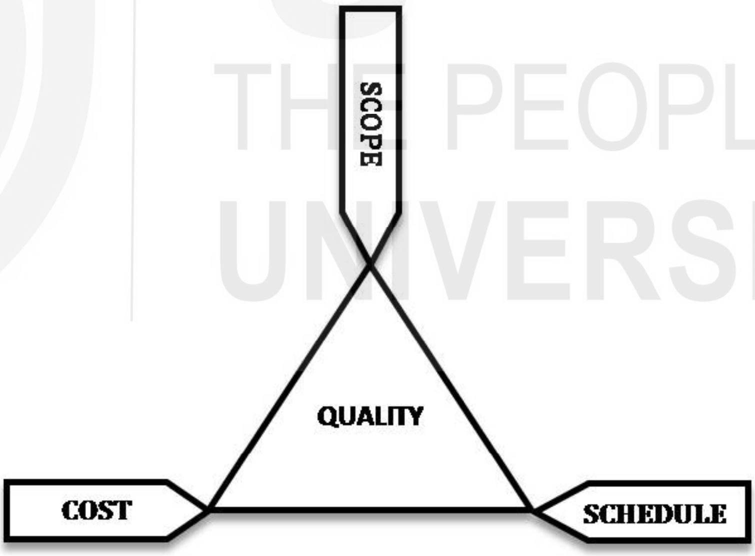

Fig. 6.1: Project Triangle.

Project planning provides the framework for the execution of all the activities of the project keeping in view their relationships and interdependencies.

Planning provides a basis for control. The planning & control of a complex project is one of the major challenges to the managers of industry and business. Based on project objectives, requirements, and scope, implementation plans are developed.

Planning and Control of Projects

In planning and control, managers come across the following questions while dealing with control:

- How long the project is going to take?
- What are all the jobs or activities that are to be carried out in completing the project?
- At what points in time can the project manager expect to start and complete various activities?
- If a project is to be completed on a scheduled date, what are the latest points in time when various jobs can be started and completed?
- How long can any of the jobs be delayed without affecting the scheduled completion date of the project?
- If a job in the project takes more time than originally estimated to take, how will this affect other activities and the project completion date?
- If extra resources become available, on which jobs could these profitably be put?
- How will a change in plan (change of technology, the sequence of jobs, etc) affect the project plan?

Planning Tools like Bar charts, Network techniques like PERT, CPM, Precedence diagrams, and Line of Balance help in planning, scheduling, and control of projects.

6.2 PLANNING TOOLS

Tools: "Something tangible, such as a template or software programme used in performing an activity to produce a product or result."

There are many planning tools available to assist in accomplishing the tasks and executing the responsibilities in projects. Some require a computer with supporting software, while others can be used manually.

Project managers should choose a planning tool that best suits their requirements. Bar charts and networks (CPM, PERT, Precedence Networks) are two of the most commonly used planning tools. Both these project planning tools can be used manually or with readily available project management software.

The Line of Balance (LOB) process is employed when a repetitive process exists within the scope of work of the contract. The manufacturing of parts and the assembly of units in the factory are two candidates for the use of LOB.

6.3 BAR CHARTS

Bar charts are also commonly referred to as Gantt charts. Gantt charts are useful tools for analyzing, planning, and controlling projects. When a complex or multi-task project is underway, Gantt charts assist in monitoring whether the project is on schedule, or not. If not, the Gantt chart allows you to identify easily what actions need to be taken to get the project back on schedule.

A **Gantt chart** is a type of bar chart, developed by Henry Gantt that illustrates a project schedule. Gantt charts illustrate the start and finish dates of the terminal elements and summary elements of a project.

Gantt charts can be used to show the current schedule status using the percentage of completion.

6.3.1 Advantages and Limitations of Bar Charts

Advantages of Bar Charts:

- Gantt charts have become a common technique for representing the phases and activities of a project work breakdown structure (WBS), so they can be understood by all the project participants.
- The WBS should be fully defined to develop the bar charts for the project schedule.
- Bar charts can be developed by using Project Management packages like MS Project.

Limitations of Bar Charts

- Although a Bar chart is useful and valuable for small projects that fit on a single sheet or screen, it can become quite unwieldy for major complex projects.
- Larger bar charts may not be suitable for most computer displays.
- Projects are often more complex and the interdependencies of various activities cannot be clearly indicated in Bar charts.
- Bar charts represent only part of the triple constraints (cost, time, and scope) of projects because they focus primarily on the schedule management.
- Although project management software can show schedule dependencies as lines between activities, displaying a large number of dependencies may result in a cluttered or unreadable chart.

6.3.2 Importance of Gantt Charts

Gantt chart:

- Gives an easy-to-understand visual display of the scheduled time of a task or activity.
- Makes it easy to develop "what if" scenarios.
- Enables better project control by promoting clearer communication.
- Becomes a tool for negotiations.
- Shows the actual progress against the planned schedule.
- Can report results at appropriate levels.
- Allows comparison of multiple projects to determine risk or resource allocation.

Gantt charts are used to show calendar time task assignments in days, weeks, or months. The tool uses graphic representations to show the start, elapsed, and completion times of each task within a project. Gantt charts are ideal for tracking progress. The number of days actually required to complete a task that reaches a milestone can be compared with the planned or estimated number. The actual workdays, from actual start to actual finish, are plotted below the scheduled days. This information helps target potential timeline slippage or failure points. These charts serve as a valuable budgeting tool and can show funds allocated versus funds spent.

Bar chart –Example

Bar Chart example is given in Figure 6.2.

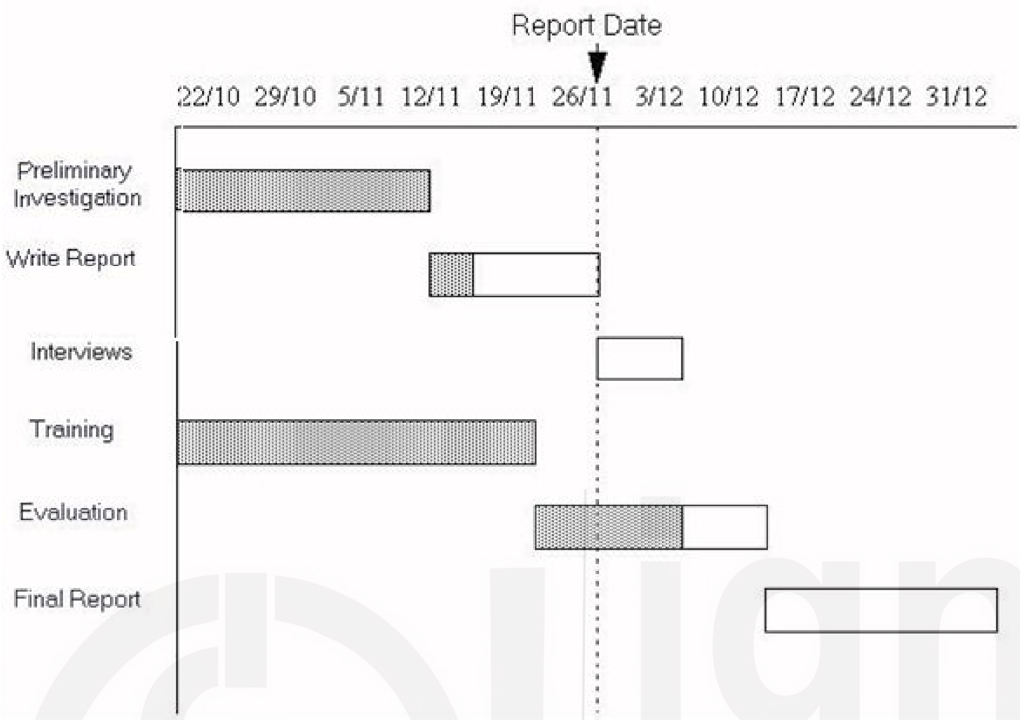

Fig. 6.2: Example-Bar chart.

Check Your Progress 6.1

Note : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

1. List the planning tools.

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2. Explain the Gantt chart.

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3. Indicate the advantages of the Bar chart.

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Activity 6.1:

Identify the activities involved in organizing a marriage function. Assess the time required for each of the activities. Prepare a Bar chart indicating the plan for a marriage function.

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6.4 NETWORK TECHNIQUES

"Network techniques are essentially a group of techniques for project information relating to time and resources to assist managers in planning, scheduling, and control of projects. The information presented by a network includes the activities, the logic (indicating the sequence, interdependencies, and relationships), the time estimates, and the criticality of various activities of the project. Networks present a visual picture of the project to all concerned".

Networks include arrow diagramming methods like CPM, PERT, and also Precedence Diagram Method (PDM).

Although the arrow diagram ("Network Chart") is still used in some places, it has generally been superseded by the precedence diagram, where each activity is shown as a box or node and the arrows represent the logical relationships going from predecessor to successor.

