where emphasis is on optimizing resource allocation. However, now-a-days the two techniques are used synonymously in network analysis and the differences are considered to be historical.

Both CPM and PERT describe the work plan of project where arrows and circles respectively indicate the activities and events in the project. This arrow or network diagram includes all the activities and events that should be completed to reach the project objectives. The activities and events are laid in a planned sequence of their accomplishments. However, there are two types of notations used in the network diagram. They are as under,

1. Activity-on-Arrow (AOA), and
2. 2. Activity-on-Node (AON).

In AOA notation, the arrow represents the work to be done and the circle represents an event – either the beginning 0f another activity or completion of previous one. This is shown in figure 3.

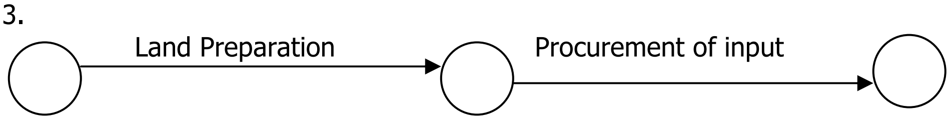


Figure 3. Activity on Arrow

For AON notation, a box (or node) is used to show the task itself and the arrow simply show the sequence in which work is done. This is shown in figure 4.

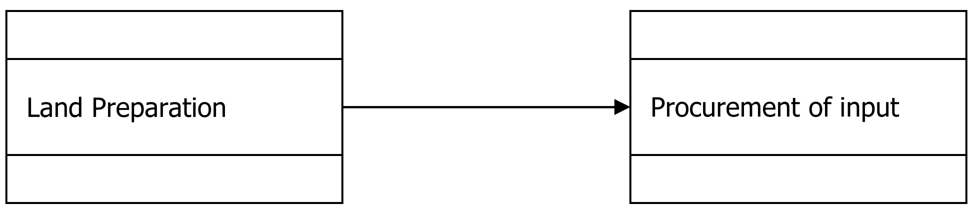


Figure 4. AON Diagram

Most project management software usually uses AON diagram. AOA network diagram are usually associated with the PERT diagram. This would be used in the following sections.

1.3.1 Programme Evaluation and Review Technique (PERT)

The PERT technique is a method of minimizing trouble spots, programme bottlenecks, delays and interruptions by determining critical activities before they occur so that various activities in the project can be coordinated.

PERT terminology

Some of the terms frequently used in PERT are as follows.

Activity : A recognizable work item of a project requiring time and resource for its completion.

Dummy Activity: An activity that indicates precedence relationship and requires no time nor resource.

Critical Activity: Activities on the critical path having zero slack / float time.

Critical Path: The longest time path connecting the critical activities in the project network. The total time on this path is the shortest duration of the project.

Event: An instantaneous point in time signifying completion or beginning of an activity.

Burst Event: An event which gives rise to more than one activity.

Merge Event: The event which occurs only when more than one activity are accomplished.

Expected Time: The weighted average of the estimated optimistic, most likely and pessimistic time duration of a project activity:

$$\text{Expected Time } (T_E) = \frac{T_o + 4T_M + T_P}{6}$$

where T_o is the Optimistic time, T_M is the Most likely time

T_P is the Pessimistic time

Earliest Start Time (EST): The earliest possible time at which the event can occur. The EST also denotes the Earliest Start Time (EST) of an activity as activities emanate from events. The EST of an activity is the time before which it can not commence without affecting the immediate preceding activity.

Latest Start Time (LST): The latest time at which the event can take place. Also referred as the Latest Start Time (LST) indicating the latest time at which an activity can begin without delaying the project completion time.

Slack: The amount of spare time available between completion of an activity and beginning of next activity.

Steps For Network Analysis

The six steps of network analysis are as follows.

1. Prepare the list of activities
2. Define the inter relationship among the activities.
3. Estimate the activity duration
4. Assemble the activities in the form of a flow diagram
5. Draw the network
6. Analyze the network i.e. compute EST and LST; identify critical events, critical path and critical activities.

Step1: Prepare the list of activities

An activity in a project is the lowest level of resource consuming, time-bound work having a specified beginning and endpoint. It should be quantifiable, measurable, costable, and discrete. The total project is subdivided into activities and each activity is given an alphabetical symbol / code. When the number of activities is more than 26, alphanumeric or multi -alphabet codes can be used. This involves a detailed delineation of the activities to be performed to complete the project. There is no limit to the number of activities to which the project should be splitted. However, it is advisable to limit the number to the minimum required from managerial consideration for avoiding unnecessary complexity. In a simple project it may be easier to identify the activity. In complex projects project activities are identified by splitting it into different hierarchical levels (sub-projects). For example in the activities of a watershed project could be broken down in to sub-projects such as agricultural sub-projects, Soil & water conservation sub-projects, Aforestation sub-project etc. For each of these subprojects the activities could be identified. Depending on the size and nature of the project sub-projects could be further divided into sub-sub project.

For illustration of the process, a simple example of creating facility for lift irrigation in a farm would be used in the following text. Some of the assumptions are as under.

1. It is assumed that the competent authority has approved the project and the project scheduling starts with the activity of "Site selection".
2. Irrigation would be provided from a newly dug well.
3. Field channels from the well would be laid after its digging.
4. Suitable pump would be procured and installed for lifting water.
5. Specification for the pump is finalized based on the groundwater prospecting data before digging.
6. Pump and other inputs would not be procured until the site is selected.
7. Pump would be installed after digging the well.

With above assumptions, the activities of the project are listed in Table 1. It may be noted the list is not exhaustive. The list would be different with different set of assumption or the perception of the project manager. More activities could be added to the list or some of the activities could be further subdivided. The number of activities in this example has been delineated and limited to only six numbers with objective of simplicity and to demonstrate the process of networking.

Table 1. List of activity

Sr. No	Activity	Symbol / Code
1.	Site selection	**A**
2.	Digging well	B
3.	Laying field channels	C
4.	Procurement of Pump	D
5.	Installation of pump	E
6.	Test run	F

Step 2: Define the inter relationship among the activities

The relationship among the activities could be defined by specifying the preceding and succeeding activity. Preceding activity for an activity is its immediate predecessor, i.e. the activity that needs to be completed before the start of the new activity. In the given example, selection of the site precedes digging of well. In other words the site needs to be selected before digging of the well. Thus the activity "Selection of site" becomes proceeding activity to the activity of "Digging the well" Succeeding activity is the one that immediately starts after completion of the activity. "Digging well" is the succeeding activity to "Selection of site".

In PERT the interrelationship is generally defined using the preceding activity. Only the terminating activities will not have any preceding activity. And all other activities must appear at least once as a preceding activity in the table. The inter relationship among the activities listed in the example is as in Table 2.

Table 2. Interrelationship of activities

Sr. No	Activity	Symbol	Preceding activity
1.	Site selection	A	----
2.	Digging well	B	A
3.	Laying field channels	C	B
4.	Procurement of Pump	D	A
5.	Installation of pump	E	B, D
6.	Test run	F	C, E

Step 3: Estimation of activity time

The activity time is the time, which is actually expected to be expended in carrying out the activity. In deterministic cases as in CPM one time estimate is used. In probabilistic cases as in PERT, the activity time has some kind of probabilistic distribution and is the weighted average of three time estimates (Optimistic time, Pessimistic time and Most likely time) for each activity. The expected time for each activity is computed as following:

$$\text{Expected Time } (T_E) = \frac{T_o + 4\,T_M + T_P}{6}$$

where T_o is the Optimistic time,(minimum time assuming every thing goes well)

T_M is the Most likely time, (modal time required under normal circumstances)

T_P is the Pessimistic time, (maximum time assuming every thing goes wrong)

Example: Estimation of estimated time for the activity "Site selection"

For this activity the tree time estimates i.e., Optimistic, Most likely and Pessimistic times are 4, 6 and 14 days respectively.

i.e. $T_O = 4$, $T_M = 6$, and $T_P = 14$.

$$T_E = \frac{4 + 4*6 + 14}{6} = \frac{4+24+14}{6} = \frac{42}{6} = 7 \text{ days}$$

Three time estimates, optimistic, pessimistic and most likely, could the decided on past experiences in execution of similar activities or from the feedback from individuals with relevance experience. The three time estimates and computed estimated time for the project activities are given in Table 3.

Table 3. Activity time estimates

Sr. No	Activity	Symbol	Preceding activity	Time (Days)			
				Optimistic Time T_O	Most likely time T_M	Pessimistic time T_P	Estimated time T_E
1.	Site selection	A	----	4	6	14	7
2.	Digging well	B	A	2	3	4	3
3.	Laying field channels	C	B	7	16	19	15
4.	Procurement of Pump	D	A	4	7	10	7
5.	Installation of pump	E	D, B	3	4	11	3

6.	Test run	F	C, E	1	2	3	2

Network Diagram

Having decided on activities, their relationship and duration (estimated time of the activity), next step is to draw the network diagram of the project. PERT network is a schematic model that depicts the sequential relationship among the activities that must be completed to accomplish the project.

Step 4: Assemble the activities in the form of a flow chart.

In a flow chart the activity and its duration is shown in a box. The boxes are connected with lines according to the preceding and succeeding activity relationship. The flow charts do not give details like start and completion time of each activity until unless it is super imposed on a calendar. It also does not facilitate computation of various slacks. However, the critical path for the project can be identified by comparing the various path lengths (sum of activity time, from start to finish, on any path). The longest path in the chart is the critical path. The flow diagram for the project considered for illustration is as in Figure 5 .

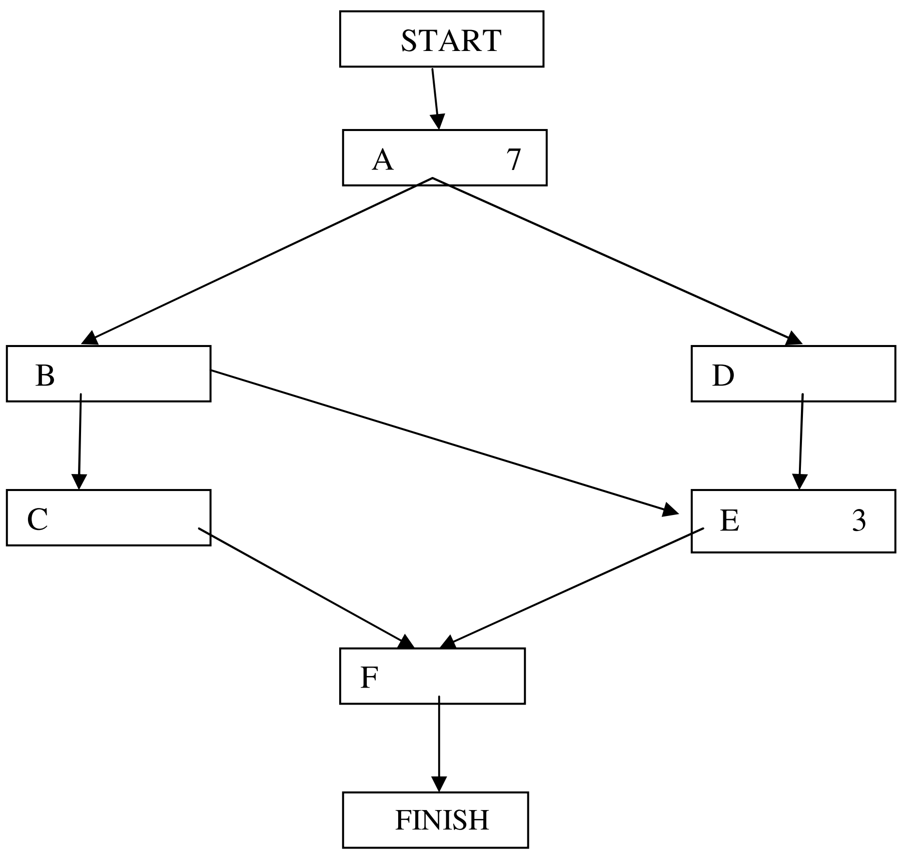


Figure 5. The flow diagram

Path I A-B-E-F 7+3+3+2 = 15

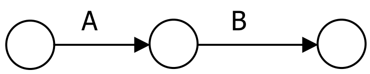
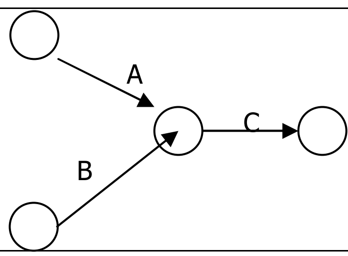
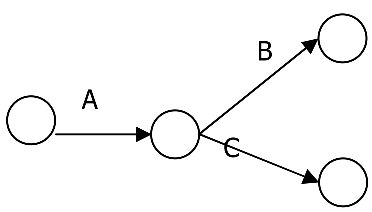
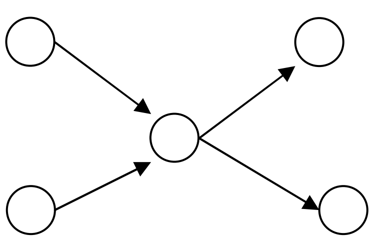
Path II A-B-C-F   7+3+15+2 = 27

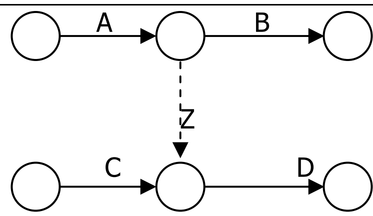
Path III A-D-E-F   7+7+3+2 = 19

Path II i.e., A-B-C-F being the longest path (27 days) is the Critical path .

Step 5: Draw the network

This graphical representation of the project shows the precedence relationship among the activities. An arrow generally represents activities in the diagram while a circle represents event. Each activity starts with an event and end in an event. Activities in a project are performed either sequentially i.e. one after another or they are undertaken concurrently i.e. simultaneously. To draw the network it requires the knowledge of specifying which activities must be completed before other activities can be started, which activities can be performed in parallel, and which activities immediately succeed other activities. Some of the common combination of activity in a project is as follows,

Sl No	Diagram	Logic
1		Activity "A" is preceding activity of "B". i.e. activity 'A" need to be completed before start of activity "B". In other words "B" starts after "A" is finished.
2		Activity "A" and "B" are concurrent. Activity "C" cannot start until both the activities "A" and "B" are completed.
3		Activity "B" and "C" are concurrent activities. Any one of these cannot start until activity "A" is completed.
4		Neither activity C nor D can start until both the activities A and B are completed. But C and D can start independently.
5		

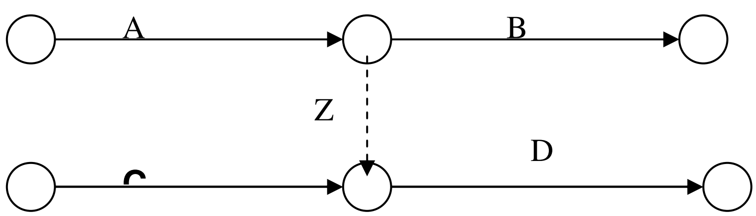
<table>
<tr>
<td></td>
<td>
</td>
<td>Activity D cannot begin until both A & C are completed. But B can start after A is complete. The activity Z, represented by dashed arrow, is a dummy activity (Explained bellow). It specifies the inter relation ship.</td>
</tr>
</table>

Dummy Activity:

For example in a project Crop 2 is to be raised in same plot of land after harvesting of Crop 1. The activities and there inter relation could be as under

Sl No	Activity	Code	Preceding activity
1	Harvesting of Crop-1	A	-
2	Sale of Crop – 1	B	A
3	Raising nursery of Crop-2	C	-
4	Transplanting Crop-2	D	A, C

The network diagram of the above project would be as follows



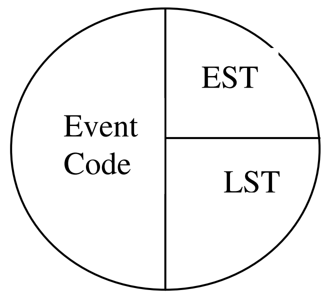
The activity "Z", represented by dashed arrow in the diagram, is a dummy activity. This does not consume any resource i.e. have zero time and zero cost. This only represents the logical relation among the activities.

Rules for Drawing the Network:

1. Each activity is represented by one and only one arrow in the network
2. All the arrows must run from left to right.
3. Dotted line arrows represent dummy activities.
4. A circle represents an event.
5. Every activity starts and ends with an event.
6. No two activities can be identified by the same head and tail event.

7. Do not use dummy activity unless required to reflect the logic.
8. Avoid Looping and crossing of activity arrows by repositioning.
9. Every Activity, except the first and the last, must have at least one preceding and one succeeding activity.
10. Danglers, isolated activities must be avoided.
11. For coding use alphabets for all activities including the dummy activity and numbers for events.