The basic approaches of arrow diagrams and precedence diagrams are common.

Benefits of network techniques in project planning include:

- They force the managers/executives to plan the details.
- The network makes it easier to analyze the effects of alternate decisions.
- Helps in communication and coordination.
- Helps in identifying the delays and bottlenecks to enable the management to take timely corrective action.

Hierarchy of Networks

In project planning, networks are prepared to show different degrees of details to suit different levels of management to facilitate focus.

- Before the project execution work starts in the field, a plan is prepared to specify the project requirements with tasks, responsibilities schedules, and budgets.
- During work execution, the progress of jobs and activities is compared with plans to find out the deviations in terms of time, cost, and project performance.
- Based on the earlier step, corrective actions are taken and plans, schedules, and budgets are updated.

6.5 CRITICAL PATH METHOD (CPM) AND PROGRAMME EVALUATION AND REVIEW TECHNIQUE (PERT)

The key concept used by CPM/PERT is that a small set of activities, which make up the longest path through the activity network, control the entire project. If these "critical" activities could be identified and assigned to responsible persons, management resources could be optimally used by concentrating on the few activities which determine the fate of the entire project.

Non-critical activities can be re-planned, rescheduled and resources for them can be reallocated flexibly, without affecting the whole project.

6.5.1 Steps for Development of Network

Essentially, there are six steps that are common to both techniques. The procedure is listed below:

I. Define the project and all of its significant activities or tasks. The project (made up of several tasks) should have only a single start activity and a single finish activity.

II. Develop the relationships among the activities. Decide which activities must precede and which must follow others.

III. Draw the "Network" connecting all the activities. Each activity should have unique event numbers. Dummy arrows are used where required to avoid giving the same numbering to two activities.

IV. Assign time and/or cost estimates to each activity.

V. Compute the longest time path through the network. This is called the critical path.

VI. Use the Network to help plan, schedule, monitor, and control the project.

Work Breakdown Structure (WBS) provides the basis for CPM and PERT networks.

Five useful questions that need to be asked when preparing an activity network are:

- Is this a Start Activity?
- Is this a Finish Activity?
- What Activity Precedes this?

- What Activity Follows this?
- What Activity is Concurrent with this?

Some activities are serially linked. The second activity can begin only after the first activity is completed. In certain cases, the activities are concurrent, because they are independent of each other and can start simultaneously.

6.5.2 Symbols and Conventions followed in CPM and PERT

- ***Symbols used***

Activity: An activity in the project is one that consumes time and resources. Activity is represented by an arrow. The length of the arrow has no significance. (Fig.6.3.A)

Examples of Activities include Design, Procurement, Construction, Approval, etc.

Event: The start and points of activity are termed Events. Events are represented by Circles. The start point of an activity is referred to as the start or tail end event and the completion point of an activity is referred to as the succeeding event or head end event. An event is an instantaneous occurrence signifying the start or completion of an activity. (Figure 6.4. A)

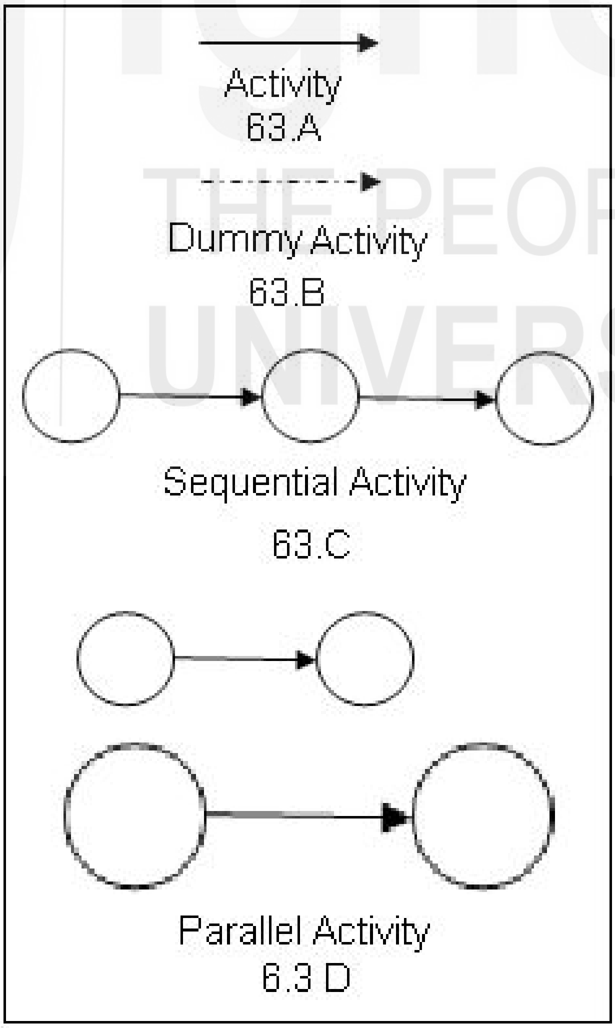

Fig. 6.3(A-D): Activity Symbols.

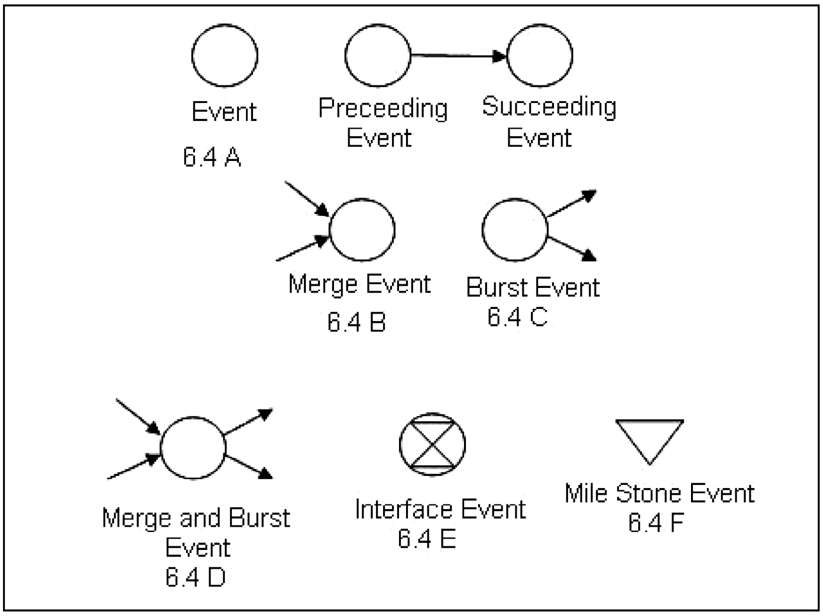

Fig. 6.4(A-F): Event Symbols.

Examples of Events include: starting of design, completion of design, starting of construction, completion of construction, procurement order placed, procurement completed, etc.

Dummy activity: Dummy activities are introduced in project networks mainly to facilitate the logic of the flow of the activities. Dummy activities are represented by broken arrows. Dummy activities consume zero time and zero resources. (6.3.B)

Examples: Suppose two activities "a" and "b" have to start from the same event (node 1) and end at some other but same event (node 2) then both "a" and "b" cannot be given the same number, so one is taken as a dummy activity and is represented by dotted lines.

Sequential activities: This represents a situation where an activity cannot be started unless some other activity is completed. (Fig.6.3.C)

Example: Unless the foundation is ready, the work on the superstructure cannot start. An activity may be preceded or succeeded by more than one activity.

Parallel activities: The activities that can be taken up parallelly or simultaneously. (Fig.6.3.D)

Examples: Equipment procurement and building construction can be parallel activities.

Merge events: The event where more than one activity is converging. (Fig.6.4.B)

Burst event: The event from which more than one activity is emerging. (Fig.6.4.C)

Merge and Burst event: An event may be a merge event with respect to some activities and a burst event with respect to some other activities. (Fig.6.4.D)

Interface events: Represent that the occurrence of the event related to external activities which are not included in the project network. These events also facilitate linking Master control networks with detailed networks. (Fig.6.4.E)

Milestones/Milestone event: Indicate the important goals in the completion of a project. (Fig.6.4.F)

- ***Conventions Followed***

  – Activity arrows are always directed from left to right /right to left.

  – The length of the arrow has no significance (does not represent the time taken).

  – All activities are coded in the sense that abbreviations are used instead of mentioning the full description of the activity.

  – Activity codes are normally given on the top of the arrow (activity).

  – Activity times are indicated below the arrow (activity).

  – In developing the logic for the network, loop formation is always to be avoided.

  – For example, if we consider that activity B depends on activity A, and activity C depends on activity B we cannot have a situation where activity A depends on activity C.

  If we say activity B depends on activity A, activity C depends on activity AB it is implied that activity C depends on activity A and we need not show the superfluous relationship.