12. Standard representation of the event :



The network diagram for the project detailed in Table 4 is as follows (Figure 6)..

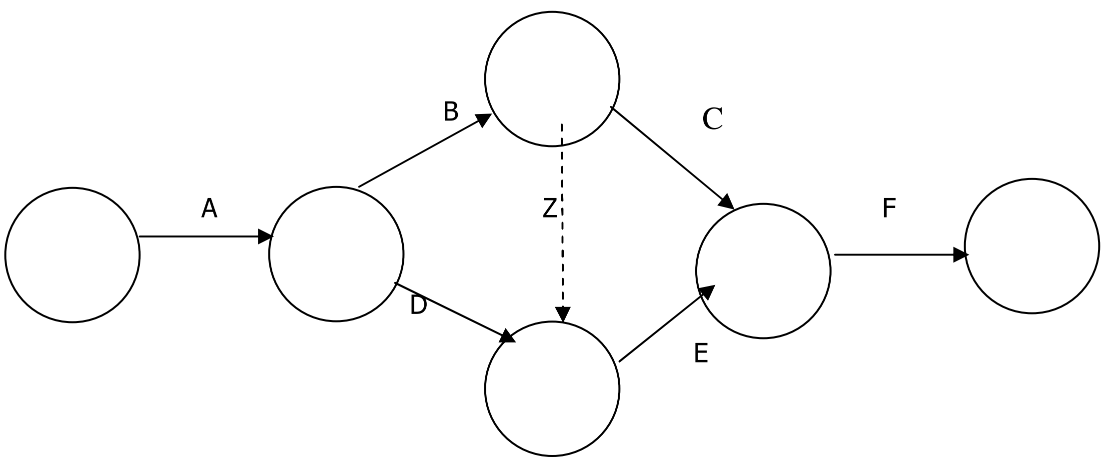


Figure 6. Activity inter-relationship

Network Analysis

Introduction

Network analysis helps the manager to calculate the duration and identify critical activities in a project. Critical activities are those activities, which determine the overall duration of the project. The duration of the project is not necessarily the simple arithmetical sum of the individual activity durations because several activities occur concurrently in the project. Project duration would be equal to the sum of all individual activity durations only when all the activities in the project are sequential. The starting and finishing time for each individual activity is calculated through the network analysis. These computations provide a strong base for determining the work schedule. The network analysis includes the following.

a. Event numbering
b. Computation of the Earliest Start Time (EST)
c. Computation of the Latest Start Time (LST)
d. Computation of Earliest Finish Time (EFT)
e. Computation of the Latest Finish Time (LFT)
f. Identification of Critical Path
g. Computation of Slack or Float

Event Numbering

It is common practice to number every event in the network so that they are not duplicated, every event is identified with a reference number in the network and every activity is identified by its preceding and succeeding event numbers. There are two systems in vogue for numbering events:

1. Random numbering system
2. Sequential numbering system

Random numbering system; In this system, events of a network are numbered randomly, thereby avoiding the difficulty in numbering extra events due to insertion of new jobs.

Sequential numbering system: In this system the events are numbered successively from the beginning to the end of the network. For any individual job, the head (succeeding) event must bear a higher number than the tail (preceding) event.

Fulkerson has reduced this sequential numbering to the following routine;

1. Find the initial event and number it '1' (An initial event is one which has arrows emerging

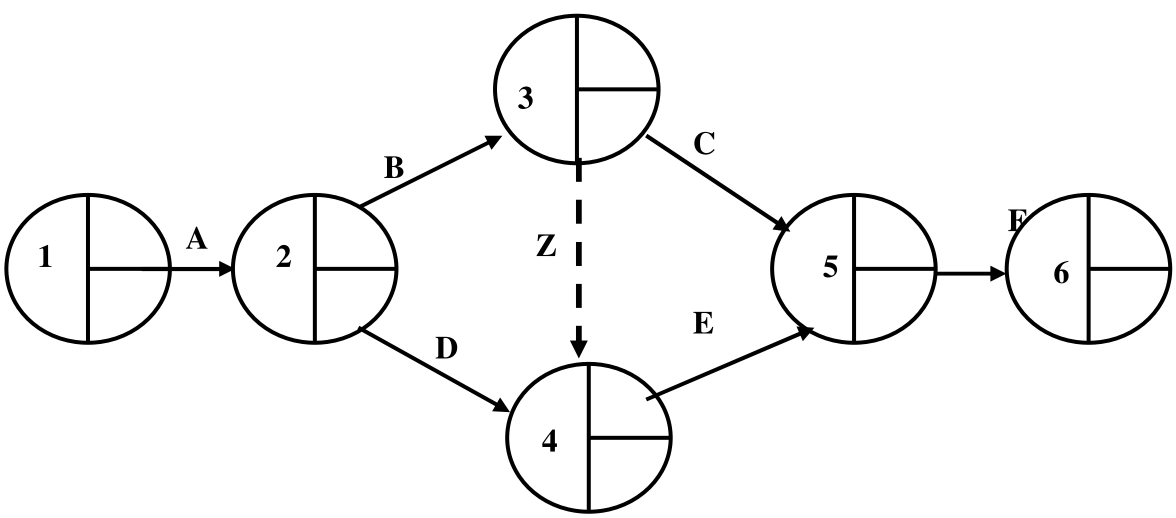
from it but none entering it).

2. Now delete all the arrows emerging from the already numbered event(s). This will create at least one new initial event.
3. Number all the new initial events '2', '3' and so on till the final event is reached (the final event is one which has no arrows emerging from it).

The complete sequential numbering system described above is inconvenient when extra jobs have to be inserted. Extra jobs often mean extra events; when these events are numbered, all the events following them must be renumbered. One way to overcome this difficulty is to use tens only like 10 for the first event, 20 for the second event and so on. The event numbering of the network diagram for the project below (Table 1) is shown in figure 1.

Table 1. Lift Irrigation in the farm.

Sr. No	Activity	Symbol	Preceding activity	Time (Days)
1.	Site selection	A	----	7
2.	Digging well	B	A	3
3.	Laying field channels	C	B	15
4.	Procurement of Pump	D	A	7
5.	Installation of pump	E	D, B	3
6.	Test run	F	C, E	2



Step 6: Computing Earliest Start Time (EST) and Latest Start Time (LST)

The EST represents the time before which the activity cannot begin and LST refers to the latest time by which the activity must begin. The EST and LST are computed in two phases. The EST is calculated first in the forward pass beginning from the start event. For the start event the EST is always set to zero so that it can be scaled to any convenient calendar date at a later stage. The EST at the last event is generally considered to be the project duration i.e. the minimum time required for project completion. Therefore, EST and LST are equal at the end event. LST for other events is then calculated through backward pass starting from the end event. Steps involved in computation are listed below.

EST	LST
Through forward pass	Through backward pass
Calculation begins from start event	Calculation stars from end event
Proceeds from left to right	Proceeds from right to left
At start event EST is Zero	At end event LST equals to EST
Adding the activity time to EST	Subtracting the activity time from LST
At a merge event take maximum value	At a burst event take minimum value

Example: Computation of EST

EST of an activity = EST of preceding activity + Activity duration

EST at start event 1 (for activity A) is Zero. To compute EST at event number 2, add 7 i.e. the duration of activity A to zero. This is also the EST for both activities B and D starting from event 2. Continuing, EST at event 3 is 10 i.e. (7+3). At event 4, being a merge event, will have two estimates of EST (considering Dummy activity Z and activity D). It is 10 (10+0) and 14 (7+7). In cases where there is more than one estimate the maximum the estimates is considered. In this exercise maximum of 10 and 14 i.e. 14 is the EST at event 4. It is also EST of activity E. EST for the network is computed figure 2 and table2 .

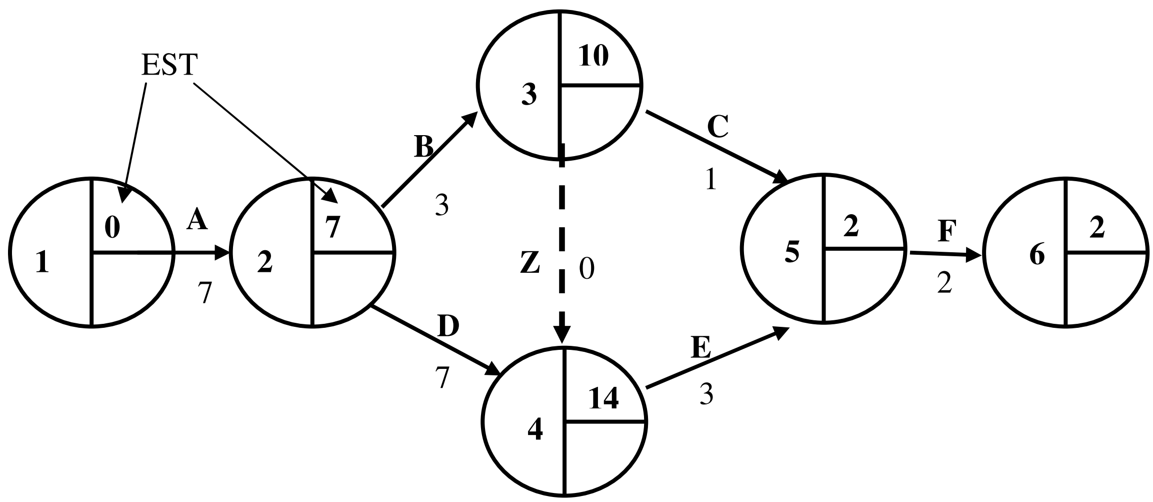


Figure 2. Computation of EST

Example: Computation of LST

LST of an activity = LST of succeeding activity – Activity duration

Computation of LST starts from the end event of the project and proceeds backward. At the end event the LST is equal to the EST In this example at the event 6, the LST is equal to the EST and it is 27. At event 5, the LST is 27-2=25. Similarly at event 4 it is 25-3=22. Event 3 being a burst event (i.e. more than one activity emanating from this event) will have two estimates of LST and in such cases only the minimum value of the LST is considered. Accordingly at event 3, the two estimates are 22-0=22 and 25-15=10. Minimum of these two values 10 is the LST at event 3. Similarly at event 2 it is the minimum of 10-3=7 and 22-7=15 i.e. 7. Accordingly at event 1, LST is 7-7=0 which is equal to the EST at the start event. Both the EST and LST values for the project activities are presented in figure 3 . and table 2 .

Table 2. The EST and LST of activities

Event No.	EST		Event No.	LST
1	0		6	27
2	0+7 = 7		5	27-2 = 25
3	7+3 = 10		4	25-3= 22
4	Max. (7+7=14, 10+0=10) = 10		3	Min.(25-15=10,25-0=25) =10

5	Max. (10+15=25, 14+3=17) = 25		2	Min. (10-3=7, 22-7=15) = 15
6	25+2 = 27		1	7-7=0

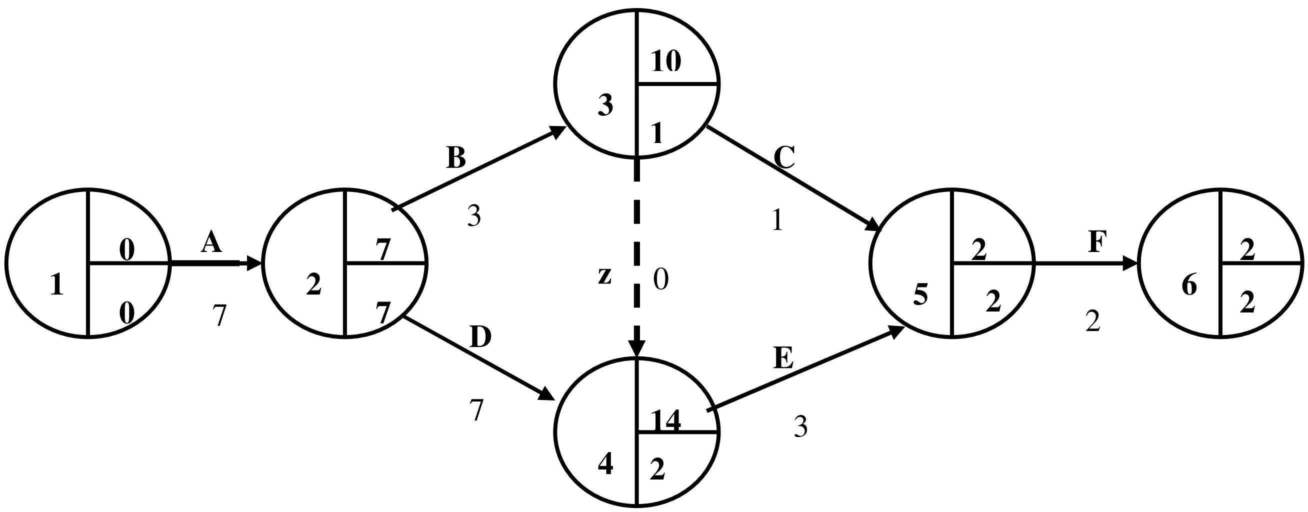


Figure 3. The EST and LST of activities

Computation of the Earliest Finish Time (EFT) and the Latest Finish Time (LFT)

The EFT for each activity is calculated starting from the first activity, which commences after the start event. It is given by

EFT of an activity + EST of preceding activity + activity duration.

The calculation of LFT starts from the last activity of the network or from the computed LST and is given by,

LFT = Latest Starting Time (LST) of succeeding event

The various computed for the project is given in table 3.

Table 3. Computed times for the activities

Sl No	Activity	Duration	EST	LST	EFT	LFT
1	A	7	0	0	7	7
2	B	3	7	7	10	10
3	C	15	10	10	25	25
4	D	7	7	15	14	22
5	E	3	14	22	17	25
6	F	2	25	25	27	27

Calculation Of Slacks / Floats

Slack or float is used to indicate the spare time available with in a non-critical activity. However, in general slack relates to an event and floats to an activity. These are important for smoothening the resource utilization in a project. The various floats and slacks are computed as follows

a. Event Slack = LST-EST
b. Total Flot is the time available for an activity over and above the requirement for its completion.

   Total Float = LST of end event – EST of Starting event- Duration of reference activity
c. Free Float is the time available for an activity to expand without influencing the later activities.

   Free Float = EST of end event – EST of starting event – Duration of reference activity.
d. Independent Float is the time with which an activity can expand without influencing the preceding or succeeding activities. Seldom the independent float could be negative. In such cases it would be considered to be equal to zero.

   Independent float = EST of end event – LST of starting event – Duration of reference activity.

Floats and their relation ship

Various floats and their relationship is shown in Figure 3 . It may be observed that

Total Float is more than or equal to free float. And free float is more than or equal to independent float. I.e. TF>= FF >= IF