  – In estimating the time required for activities, an assumption is made that the resources required are available in the required quantities at the required time. This assumption is required for the development of the network for project planning.

- ***CPM/PERT Network Analysis:***

The focus of analysis in CPM networks will be on:

Let i-j be an activity as given below in Figure.6.5 and let t_{ij} be the time required for the activity.

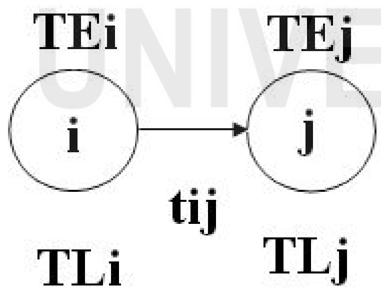

Fig. 6.5: Activity-i-j.

For each activity in the network, the following are to be calculated to provide the analysis for project executives.

- Forward pass analysis: In the Forward pass analysis, we start with the start event occurring at zero time. We add the intervening activity duration to arrive at the earliest time of occurrence of the succeeding event. In the case of merge events where more than one activity converges we calculate the value by all the possible paths and choose whichever is maximum. We do this exercise for all events from start to finish. The earliest occurrence time of the last event indicates the project duration.

- Forward pass analysis help in finding the earliest event occurrence time TE for all events in the network and in calculating early start time ES for all activities of the network.

- Backward pass analysis: In the backward pass, we start from the last event where we consider the earliest occurrence time TE and the latest occurrence time is TL as equal. We subtract the intervening activity duration to arrive at the latest occurrence time for the preceding event. In the case of Burst events, we consider the value by all the possible paths and take whichever value is minimum. We continue this exercise for all events in the network till we reach the start event.
- Through backward pass analysis, we can calculate the latest allowable occurrence time TL for all events and the latest finish time for all activities in the network LF.

Earliest Event Occurrence Time (TE): Indicates when the event is calculated.

Latest Time of Event (TL): Indicate the latest allowable occurrence time for the event.

Earliest Start (ES): The earliest time at which the activity can start given that its precedent activities must be completed first. It is also the earliest occurrence time of the tail end event TE_i

where TE represents the earliest occurrence time for the event i

Earliest Finish (EF): This is equal to the earliest start time for the activity plus the time required to complete the activity i.e. Earliest Start + Duration. This can also be taken as $TE_i + t_{ij}$

Latest Finish (LF): The latest time at which the activity can be completed without delaying the project. This can also be taken as TL_j

Latest Start (LS): It is equal to the latest finish time minus the time required to complete the activity i.e. Latest Finish - Duration. This can also be taken as $TL_j - t_{ij}$

There are two important types of Float for activities. These are Total Float and Free Float.

<u>Total Float</u> is the spare time available when all preceding activities occur at the **earliest** possible times and all succeeding activities occur at the **latest** possible times.

Total Float (TF) = Latest Start of (i-j) - Earliest Start (i-j)

or

Total float (TF)= $TE_j - TE_i - t_{ij}$

Activities with zero Total Float are on the Critical Path

<u>Free Float</u> is the spare time available when all preceding activities occur at the **earliest.**

Free Float(FF)= Earliest start time of succeeding activity (j-k)- Earliest finish time of preceding activity (i-j)

or

Free Float (FF) = $TE_j - (TE_i + t_{ij})$

Slack (S): Latest occurrence Time of an event(TL)-Earliest Occurrence time of the event(TE).

Slack indicates the spare time or cushion available in planning.

- ***Critical path and its importance:***

Critical Path: "Critical Path is the longest path in the network which decides the duration of the project and the activities on the critical path have zero or minimum float".

The critical path is the path through the project network in which none of the activities have float or slack, that is, the path for which ES=LS and EF=LF for all activities in the path.

Identification of critical path & critical activities help managers

- to find out where they have to keep close control
- to decide the delegation of work and authority
- in crashing the project duration
- in project scheduling for resource optimization.

Check Your Progress 6.2

Note : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

1. What is the importance of networks?

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2. Explain the concept of Forward pass and backward pass in network analysis.

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3. Define the critical path.

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6.5.3 Critical Path Method (CPM)

Critical Path Method (CPM) essentially lays stress on activity time. Here, for the activities, the single time estimate is followed (also called the deterministic approach). Here, the time estimates are based on the knowledge and the experience of the estimator and normally he is confident that the time estimates are realistic. Other purposes served by CPM are:

- The critical path method facilitates monitoring of project progress by considering the partial completion of activities.
- Planning and control in CPM networks, in terms of the analysis, monitoring and reporting is activity-oriented.
- CPM networks are commonly used for most construction and production projects.
- Critical Path Method of planning and control will be helpful for all levels of managers/ executives in a project.

Critical Path Method (CPM) example:

An example given below will help in getting an understanding of the development and use of the CPM method.

The following are the activities indicating their dependencies and the time estimates for the activities. (Table.6.1)

Table 6.1

Activity	Preceding Activity	Time (Weeks
A	-	3
B	-	6
C	-	5
D	A	5
E	B	4
F	B	6
G	B	3
H	C,G	Dummy Activity (0)
I	C,G	4
J	D,E	8
K	D,E	4
L	F,H,K	6
M	F,H,K	5
N	J,L	3
P	I,M	7

When activities N and P are completed the project is completed.

The CPM network for the above project is shown in Figure 6.6.

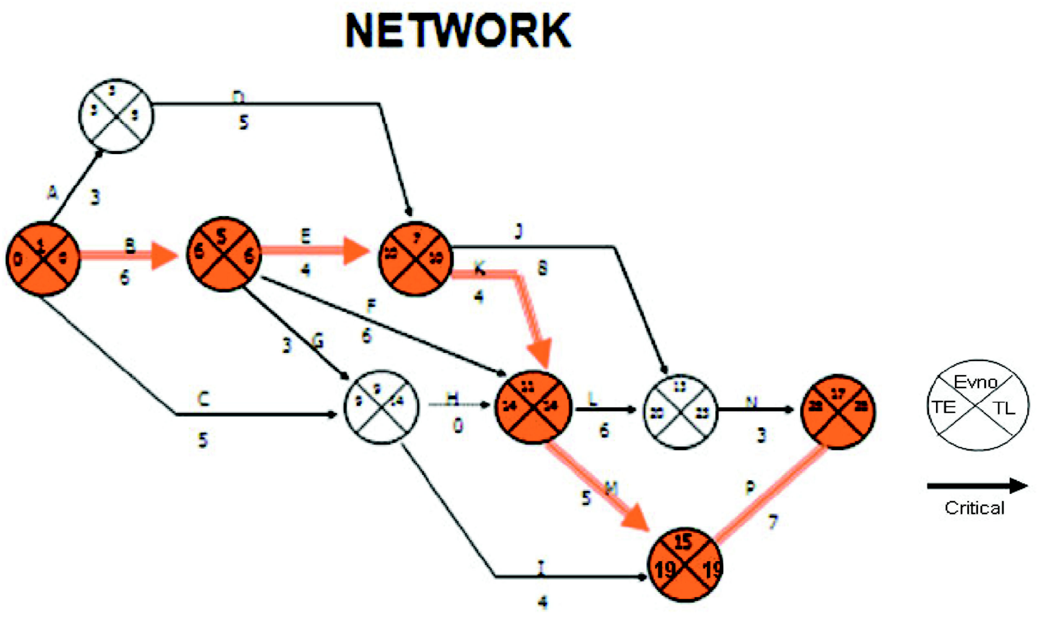

Fig. 6.6: CPM Network

The analysis for the project network of the example is given in Table 6.2.

Table 6.2: Analysis of the CPM Network.

Activity	Early Start(ES)	Late Start(LS)	Early Finish(EF)	Late Finish(LF)	Total Float (TF)	Free Float (FF)
A	0	2	3	5	2	0
B	0	0	6	6	0	0
C	0	4	5	9	4	4
D	3	5	8	10	2	2
E	6	6	10	10	0	0
F	6	8	12	14	2	2
G	6	11	9	14	3	3
H	DUMMY	ACTIVITY				
I	9	15	13	19	4	4
J	10	15	18	23	5	5
K	10	10	14	14	0	0
L	14	17	20	23	3	3
M	14	14	19	19	0	0
N	20	23	23	26	3	3
P	19	19	26	26	0	0

The project duration is: 26 Weeks

The critical path for the project network is: B-E-K-M-P

6.5.4 Programme Evaluation and Review Technique (PERT)

PERT is based on statistical methods and uses a probabilistic approach. In Research & Development projects, or in Social Projects which are defined as "Process Projects", where learning is an important outcome, the cause-effect relationship is not so well established.

In projects which are developmental in nature, it may not be possible to specify a single time estimate. Here, the PERT approach is useful, as it can accommodate the variation in event completion times.