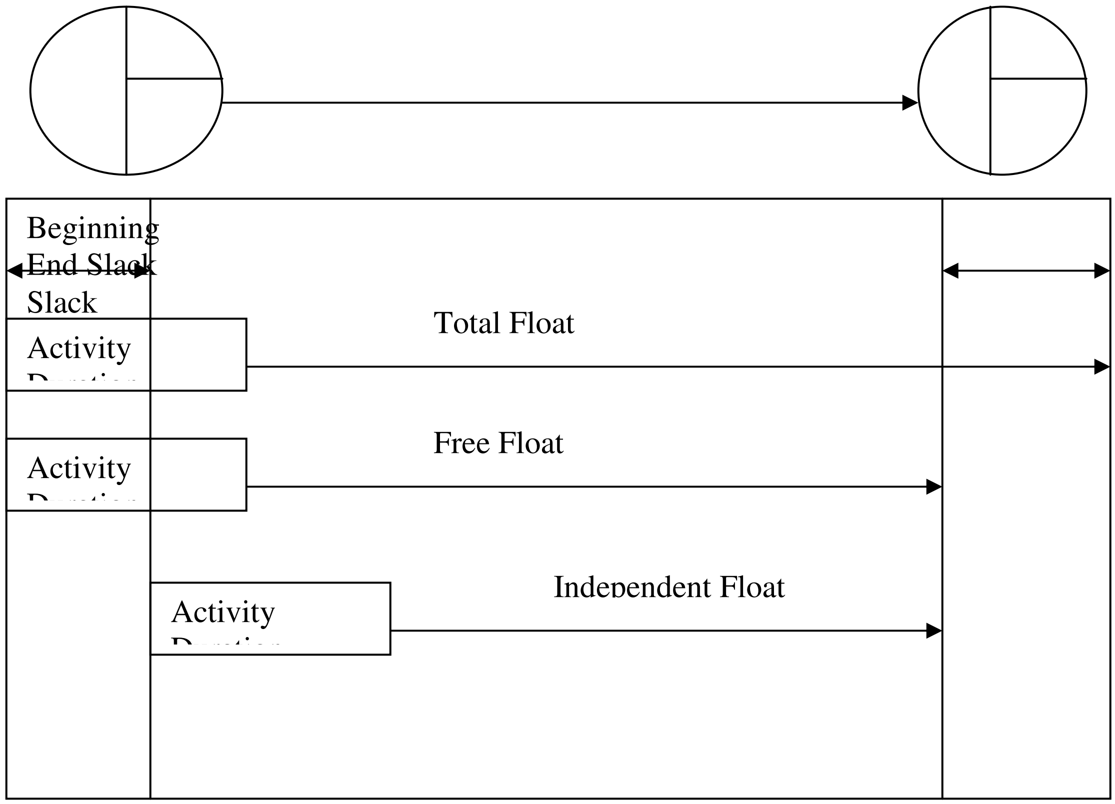


Figure 4. Relationship between the floats

Identification of Critical Events

The critical events of the project are identified by the event slack i.e. the difference between LST and EST. For critical events this slack is zero i.e. the value of LST and EST are equal. The event slack computed for all the events of the project are as follows Table 4:

Table 4. Event Slacks

Event No	LST	EST	Event slack	Critical / NC
1	0	0	0	Critical
2	7	7	0	Critical
3	10	10	0	Critical
4	14	22	8	Not Critical
5	25	25	0	Critical
6	27	27	0	Critical

With above values of EST, LST and event slack the Critical Events are 1,23,5, and 6.

Identification of Critical Activity

An activity can be called as critical activity if the following conditions are satisfied.

i. LST and EST are equal at the head event
ii. LST and EST are equal at tail event
iii. Difference between EST at head and tail event of the activity equals to the activity time.
iv. Difference between LST at head and tail event of the activity equals to the activity time.

Review of computation results suggests that the critical activities in the project are A, B, C, and F.

Identification of Critical Path

The critical path is the chain of critical activity spanning the network from start to end i.e. the path joining all the critical events. It is also the longest path from start to end of the project network. Alternatively therefore comparing all the possible path lengths can identify the critical path (see flow diagram). The critical path time is the shortest duration of the project. The critical path is denoted preferably by denoting the critical events on the path.

Critical path for the project is, A – B –C – F.

The critical path of the project can also be denoted in terms of the event numbers. In the present project it is 1- 2–3 – 5-6. To distinguish the critical path from other paths in the project, it is preferable to use a thicker line to demarcate the critical path. It is quite possible that a project can have multiple critical paths. In such case the length of all the critical paths will be equal.

Critical Path and Project Management:

The critical path time being the shortest project time any delay in completion of any of the activity on the critical path would delay the entire project. Therefore it is the critical activity that needs to be monitored for timely completion of the project. However, the activities with positive event slack could be rescheduled within the available time frame for efficient utilization i.e. smoothing of the demand on the available resources. If the duration of the project requires to be reduced, activities on the critical path will be the ones to be considered for completion at an early date with allocation of additional resources.

Network Revision

So far the steps involved in developing the initial network provided two basic pieces of information an estimate of the project duration and the critical path.

The initial network constructed is examined to convert it into a valid, practical network which satisfies the project requirements and provides the basis for effective implementation and control. This process is called network revision.

The purpose of revision is two-fold. Firstly, it is concerned with improving the quality of the information in the network; information about the relationships and durations of activities. Secondly, it is concerned with ensuring that the final network satisfied the project objectives. These relate to four factors; time, cost, resources and performance.

Reviewing the relationships: The first task is to review the activities and their relationships. Some relationships may not have been shown properly in the initial network. A sequence of activities which at first sight appear to need serial representation, can sometimes be arranged to take place in parallel with one another. Often it is s only a part of an activity which really conditions the start of the following activity, and in these cases, the activity can be subdivided and part of it depicted on the network as occurring in parallel with other activities. If the activity thus treated is on the critical path, a useful shortening of the project duration can be achieved.

Reviewing the duration of activities: At the revision stage, the activity durations must be re-examined in the light of information about the project duration and critical path. Work may have to be analyzed in greater detail, suppliers may have to be contacted for confirmation of current delivery periods and so on. Less accurate estimates can usually be tolerated for activities with plenty of float.

For some activities, the duration is variable. The time required to carry out the work depends almost entirely upon the quality or accuracy of performance specified. Estimates for research and development work and producing advertising copy or design work may be of this type. One approach for reviewing the duration of the activities when they are not critical is the use of the concept of available time.

One useful little check, which can be applied to the activity durations, is to calculate the parentage of even number durations in the network. Because of a fairly general bias towards even numbers, the percentage is rarely as low as the theoretical 50%.

Project objectives while in theory, the objectives of every project should be clearly defined at the outset, in practice this is not always done. On the other hand, the initial network assists and forces the clear definition of project objectives. Statement about objectives is usually expressed in term of time, cost, resources and performance. It will be realized that the objectives stated in terms of one factor may conflict with others. For example, it may not be possible to complete a project in the shortest time and at minimum cost. If a network is to be checked to see whether it satisfies the project objectives, then these objectives must have been stated in such a way as to recognize and assign priority to their relationships.

Meeting time objectives; It is likely that the project duration calculated from the initial network may not be acceptable to the management. This means that at the revision stage, the network must be modified to satisfy any time limits set for the project. If the project duration is to be reduced, the critical activities must be subjected first to careful examination. Changes in the relationships in turn affect the time along the concerned path as discussed earlier.

But once the possibilities for changes in relationships have been exhausted, the scope for reduction in the duration of critical activities must be examined. In some cases, this may mean diverting resources from non critical activities to critical, ones. In others, this may mean the use of more labour, more machines; overtime work or extra shifts.

Meeting cost objectives: The cost of a project is usually given in terms of an estimate which may be required for such purposes as establishing feasibility, finding out return on investment, obtaining approval or getting out a price for a job, etc. The time involved will be important and a realistic cost target cannot be set without a careful study of the plan embodied in the network. The plan will determine in broad terms the pattern of expenditure over the period of the project. The network can be used to investigate this pattern of expenditure and the results can be compared with the availability of money. The network may indicate a pattern of expenditure in excess of what is possible, in which case the plan will have to be modified.

Certain activities can be speeded up or slowed down depending upon the amount of money spent on them. The network can be used to examine the relationship between total time and total cost, and the project duration established for which the total cost is minimum. These aspects will be discussed in more detail later.

Meeting resource objectives: The initial network is drawn without considering the resources as this does not affect the relationships between activities. However, if the resources are limited, the plan must be examined to see to what extent it will have to be modified in the light of resource availability. Activities which are independent may have to be made dependent upon one another because they will be done by the same machine or by the same man. For example, a number of fitting jobs may be unrelated in the network, but if there is only one fitter to whom this work can be allocated then the jobs will have to be done one after the other. If the jobs have sufficient float to allow this, the project completion date will remain unaffected; but if the float is inadequate, an additional fitter has to be employed or a later completion date accepted. The plan. should be modified accordingly.

Another aspect which should be considered at this stage is the relationship between to duration of an activity and the resources allotted to it. The original duration assumes normal resources but for some activities, this time may be varied by altering resources put on the job. Thus certain critical activities may be speeded up by putting on additional resources, while activities with plenty of float may be allowed to take longer time with less resources, thus releasing men for more critical activities.

Examination of the network can throw some light on the resource implications of the plan in a general way. Often a detailed analysis of the network is necessary, if the information is going to lead to management action. The analysis of network with respect to resources will be discussed in detail later.

Meeting the performance objectives: There are two ways in which the plan influences the specification of the project. Firstly, it will embody methods of working and procedures which influence performance and these may have to be revised in order to effect a reduction in the project duration. It may be necessary to find alternative ways of doing things which are less satisfactory and the implications of these decisions must be carefully evaluated in relation to the project as a whole and the possible effect on the specification.

The second aspect, already mentioned, is the relationship between performance and time for certain activities. Any reduction in the time allowed for development work and testing may affect ultimate performance and the plan must be checked to establish whether the original specification can still be met. In this way the network can give some indication of the relationship between time and performance, allowing the decisions to be made which are consistent with overall project objectives.