PERT Networks –Key Principles and Applications:

- PERT Networks are based on three-time estimates—optimistic time, pessimistic time, and most likely time.
- PERT networks are event-oriented in terms of event occurrence.
- PERT networks stress the starting or completion of an activity.
- Partially completed activities are not much relevant in PERT networks.
- PERT networks also involve a critical path. But here the underlying assumption is that there is a 50% probability of completion of the project based on the critical path.
- Further one can also analyze the probability of completion in a duration of less time or more time than the time originally indicated by the critical path.
- Depending upon the probability of completion of the project, the managers can decide the attention required for project completion.
- PERT Networks are more useful for top and senior-level managers in planning and control.

PERT Network applications:

PERT Networks are normally used in:

- Research & Development projects
- Social development projects
- Other complex projects where the knowledge and experience of the people is limited

PERT Calculations

For each activity, three-time estimates are taken:

- **Optimistic Time:** When everything goes as planned.
- **Most Likely Time:** When something goes as planned as some not as much according to plan i.e. some gap in actual versus planned.
- **Pessimistic Time:** When nothing goes as planned.

The duration of an activity is calculated using the following formula:

$$t_e = (t_0 + 4t_m + t_p) / 6$$

- Where, t_e = Expected time, t_0 = Optimistic time, t_m = Most probable time, t_p = Pessimistic time.
- The weights are based on an approximation of the Beta distribution.
- The Standard Deviation, which is a good measure of the variability of each activity is calculated by the rather simplified formula:

$$SD = (t_p - t_0) / 6$$

- The expected length of a project = Sum of their separate expected lengths (Σte along the critical path).
- Similarly the variance of a sum of independent activity times = Sum of their individual variances. (Σ Variances along the critical path)
- The higher the standard deviation, the greater the uncertainty that the project will be completed on the due date.
- Although the t_e's are randomly distributed, the average or expected project length t_e approximately follows a Normal Distribution.

Since we have a lot of information about a Normal Distribution, we can make several statistically significant conclusions from these calculations.

PERT Network Example

An example will help us in understanding the concept and analysis of the network.

The list of jobs and the three time estimates for the jobs of a project are given in Table 6.3.

Table 6.3

Job I -j	Optimistic Time Weeks o	Most likely time Weeks m	Pessimistic Time Weeks p
1-2	3	6	15
1-6	2	5	14
2-3	6	12	30
2-4	2	5	8
3-5	5	11	17
4-5	3	6	15
6-7	3	9	27
5-8	1	4	7
7-8	4	19	28

Draw the network, find the critical path and project duration and find the probability of completing the project in 30 Weeks.

The network for the project is given in Figure 6.7. The earliest occurrence times (TE) of the events are given on the top of the event. The latest allowable occurrence time

(TL) of events is given below the event. The mean activity time of activity t_e is given below the activities.

Calculation of $t_e = \frac{O+4m+p}{6}$

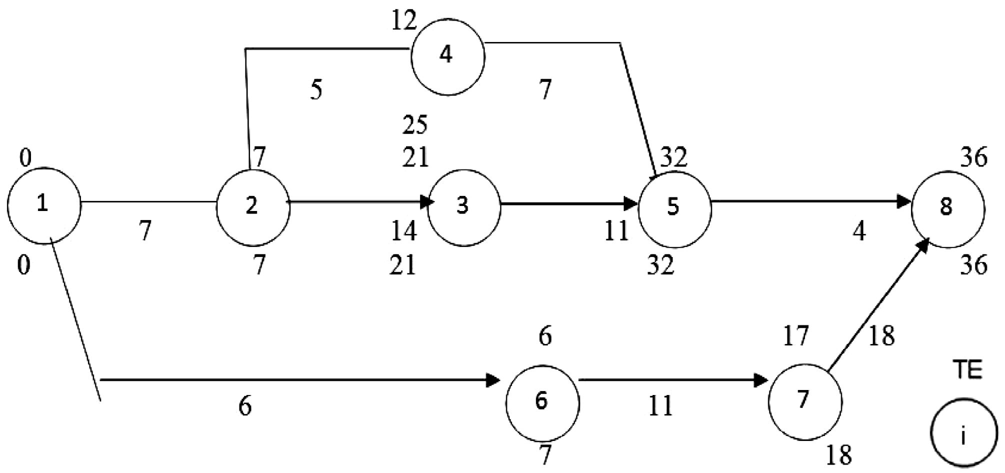

Fig. 6.7 : PERT Net Work

The Total float (TF) and Free Float (FF) for the activities are calculated from the formulas:

Total Float (TF) = TL_j - TE_i - t_{ij}

Free float (FF) = $TL_j - (TE_i + t_{ij})$

The analysis for the network given in Table.6.4

Table.6.4: PERT Network analysis

Activity	Total Float (TF)	Free Float (FF)
1-2	0	0
2-3	0	0
2-4	13	0
3-5	0	0
4-5	13	13
1-6	1	0
6-7	1	0
5-8	0	0
7-8	1	1

The project duration is 36 Weeks.

Critical path: 1-2, 2-3, 3-5, 5-8.

Standard Deviation of Critical Activities		
Activity	Standard Deviation σ	Variance σ^2
1	$\frac{15 - 3}{6} = 2$	4
2-3	$\frac{30 - 6}{6} = 4$	16
3-5	$\frac{17 - 5}{6} = 2$	4
5-8	$\frac{7 - 1}{6} = 1$	1

Sum of Variance of critical project activities

Standard deviation of critical project duration $= \frac{19}{\sqrt{19}}$

$= 4.36$

Probability of completion of the project when 30 weeks

$$Z = \frac{D-T}{\sigma}$$

$$= \frac{30-36}{\sqrt{19}}$$

$$= \frac{-6}{4.36} \quad = \; - 1.376$$

From the normal distribution tables, it can be noted that the probability of completion of the project in 30 weeks is 8.4%

When the probability of completion of the project is low, the project manager must pay greater attention.

Check Your Progress 6.3

Note : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

1. Explain the approach of CPM.

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2. What is the PERT approach?

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3. Differentiate CPM and PERT.

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Activity 6.2:

Consult your colleagues and list the activities involved in the construction of a house. Make appropriate assumptions and decide the interdependencies of the activities. Also estimate the time required for the activities identified. Prepare a CPM Network, analyze and find the critical path.

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Activity 6.3:

Consult your colleagues and identify the activities involved in the development of a new product. Make suitable assumptions and decide the activity inter dependencies. Estimate the times for the activities (three time estimates for each activity-signifying-optimistic, pessimistic and most likely times).Develop a PERT Network, analyze and identify the critical path.

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6.6 PRECEDENCE DIAGRAM METHOD (PDM)

The **precedence diagram method** is a tool for planning the activities of a project. It is a method of constructing a project network diagram that uses boxes, referred to as nodes, to represent activities and connect them with arrows that show the dependencies.

The arrow diagrams CPM/PERT normally indicate that in sequential activities, unless the preceding activity is completed the succeeding activity cannot start. In real-life projects, the interdependencies of activities are many.PDM Networks facilitate the consideration of various types of dependencies and overlaps which makes network planning more useful.

PDM Networks cover different types of relationships for project activities as shown in figure 6.8.

Further if required we can also indicate the time gap to be maintained between the two activities.

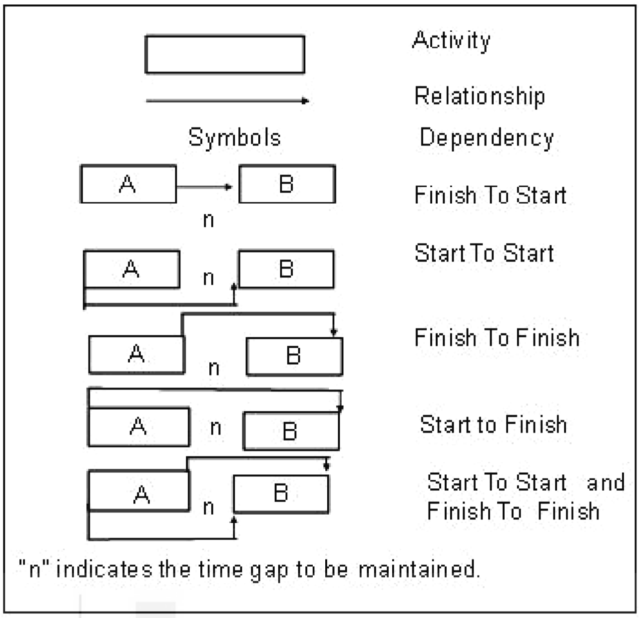

Fig. 6.8: Project activity relationships in PDM networks.