The final network: There are usually a number of ways in which the plan can be revised to meet project objectives and each will have different implications. The use of network to simulate these alternatives can help in finding the right balance between the objectives. Many changes will be made to the initial network before a final plan can be agreed upon and on the basis of the final plan detailed work schedules are worked out.

Activity Scheduling

Once the final network is drawn the next step is to convert this into a programme of work. This step is known as Scheduling.

Critical activities, by definition have only one possible starting time if the project completion date is to be met. All other activities in the network have a range of possible start times from the earliest to the latest start time. The actual starting times of activities are decided based upon any one of the following approaches;

All activities started

1. at earliest start times
2. at latest start at times
3. by distributing float
1. at arbitrary start times
2. by considering resource availability

All activities started at earliest start time

In order to minimize the effect of delays on the project completion date due to unforeseen delays in some activities, it is desirable to preserve the float for later use. One way of ensuring this is to start all activities at their earliest start times.

The schedule start time can be read straight from the network without further computation. This approach, though simple has its disadvantages. Using the network as a rigid schedule to start activities as early as possible may result in unnecessary increase in costs. Expensive plant and equipment delivered at the earliest possible time may be lying idle awaiting installation, or staff may be recruited well before there is any work for them. From the angle of finance, money should be spent as late as possible; this means carrying out activities as late as possible.

All activities started at latest start times

From the financial point of view this approach is far better and might result in significant saving of money. But the disadvantages are so obvious, schedulers dare not use this approach. Starting all activities at their latest start times will mean deliberately discarding available float with the result that all activities, in the project become critical. The project becomes extremely sensitive to delays and its chance of being completed on time is very remote.

All activities started by distributing float

As a compromise between the two above mentioned extremes, viz, starting all activities at earliest start times and starting all activities at latest start times, it is possib1e to distribute the total float which exists in a chain of activities in such a way that, each individual activity is allocated a portion of it. This approach is based on the assumption that since most activity times will vary, from the original estimate, it is advisable to allow for some variation in as many activities as possible.

The main objection to this method is that it allows float to be given up and used as a contingency allowance, and that if a major delay occurs one may find that the float given away earlier is now desperately needed. There is always a danger that once float is allocated to an activity, it will be used up, whether it is really required or not in accordance with the famous Parkinson's law which states that 'work expands to fill the time available for its completion'.

All activities started at arbitrary start times

One way out of this dilemma is to leave the decision about the actual start time to the person responsible for the execution of the activity, pointing out that it must be started between earliest start time and latest start time. This approach is usually unsatisfactory and leads to lot of confusion as the project proceeds, as no one can be really sure when activities carried out by others are going to finish, and hence they cannot easily plan their own work. This approach also has the disadvantage of distributed float method as for one reason or the other the float would have been gradually used up leaving all the remaining activities critical.

All activities started by considering resource availability

Resource availability is one factor which may have an important influence on when activities can actually be started. The initial network ignores this factor, and it is at the scheduling stage that the resources have to be taken into account. Activities which could logically be carried out in parallel may have to be done in series and this phasing of activities to meet resource limitations will involve the use of float. The planning of work to balance such requirement against availability may be an overriding factor in deriving schedules and these aspects are discussed in detail later.

In practice no approach other than that of resource considerations, can be used to determine the start times of all activities in the project.

Resource Analysis and schedu1ing

In some projects, time is all-important and considerations of cost and resources are secondary. Examples of this type are research and development projects. But for most projects, resources are always limited and hence the success of the projects depends on the ability to use the available resources effectively. This calls for a careful analysis of the network to see how far the requirements can be met, what changes may be needed to the plan and how efficiently the resources can be used. A network is primarily designed to give information about time, but can be used to study resources as well, as discussed below:

Resource analysis: By associating with each activity in the network, the units of resources that would normally be used to carry it out, it is possible to analyse the total resources requirement against time over the duration of the project. From a schedule where all activities start at their earliest start times, a resource histogram can be constructed, showing the total units of resources required for each unit of time through the project. This procedure is called resource analysis. If the units of available resources are known, the histogam can be used to investigate whether the schedule creates less/same/more demands on resources. The procedure is illustrated in the following example.

Project: Establishment of a Mango orchard

Activity	Symbol	Preceding	Duration (Day)	Manpower/day
Land preparation	A	-	3	4
Digging pits	B	A	5	4
Purchse saplings	C	A	3	2
Application of FYM	D	B	3	3
Transplant saplings	E	C,D	4	4

The network diagram for the project is given in figure 4.

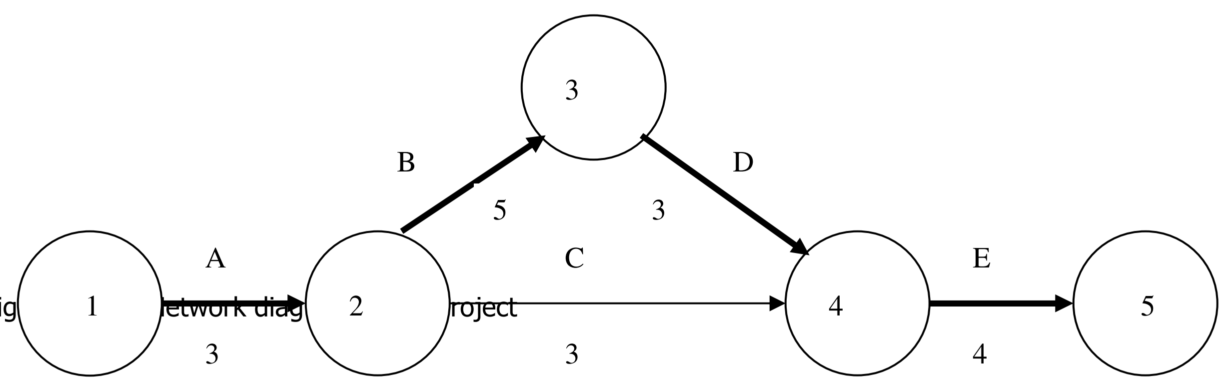


Fig etwork diag roject

In the above diagram the critical path is A-B-D-E and the project duration is 15 days. The Total float of the activity C is 5 days. Assuming the activities are scheduled on the Earliest Start Time (EST) the manpower requirement for the project is shown in figure 5.

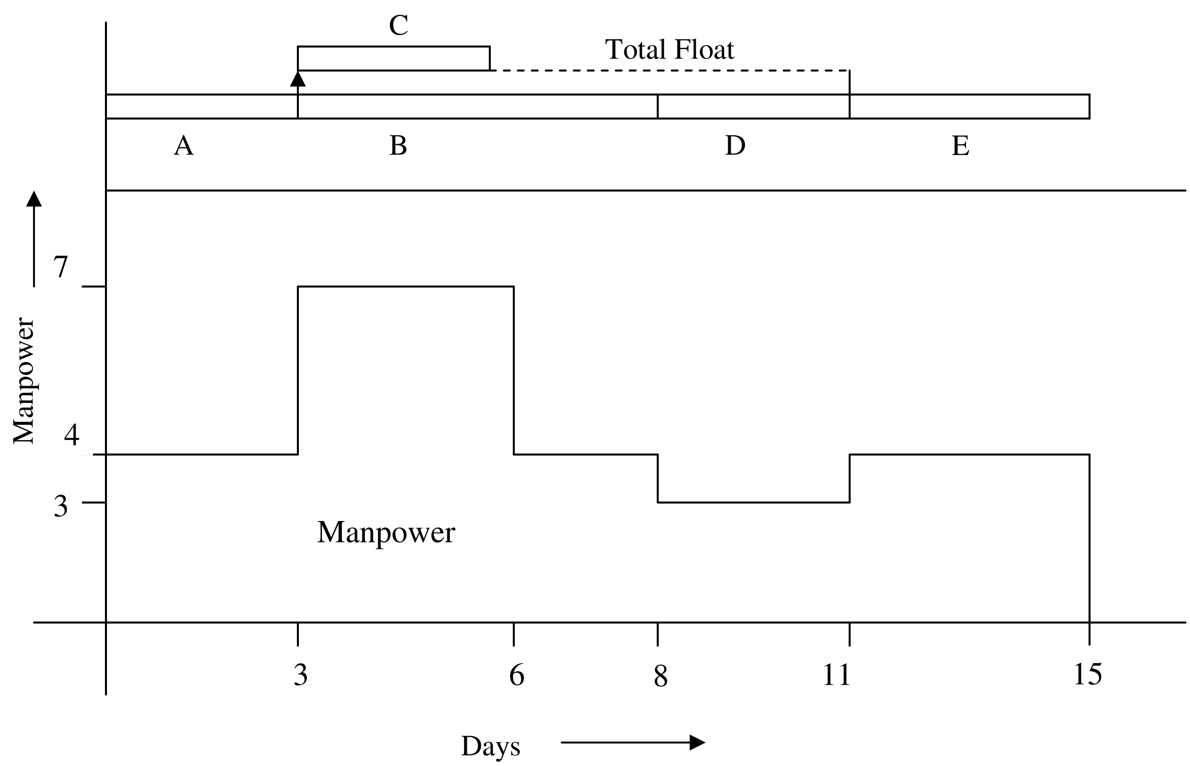


Figure 5: Pattern of manpower requirement

From the above figure it is evident that the manpower requirement is to the maximum of 7 numbers during 3rd to 6th day of project commencement and the minimum requirement is 3 persons during 8th and 11th day. The difference is 4 persons.