The symbols and notation used in PDM networks are also given in Figure.6.9

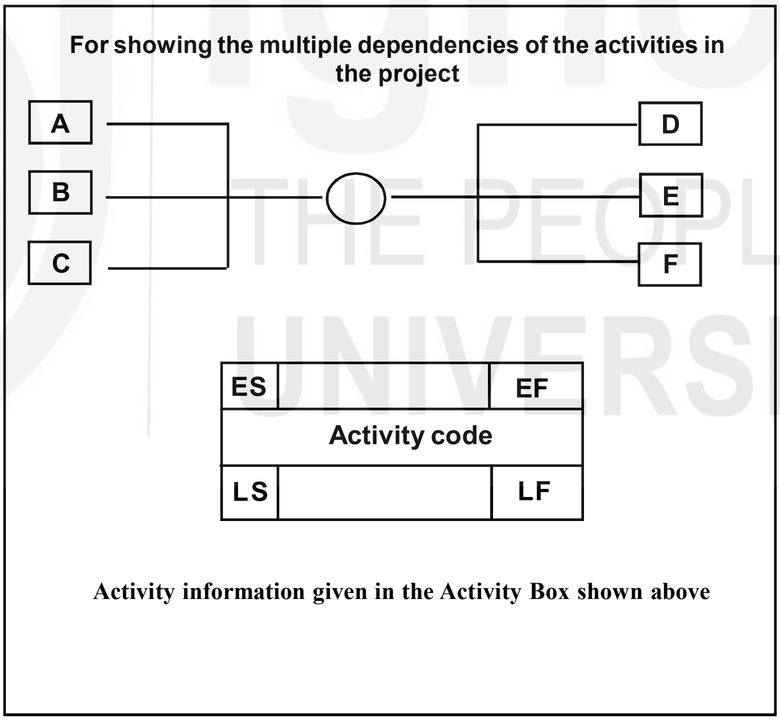

Fig. 6.9: Precedence network symbols notation.

For PDM networks also the basis is Work Breakdown Structure. These networks show critical tasks, non-critical tasks, and slack time.

In PDM Networks, the key elements include determining predecessors and defining attributes such as.

- early start date
- late start date
- early finish date

- late finish date
- duration

The forward pass and backward pass analyses are similar to the approach followed in CPM/PER networks.

The analysis provides Early start(ES), Late Start(LS), Early Finish (EF), Late Finish (LF), Total Float(TF), and Free Float (FF) for all activities of the project. The analysis identifies the critical activities and the critical path.

Precedence Diagram Method (PDM) Example

An example will help in understanding the development and analysis of PDM networks.

A small maintenance project consists of the following activities (Table 6.5):

Table.6.5

Activity	Preceding Activity	Duration (Days)
A	-	2
B	A	3
C	A	5
D	B	4
E	B	1
F	C	6
G	C	2
H	D	8
I	F	7
J	G	4
K	E, H, I, J	3

Draw the Precedence Diagram. Find out the Early Start (ES), Late Start (LS), Early Finish (EF), Late Finish (LF), Total float (TF), and Free Float (FF) for the activities of the project. Find the critical path and the project duration.

The PDM Network for the above problem is given in Figure 6.10.

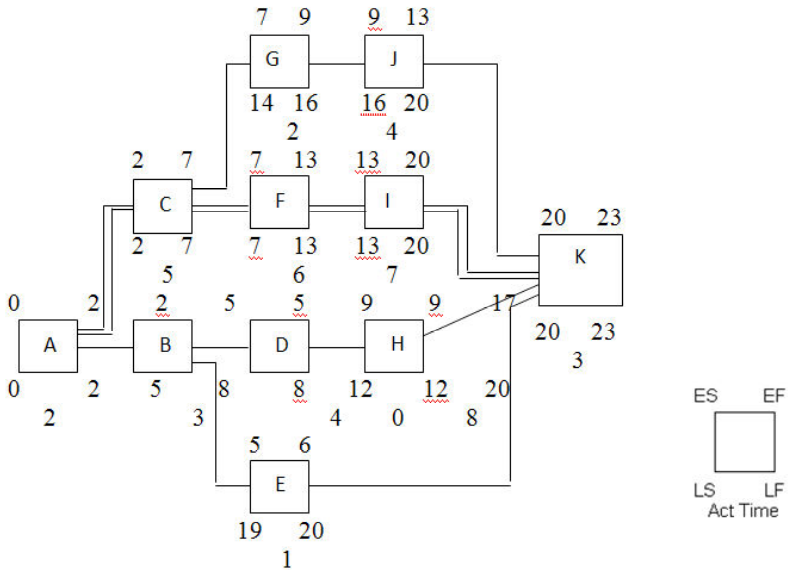

Fig. 6.10: Precedence Diagram

The analysis for the network is given in Table 6.6.

Table 6.6: Analysis of Precedence Network.

Activity	Duration	Early Start (ES)	Late Start (LS)	Early Finish (EF) (Col2+Col3)	Late Finish (LF) (Col2+Col4)	Total Float (TF) (Col6-Col 5)	Free Float (FF) (Col6-Col 3-Col 2)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A	2	0	0	2	2	0	0
B	3	2	5	5	8	3	0
C	5	2	2	7	7	0	0
D	4	5	8	9	12	3	0
E	1	5	19	6	20	14	14
F	6	7	7	13	13	0	0
G	2	7	14	9	16	2	0
H	8	9	12	17	20	3	3
I	7	13	13	20	20	0	0
J	4	9	16	13	20	7	7
K	3	20	20	23	23	0	0

Project Duration: 23 Days

Critical Path is: A-C-F-I-K

Check Your Progress 6.4

Note : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

1. Indicate the advantages of PDM networks.

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2. Identify the types of relations that can be represented in PDM networks.

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Activity 6.4:

Identify the activities involved in organizing a picnic. Find their interdependencies, Estimate the time for each activity (single time estimate). Prepare a Precedence Diagram Network, analyze and find the critical path.

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6.7 NETWORK TECHNIQUES FOR PROJECT COST CONTROL

Network techniques are effective in controlling the project with respect to cost. In this context, the time-cost relationship is very important.

6.7.1 Time-Cost Relationship

Project costs are categorized as direct costs which can be directly attributed to individual activities or work packages and indirect costs which are not directly attributable to the project activities.

The behavior of direct and indirect costs with respect to time is shown in Figure 6.11.

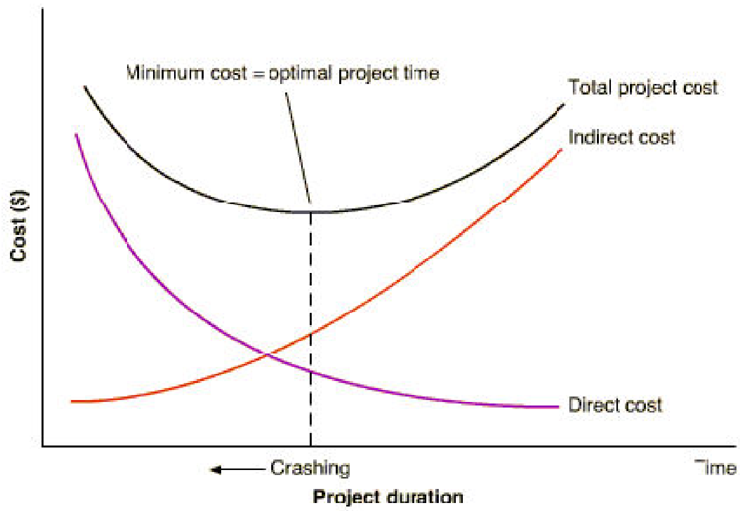


Fig. 6.11: Projects-Time-cost relationship.

6.7.2 Project Crashing

The project manager is to face a number of issues related to labour activities, in the form of overtime, assigning more resources, such as material and equipment and may have to reduce the scheduled completion time of a project to meet a deadline. Project duration can often be reduced by assigning extra resources like men, materials, equipment, etc. However, the additional resources increase the project cost. So, the decision to reduce the project duration must be based on an analysis of the trade-off between time and cost.

"Project crashing is a method for shortening the project duration by reducing the time of one or more of the critical project activities to less than its normal activity time. The object of crashing is to reduce project duration while minimizing the cost of crashing".

Objective of Crashing

To reduce the scheduled completion time to reap the results of the project sooner.

- As the project continues over time, the team consumes indirect costs.
- There may be direct financial penalties for not completing a project on time.

Project Crashing Goal:

The goal of crashing is to reduce project duration at the minimum cost.

To reduce project duration while minimizing the cost of crashing, the project team should estimate normal time, normal cost, crash time, and crash cost for each activity. The team then can estimate the total crash time, total crash cost, and crash cost per week to reduce project duration at the minimum cost.

- The project crashing may be taken up for reducing the project duration to a specific limit.
- Alternatively, the project may be crashed to find out the optimal project time and the optimal cost.

Key Terms and Approach

CRASHING: Reducing project time by expending additional resources.

CRASH TIME: An amount of time an activity is reduced.

CRASH COST: The cost of reducing activity.

For the purpose of crashing, consider the critical activities which decide the duration of the project.