Considering the float of the activity C , this activity can be scheduled for any three days between 3rd to 11th day. If it is scheduled during 9th to 11th day the manpower requirement pattern would be as in figure . The demand is almost uniform, the difference between the maximum and the minimum is only one person. The manpower demand for the project duration after rescheduling the activity C is shown in figure 6.

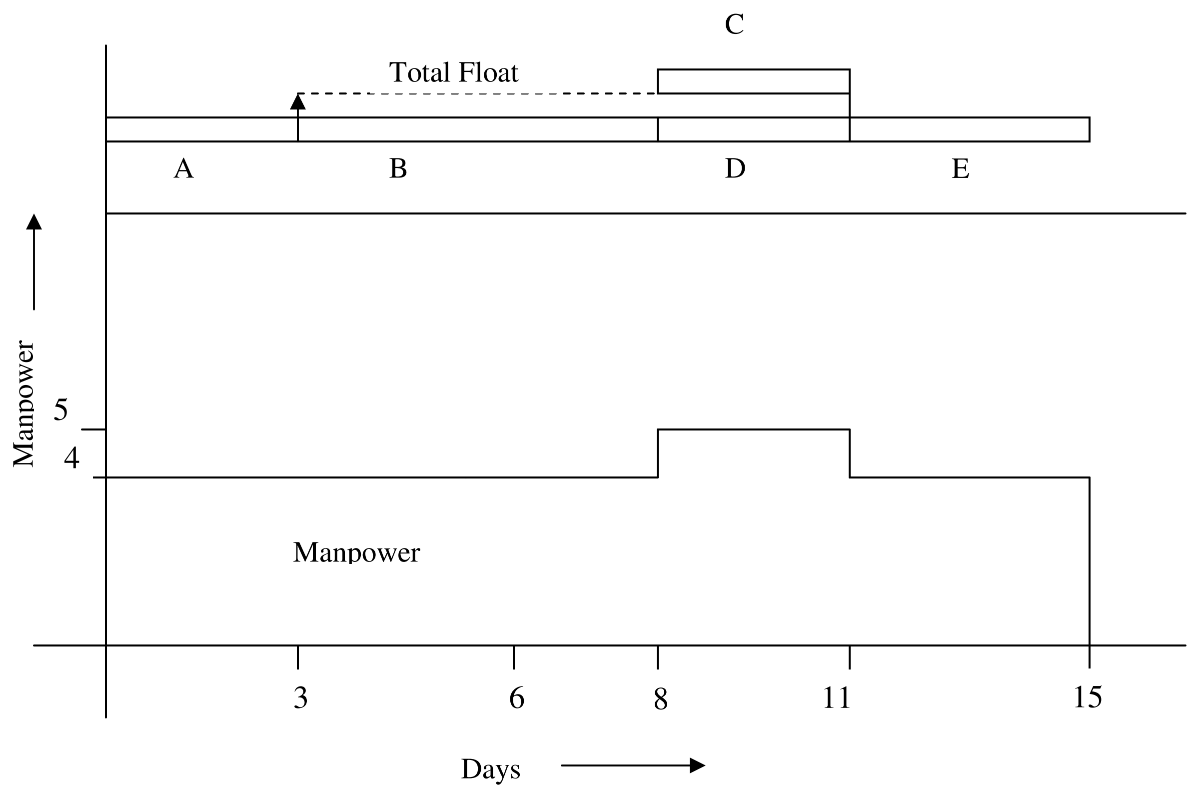


Figure 6. Revised schedule of activities.

The resource smoothing is a technique applied to distribute the resources load evenly through out the project period. In agricultural projects where the field operations are highly dependent on weather, cropping pattern, crop characteristics, application of this technique would be limited to the use of implements or to the operation those are not bound by natural phenomena.

Project Crashing and Project Control

Time-Cost Relationship Of An Activity

The time required for the performance of an activity is estimated according to the quantity of resources. Except for fixed duration activities such as crop duration, gestation period etc it is possible to mange the duration of an activity by varying the quantity of resource. If cost is not a constraint, putting more resources to the activity duration could reduce be reduced. This in other word means time and cost of a project are inversely related. The relationship between cost of an activity and its duration may take the form of the curve as depicted in figure 1.

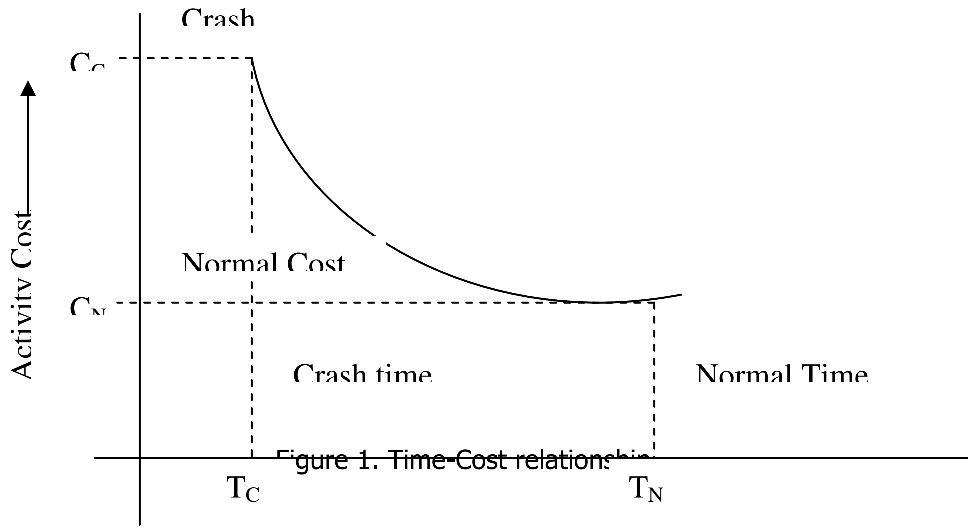


Figure 1. Time-Cost relationship

The time for the act called *Normal time* and the minimum time for the activity is called *crash time*. The costs associated with these times are called respectively the *normal cost* and the *crash cost.* Although it is possible to estimate the time and cost associated with the normal and crash conditions for each activity it is difficult to estimate the time and cost at any intermediate stage between these two points. To overcome this difficulty, it is assumed that the relationship between the time and cost as linear in the range between normal and crash situations.

Project Crashing

Project crashing is an exercise carried out to reduce the time of a project by investing more money. This becomes necessary when the dead line has to be met. For crashing only the critical are considered since duration of the project could be reduced by crashing these activities only. It is possible that when a project is crashed another non-critical activity may become critical and in the next cycle this has to be considered for further crashing. The steps involved in crashing are as under.

a. Identify critical path and critical activity
b. Compute crash cost slope i.e. (Crash cost – Normal cost) / (Normal Time – Crash Time)
c. Select the activity with the least cost slope i.e. minimum crash cost per time.
d. Check for the critical path.

As the project shortening (crashing) continues, a point is reached at which no further crashing is possible. At this point, some activities might not have reached their crash points. If these activities are crashed further, costs are increased with no saving in project duration.

Project Crashing Example

The principles of project crashing are illustrated with the help of the example. Activity table of the project and the network diagram are shown in Table1 and Figure 1 respectively. Table 2 presents the normal and crash parameters.