In deciding which activity is economical to crash the concept of cost slope will be useful.

Cost slope indicates extra money required for unit reduction of time for an activity.

$$\text{Cost slope for an activity} = \frac{\textit{Crash Cost (CC)} - \textit{Normal Cost (NC)}}{\textit{Normal time (NT)} - \textit{Crash Time (CT)}}$$

In following the project crashing method, critical points mentioned below need to be taken into account:

- The cost slope for all project activities needs to be calculated. This will help in deciding the crashing of activities that are economic.
- Crashing should be step by step approach. At a time only one activity on the critical path is to be crashed.
- Normally the activity time should be reduced by one unit in each step. This will help in ensuring that some other activities and paths have become critical.
- Sometimes, it may become necessary to reduce the project duration. It may become necessary to reduce simultaneously the activity duration for more than one activity on different paths of the network.
- The objective of crashing may be to find the optimal time and cost for the project or to reduce the project duration to a specified limit.

Project Crashing Example

An illustration will help in understanding the concept and the method of project crashing:

The network of a project is given in Figure 6.12.

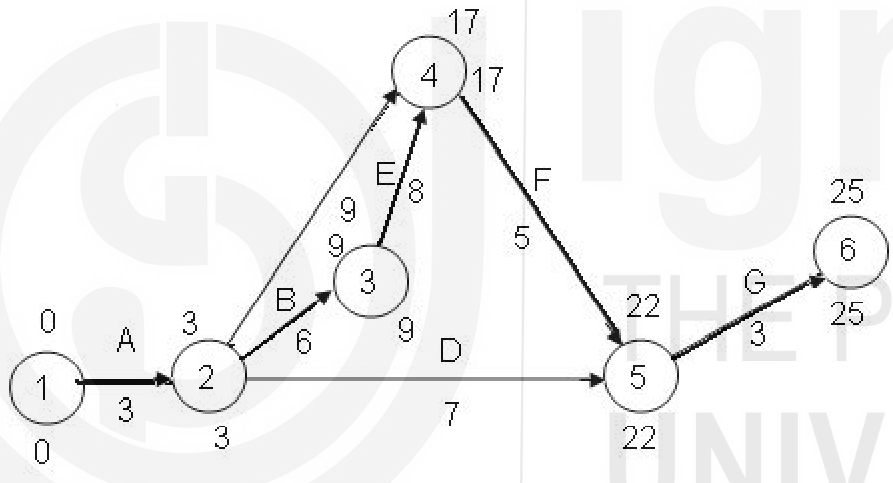


Fig. 6.12: Project Network for Crashing.

The normal duration, the crash duration, the normal cost, and the crash cost for each the activity are given in Table.6.7

Table 6.7

Activity	Normal		Crash	
	Time (days)	Cost Rs.	Time (days)	Cost Rs.
A	3	360	2	40
B	6	1440	4	1620
C	9	2160	4	2380
D	7	1120	5	1600
E	8	400	4	800
F	5	1600	2	1770
G	3	480	3	760

The indirect cost of the project is Rs160 per day.

Find the following:

- Cost slope for the activities
- The optimal time and cost for the project execution
- The minimum time required for the project and the corresponding cost

The cost slope for the project activities and the number of days reduced with direct cost implications are given in Table 6.8

Table: 6.9 gives the implications of direct and indirect costs indicating the total project.

Table 6.8

Activity	Cost Slope Rs/day	Duration Reduced by (days)	Cost of Contraction Rs.
A	40	1	40
F	85	2	170
B	90	2	180
E	100	3	300
C,E	155	1	155
G	280	1	280
		10	1125

Table 6.9

Job Crashed	Days Saved	Project duration (days)	Direct Project cost Rs	Over-head (Rs 160/day)	Total Project cost Rs
None	0	25	7560	4000	11,650
A	1	24	7600	3840	11,440
F	2	22	7770	3520	11,290
B	2	20	7950	3200	11,150
E	3	17	8250	2720	10,970
C,E	1	16	5405	2560	10,965
G	1	15	5685	2400	11,085

From the above table it can be noted:

- Project Optimum time is 16 days where the total cost is Rs.10,965/ which is the minimum.
- The minimum possible duration for the project is 15 days and the total cost of the project is Rs.11,085/-.

6.8 PROJECT SCHEDULING

Project planning networks provide the overall time frame for project activities. From the networks, the project schedules are prepared. Project scheduling and resource allocation are interlinked.

Everyone involved in a project is affected by the schedule, and it is critical for the successful completion of the project. The project manager uses the schedule to assign tasks, set deadlines, and determine what resources are needed. The schedule is used for tracking the progress of your team and provides you the guidance for changes.

A project schedule is a useful planning and communication tool for monitoring and reporting the progress of a project. During the project life, different schedules may be needed for different purposes and stakeholders.

6.8.1 Types of Project Schedules

Project schedules are categorized as time-constrained and resource-constrained schedules.

In time-constrained schedules, time is critical and resource utilization needs to be optimized with this constraint. Here, the non-critical activities only can be postponed for effective resource utilization and critical activities should not be disturbed.

In resource-constrained scheduling, resource availability is crucial and, if needed, the project duration can be extended by postponing the schedule for even critical activities.

Project schedules normally used cover:

- **Master Project Schedule**

Developed in the initial phase of project planning, the master project schedule is a summary level schedule that highlights the principal activities and tasks and their estimated duration.

- **Milestone Schedule**

As an advanced schedule, a milestone schedule is often referred to throughout the project life cycle. The milestone schedule is a summary level schedule that allows the project team leader to review and identify all of the significant and major project-related milestones during the course of a project.

- **Detailed Project Schedule**

Detailed schedules are operational schedules intended to help front-line managers in directing hourly, daily, or weekly project work.

The most common display options for presenting a project schedule are the milestone charts, Gantt charts, and network diagrams.

6.8.2 Resource Analysis and Scheduling

Approaches

- Analytical Approach
- Heuristic Approach
- Computers

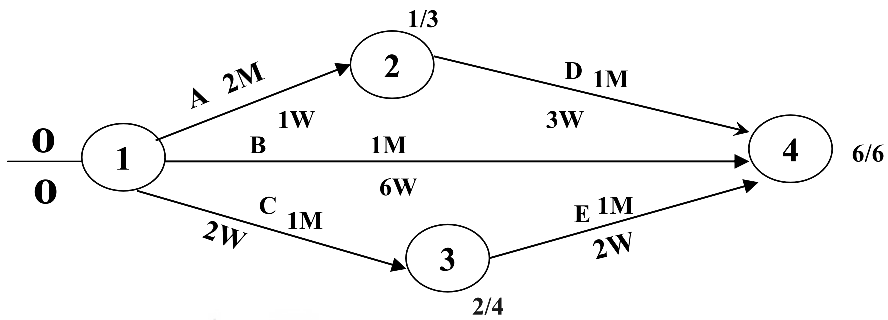
Where resource analysis is involved, the use of computers becomes almost inevitable in project scheduling because of the complexity and the costs involved in resource assessment, resource analysis is always restricted to a few critical resources.

Scheduling Example

An example will be helpful in understanding the concepts and methodology of scheduling.

Consider the simple project network given in figure 6.13 with the necessary analysis.

PROJECT SCHEDULE



ACT	ES	LS	EF	LF	TF	FF
A	0	2	1	3	2	0
B	0	0	6	6	0	0
C	0	2	2	4	2	0
D	1	3	4	6	2	2
E	2	4	4	6	2	2

Fig. 6.13: Project network with relevant details

The project duration is 6 weeks. The activity times are indicated for various activities in the network.

Let us consider that the project activities require a particular type of machine and the machines required for each activity are marked as M in the network.

Activities involved in the network are A,B,C,D,E.

Let us schedule all the activities of the network at the earliest. The schedule and the resource histogram will be as given in Figure 6.14.

EARLY SCHEDULE BAR CHART

SCHEDULE WEEKS

ACT	1	2	3	4	5	6	
A	2M						
B	1M						
C	1M						
D		1M					
E			1M				
	4	3	3	2	1	1	

HISTOGRAM

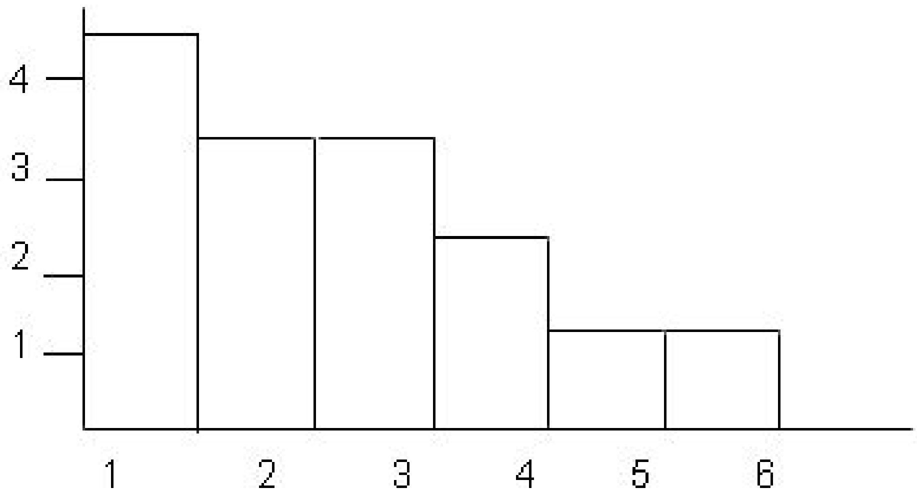


Fig. 6.14: Project Early Schedule of Activities.