Project: Development of Agro-Technology Demonstration Blocks

Table 1. Activity Table

Sl No	Activity	Symbol	Preceding activity	Duration (Weeks)
1	Leveling the land	A	-	16
2	Stone pitching	B	A	26
3	Raising seedling	C	A	26
4	Establishment of irrigation system	D	A	30
5	Development of drainage system	E	C	28
6	Making pits and transplantation	F	B	27
7	Erection of fencing	G	D,E,F	18

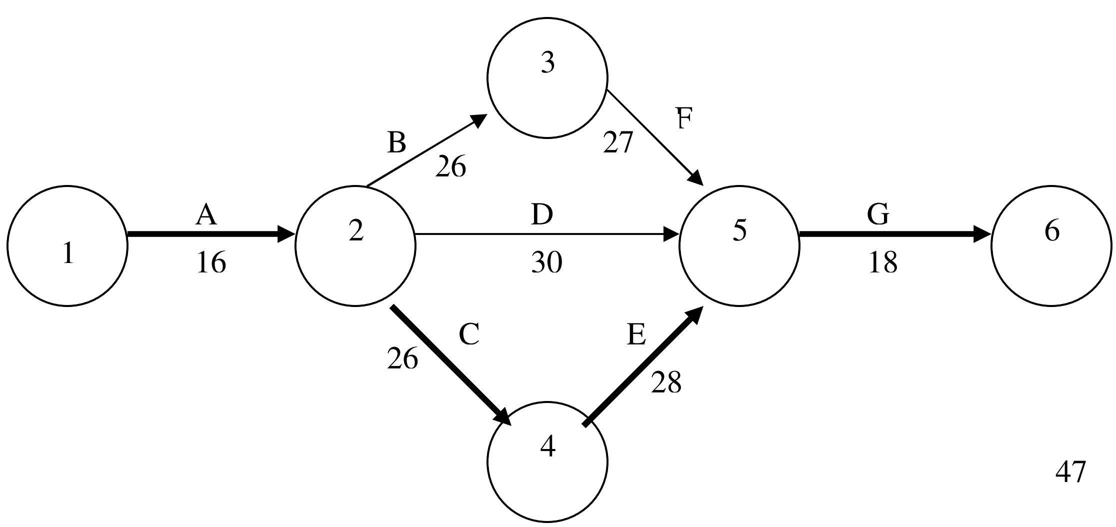


Table 2. Normal and Crash parameters

Activity	Time in weeks		Cost in Rs.		Reduction in time	Increase in cost	Cost slope (Rs./week)
	Normal	Crash	Normal	Cost			
A	16	11	36000	38000	5	2000	400
B	26	18	27000	33000	8	6000	750
C	26	21	8000	8900	5	900	180
D	30	23	135000	138570	7	3570	510
E	28	20	20000	22400	8	2400	300
F	27	23	12000	13700	4	1700	425
G	18	12	35000	36500	6	1500	2500
Total			273000	291070	43	18070	

The above project has a duration (Critical path length) of 88 weeks, normal cost Rs273000 and crash cost of Rs. 291070. For crashing, the critical activities in the project A,C,E and G are to be considered first. Activity C has the least cost slope i.e. Rs180/ week and can be crashed first from 26 to 21 weeks. After this crashing the project duration is reduced to 83 weeks (Activity C from 26 to 21 weeks) and the cost has increased from Rs.2,73,000 to Rs.2,73,900. The revised PERT network of the project after crashing is as in figure 2 .

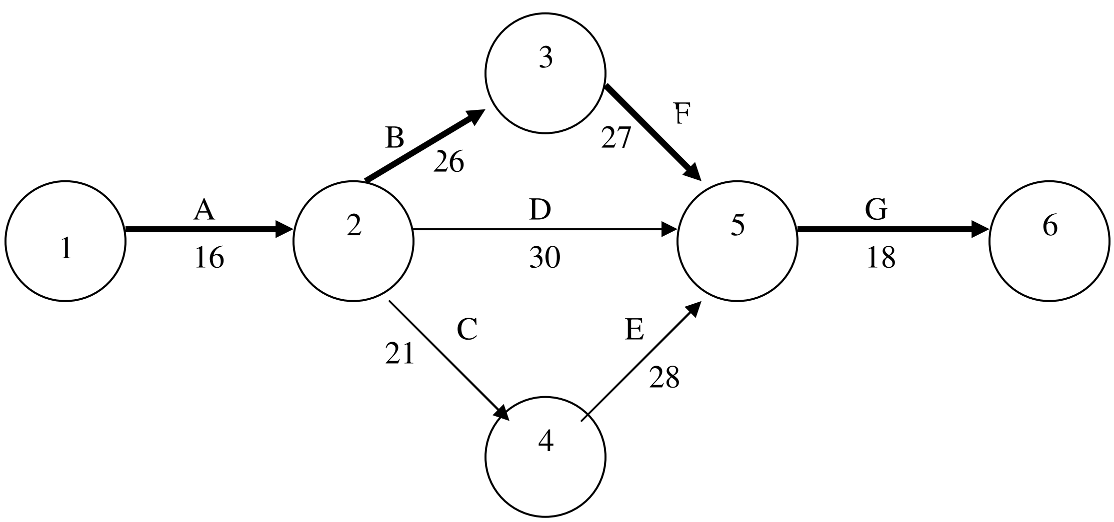


Figure 2. The network diagram after crashing activity C

In the redrawn network the new critical path is A,B,F and G. These activities are to e considered for further crashing. Among these activity G having least cost can be crashed from 18 weeks to 12. The project cost would be increased from 2,73900 to Rs 275000. After crashing the network diagram is to be drawn and the procedures could continue till a stage is reached when no further crashing is possible. The crashing result for the project is summarized in Table 3.

Table 3. Summery of crashing exercise

Crashed activity	Crashed Time (Weeks)	Crashed Time (Weeks)	Project duration in weeks			Project cost in Rs.		
			Before crashing	After crashing	Cumulative Reduction	Before crashing	After crashing	Cumulative increase
Normal			88	-	-	273000	-	-
C	5	5	88	87	1	273000	273900	900
G	6	6	87	81	7	273900	275400	2400
A	5	5	81	76	12	275400	277400	4400
F	4	4	76	72	16	277400	279100	6100
E	8	8	72	72	16	279100	281500	8500
B	8	8	72	64	24	281500	287500	14500

It may be noted from the above table that even though the activity C is crashed by 5 weeks i.e. from 26 to 21 weeks, the critical path length has not reduced to the same extent. It has reduced by only one week i.e. from 88 to 87 weeks. This in other words the crashing of 5 weeks in the activity C has resulted only one week reduction in the project time. This happen only when the difference between the critical path and the other paths are less than the crashed period (In the example Critical path was 88 weeks and the next path length was 87. This difference of one week which is less than the crashed period of 5 weeks). Cases where the network has two or more critical paths crashing one activity may not result in any reduction of project duration as in case of crashing activity. For example after crashing activity F the project will have two critical paths i.e. A-B-F-G and A-C-E-G. Further crashing of activity E would not result in reduction of project duration. Because the path A-B-F-G would still remain as critical path. The project in example could be crashed to the maximum of 24 weeks by incurring additional expenditure of Rs.14500.

Crashing of project indicates the time-cost trade-off implication. The decision on the extent to which the project is to be crashed depends on the managerial decision based on paucity / availability of fund.

Project Control

Steps in Project Control

Fixing up the Review Period

Obtaining Progress Information

Comparing Actual Progress with the Schedule

Taking Appropriate Corrective Correction

Reporting to Higher Management

Updating

Conventions for Updating

Frequency of Updating

Redrawing Network

So far the discussions were on the use of PERT/CPM in planning and scheduling a project. This unit considers the third aspect, viz. the use of this method during project execution.

No management technique, however elegant and sophisticated, can take away the responsibility of management to exercise control through making decisions. Management techniques will, however, by providing the relevant information, enable management to take better-informed decisions and thereby exercise a finer degree of control than would be possible otherwise.

A project being a dynamic entity must respond to changing conditions if it is to be completed successfully. Further projects are always executed in an environment of endless change, and there is therefore the need for continuous reassessment and reappraisal of the project. The original plan and schedule cannot therefore be executed to the last detail because of a host of influencing factors, of which the following are a few.

- Changes in the date for completion
- Changes in activity durations
- Changes in resource availability
- Changes in activity relationship
- Failure of suppliers to deliver on time
- Unexpected environmental conditions (strikes, weather, etc.)

It is, therefore, necessary to have some procedure whereby the progress of work is checked at regular intervals against the plan, discrepancies highlighted and the necessary