From the given figure 6.14 we note that the resource requirement is varying from 4 in the first week to 1 in weeks 5 and 6.

Evidently, the resource utilization is haphazard and is not acceptable.

Suppose we schedule all the project activities at the latest allowable times, the project schedule and the Resource histograms are as shown in Figure 6.15.

SCHEDULE – LATEST START BAR CHART

ACT	1	2	3	4	5	6	
A				2M			
B			1M				
C			1M				
D					1M		
E						1M	
	1	1	2	4	3	4	

HISTOGRAM

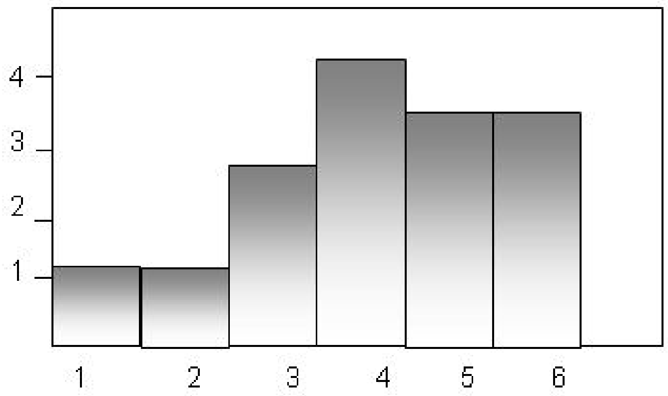


Fig. 6.15: Late Schedule of Activities

Here also, we may note that the resource requirement is varying from 4 to 1. The only difference is that the peaks and valleys of resource requirements are shifted to the latter part of the schedule.

In smaller projects, we can work out the optimal schedule, where the resource fluctuations are not much (called resource smoothing) through an analytical approach (trial and error method).

The analytical approach essentially considers the Free Float and Total Float available for the activities and shift the start dates through a trial and error approach.

The optimal schedule for this project with the associated Resource Histogram is given in Figure 6.16.

SCHEDULE – LATEST START

ACT	1	2	3	4	5	6	
A			2M				
B			1M				
C		1M					
D					1M		
E					1M		
	2	2	3	2	3	2	

BAR CHART

HISTOGRAM

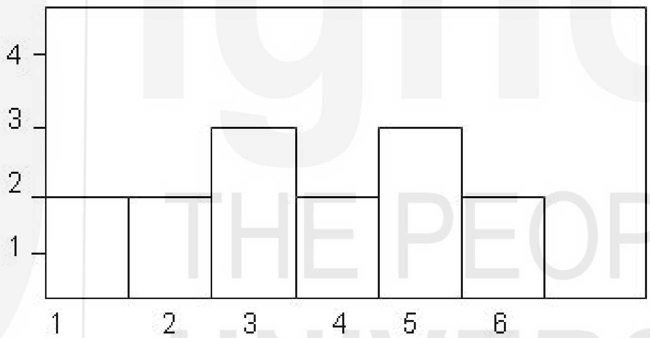


Fig. 6.16: Optimal schedule

In the case of large projects with more resources involved the use of computers will be helpful in scheduling.

Check Your Progress 6.5

Note : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

1. Explain project crashing.

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2. Indicate types of project schedules.

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3. What are the key principles in scheduling?

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Activity 6.4:

Visit an auto garage. Discuss with the managers/supervisors their approach for scheduling of jobs to meet the customer expectations. Assess whether you can suggest any improvements.

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6.9 LINE OF BALANCE (LOB)

Line of Balance (LOB) is a management control process for collecting, measuring, and presenting facts relating to time, cost, and accomplishment - all measured against a specific plan. It shows the process, status, background, timing, and phasing of the project activities, thus providing management with measuring tools that help:

1. Comparing actual progress with a formal objective plan.
2. Examining only the deviations from established plans, and gauging their degree of severity with respect to the remainder of the project.
3. Receiving timely information concerning troublesome areas and indicating areas where appropriate corrective action is required.
4. Forecasting future performance.

The "Line of Balance" itself is a graphic device that enables a manager to see at a single glance which activities of an operation are "in balance" - i.e., whether those which should have been completed at the time of the review actually are completed and whether any activities scheduled for future completion are lagging behind schedule. The LOB chart comprises only one feature of the whole philosophy which includes numerous danger signal controls for all the levels of management.

6.9.1 Steps in LOB

To do LOB, the following are needed:

1. A contract schedule, or objective chart;
2. A production plan or lead-time chart for the production process itself;
3. Control points cumulative inventories; and
4. A program status chart on which to plot LOB and the cumulative quantities of units that have passed through the control points of the assembly/production process.

LOB Charts Example

An example of an LOB Chart is given in Figure 6.17.

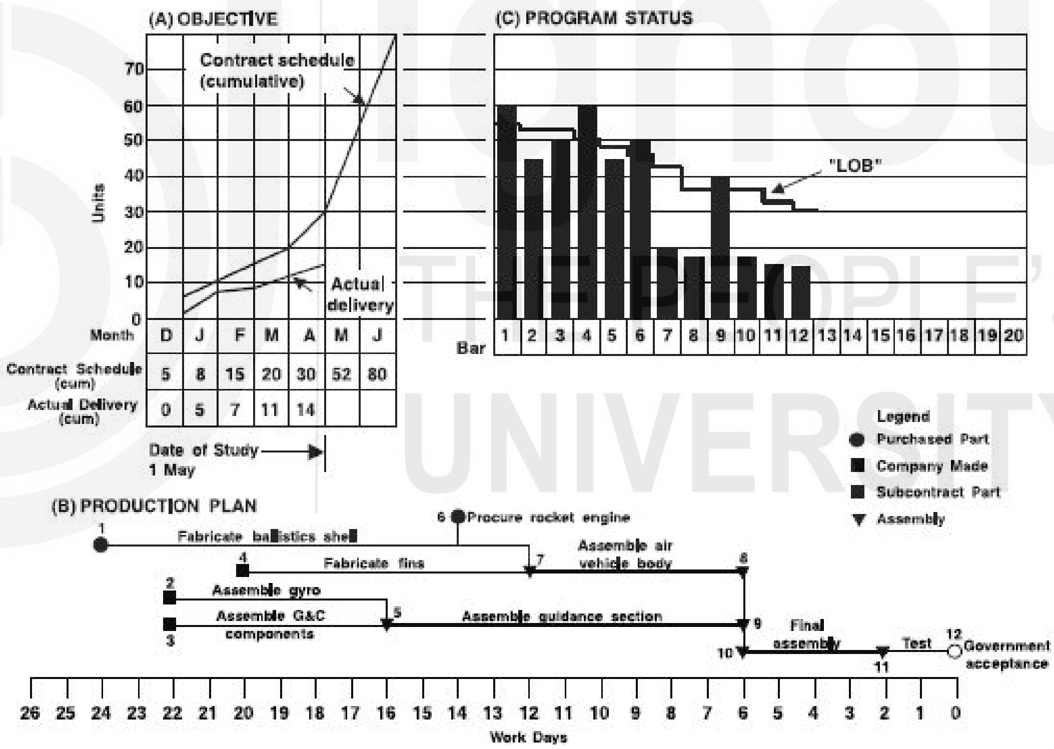

Figure 6.17: LOB Chart –Example.

6.10 COMPUTERIZED PLANNING

Application areas for computerization:

Project Formulation:

- Product Design – CAD/CAM
- Simulation for demand forecasting
- Location, Facilities Planning, and Plant layout

- Preparing Financial Projections for the projects
- Assessing Project Risk and Uncertainty

Project Implementation

- Planning and Scheduling
- Control of Project with respect to =

Time

Cost

Resources

- Project Budgeting
- Project Crashing Decisions
- Project Monitoring & Control

Evaluating Alternatives: Computers will be particularly important in evaluating different alternatives involved in decision-making.

- Cash Flow Projections
- Assessment of financial viability of projects
- Sensitivity Analysis

6.10.1 Project Management Software

Project management software in the market includes Lotus Notes, Domino, Microsoft Outlook, Excel, MS Project, Primavera, and others. The fairly comprehensive and integrated packages provide project applications for timesheets, expenses, reports, resource management, job costing, help desk services, etc.

Benefits of project management software:

- Project scheduling: Project software can help automatically produce critical path networks or Gantt charts. The software can also instantly update these time plans when new information is entered and produce automatic exception reports to monitor and control the project.
- Budgeting and Cost Control: Project software will help in planning and control of project expenditure. This also improves communication and financial reporting. After budgeted data has been recorded, actual cost and estimated costs to complete the project can be tracked and budget variations can be reported for corrective action.
- Communication and Coordination: Project software can provide automatic report templates with good graphical features. These help to provide effective communication and information system.
- Work Breakdown Structure: Project software can help in breaking projects for preparing a work breakdown structure. The project software also helps in providing schedules of work to the project staff.

- Risk Management: Project software will help managers in handling risks by providing facilities to handle What if? Questions concerned with various facets of the project.
- Web-based Project Control: Project management software also facilitates control of projects geographically spread out.
- Other Applications: Project management software provides calendars, diaries, and reminders which will help in project coordination.

Check Your Progress 6.6

Note : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

1. Discuss the concept of the LOB.

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2. Indicate the steps involved in the LOB.

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3. Explain the concept of computerized project planning.

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6.11 LET US SUM UP

A number of planning tools are available for project managers in implementing the project from concept to completion. While network techniques like CPM, PERT, and Precedence Networks are more useful for planning, Bar Charts, Gantt Charts, and Line of Balance (LOB) help in planning as well as scheduling. Planning tools are also useful in project cost control and also for project crashing decisions. Computers and software packages support the project planning tools in various facets of the project and in monitoring and control of implementation.

6.12 KEYWORDS

Activity : An element of work that must be accomplished to complete the project.

Activity Duration	:	Time required for accomplishing the activity.
Arrow Diagram (Activity on Node)	:	A Network diagramming method that uses arrows to represent activities.
Activity on Node (AON)	:	A network diagramming method that uses rectangles (boxes) or nodes to represent activities.
Backward pass analysis	:	Calculating the late finish dates for activities or the latest allowable occurrence time for the events.
Bar Chart	:	A chart showing activities; their start and finish times, keeping the relationship of the activities in view.
Crashing	:	Shortening of project duration by increasing resources and costs.
Critical Activity	:	Any activity that is part of the longest sequence of activities from project start to completion.
Critical Path	:	The series of activities in a network diagram that requires the longest time to complete. Activities on the critical path have zero floats.
Critical Path Method (CPM)	:	A project planning technique based on single time (deterministic estimate) for activities.
Dependency	:	Term used to describe the relationship between two or more activities in a project.
Dummy Activity	:	An activity to show the logical relationship in a network diagram. Dummy activities consume no time and resources.
Duration	:	The time units are required to complete an activity.
Early Start (ES)	:	The earliest possible date when an activity can start.
Early Finish (EF)	:	The earliest possible date when an activity can finish.
Estimate	:	A forecast of duration or cost for an activity.
Event	:	The start and completion of the activity are marked by events. Represented by a circle or node. Used in arrow diagrams CPM/PERT.
Float	:	The amount of time an activity can be delayed without affecting the project end date/ duration.
Forward Pass	:	The calculation of the early start time for activities or the earliest occurrence time for events by proceeding from start to completion of the project network.
Free Float	:	The amount of time an activity can be delayed without pushing the start date of the succeeding activities.
Gantt Chart	:	A type of bar chart that illustrates a project schedule. It illustrates the start and finishes dates of the terminal

		elements and summary elements of a project. Terminal elements and summary elements comprise the work breakdown structure of the project.
Late Finish (LF)	:	The latest allowable date for completion of an activity.
Latest Start Date (LS)	:	The latest allowable date for the start of an activity.
Leveling	:	The process of effectively allocating resources to activities.
Logic Diagram	:	The project network showing the workflow sequence.
Milestone	:	The recognition of an important event within a project, usually the achievement of a key project deliverable or a set of deliverables.
Monitoring	:	Collecting progress information for assessing the progress against the plan.
Network Diagram	:	A diagram showing the workflow sequence for all activities to be completed.
Network Path	:	Any series of activities in a network diagram.
PERT (Program Evaluation and Review) Chart	:	A project planning network technique, based on three time estimates (statistical approach).
Precedence Relationship	:	The description of two or more activities workflow sequence.
Project Management Software	:	A type of software, including scheduling, cost control, budget management, resource allocation, collaboration software, communication, quality management, and documentation or administration systems, which are used to deal with the complexity of large projects.
Project Management Triangle	:	A model of the constraints of schedule, cost, and scope in project management.
Resource Leveling	:	Applying available resources to a project to determine task start and finish dates, project duration, and resource utilization rates.
Resources	:	All the people, equipment, materials, and money required to complete the project.
Scope	:	The description of the intended breadth and depth of the project, its duration, and resource utilization rates.
Schedules	:	The planned dates for performing activities, indicating a specific start and completion dates.
Slack	:	The amount of time that the occurrence of an event can be delayed.

Slope (Cost slope) : The extra cost to be incurred for reducing the activity time by one unit. A concept used in crashing.

Total Float (TF) : The amount of time an activity can be delayed without impacting the project duration and the end date.

Work Breakdown Structure (WBS) : A tool that defines a project and groups the project discrete work elements in a way that helps organize and define the total work scope of the project.

6.13 SUGGESTED FURTHER READINGS / REFERENCES

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6.14 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 6.1

1. Barcharts/Gantt charts Network techniques - CPM, PERT, Precedence Diagram Method, Line of Balance (LOB).

2. Gantt charts are used to show calendar time task assignments in days/weeks/ months. The graphical chart represents the start time and completion time for various activities in the project, keeping in view the logical relationship. Gantt charts facilitate updating project progress.

3. Bar charts are common techniques used to represent the phases and activities of the project work breakdown structure. Charts are simple and can be easily understood by people working on projects.

Check Your Progress 6.2

1. Network techniques are a group of techniques for project information relating to time and resources. They help managers in planning, scheduling, and control of projects.

2. Forward pass analysis is moving from start to completion of the project for finding the earliest start time and the earliest finish time for activities. Also helps in finding the earliest occurrence time for events.

   Backward pass analysis moves from project completion to the start and helps in finding the latest start and latest finish time for activities. Also helps in the latest allowable occurrence time for the events in the project network.

3. The critical path in the network is the continuous path from start to completion of the project which decides the duration of the project. Activities on the critical path have zero floats.

   Identification of critical path and critical activities help managers in deciding where to keep close control, in project scheduling, and also in project crashing decisions.

Check Your Progress 6.3

1. CPM is the Critical Path Method used in planning, scheduling, and control of projects. CPM is based on a single time estimate (deterministic approach) for activities.CPM is used in construction and industrial projects.

2. PERT stands for Program Evaluation and Review Technique. This technique is based on three-time estimates (optimistic, pessimistic, and most likely times) for activities. This method is relevant when the time estimates for activities cannot be precisely estimated. PERT is based on a statistical approach and probability concept. PERT is used in Development projects and Research &Development projects.

3. CPM is based on a single-time estimate for activities and PERT is based on three-time estimates for activities.CPM is activity-oriented and PERT is event-oriented.CPM is useful for all levels of managers whereas PERT is useful more for top and senior managers.

Check Your Progress 6.4

1. PDM approach is based on a representation of activities in rectangles (boxes) and the dependencies (relationships) indicated by arrows. This method gives a clear visual display of the project. In this type of network, a variety of dependencies of activities can be represented.

2. Types of relationships that can be represented in PDM networks include End to Start, Start to Start, Finish finishing, Start to Finish, Start to Start and Finish to finish.

Check Your Progress 6.5

1. Project crashing is a method for shortening the project duration by reducing the time of one or more critical activities in the project. The objective of crashing is to reduce the project duration while minimizing the cost of crashing.

2. Time-constrained schedules where time is most critical and Resource-constrained schedules where the resource availability is the bottleneck.

3. A key principle in the scheduling of project activities in consideration of the availability of resources. Priority in scheduling is given to activities based on the float available. Activities that have less float are accommodated first.

Check Your Progress 6.6

1. The Line of Balance (LOB) is a management control process for collecting, measuring, and presenting facts related to time, cost, and accomplishment- of all measures affecting a specific plan.LOB helps the managers to know which activities of an operation are in balance.

2. An objective chart; a production plan or lead time chart for the production process, control points for cumulative inventories, and a program status chart on which to plan a LOB and the cumulative quantities of units.

3. Computerization is very much helpful in project planning during the preparation (Formulation phase) as well as during implementation. Computerization helps in considering and evaluating a number of alternatives and decision making to choosing the best course of action. A number of project management software like Excel, Domino, MS Project, Primavera, are available to facilitate computerized project planning, monitoring, and control.