Welcome

HUT 310 Management for Engineers

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Module IV-Topics

1. Project Management
2. Network construction
3. Arrow diagram
4. Redundancy
5. CPM
6. PERT
7. Networks
8. Scheduling computations
9. PERT time estimates
10. Probability of completion of project,
11. Introduction to crashing

Project management using PERT and CPM

- A ***project*** is defined as a combination of inter related activities that must be executed in a certain order before the entire task can be completed.

- An ***activity*** in a project is usually viewed as a job requiring time and recourses for its completion.

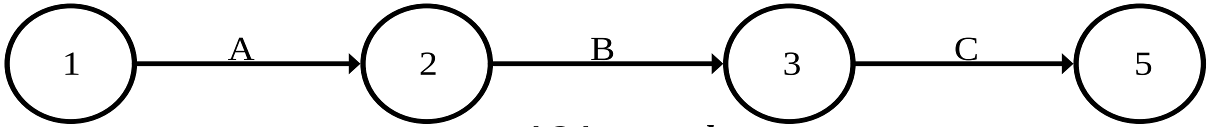
- ***Network analysis*** is the general name given to certain specific techniques which can be used for the planning, management and control of projects.

Objectives of network analysis

1. Minimize total project cost and time.
2. Effective utilization of resources.
3. Minimizing delays and interruption of the project.

Types of network

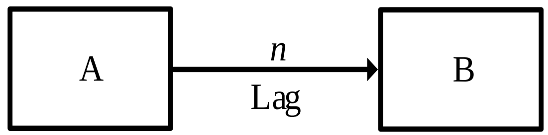
1. *AOA Network (Activity On Arrow Network)*



AOA network

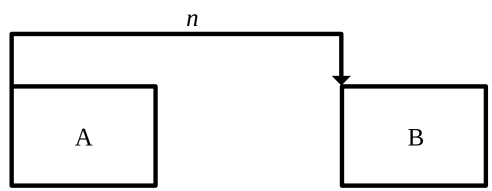
2. *AON Network (Activity On Node)*

a) Finish to Start



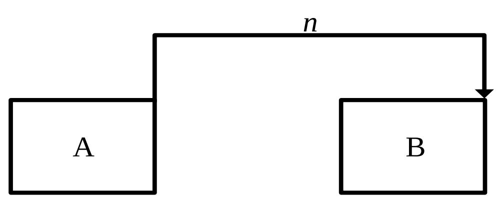
Finish to Start AON

b) Start to Start



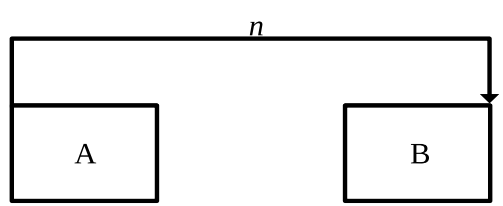
Start to Start AON

c) Finish to Finish



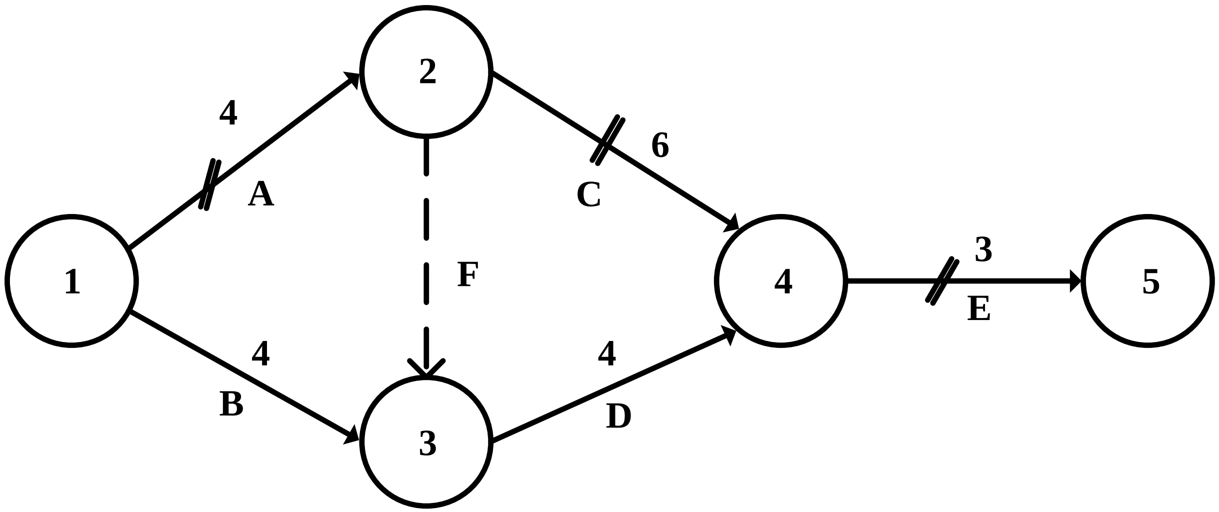
Finish to Finish AON

d) Start to Finish



Start to Finish AON

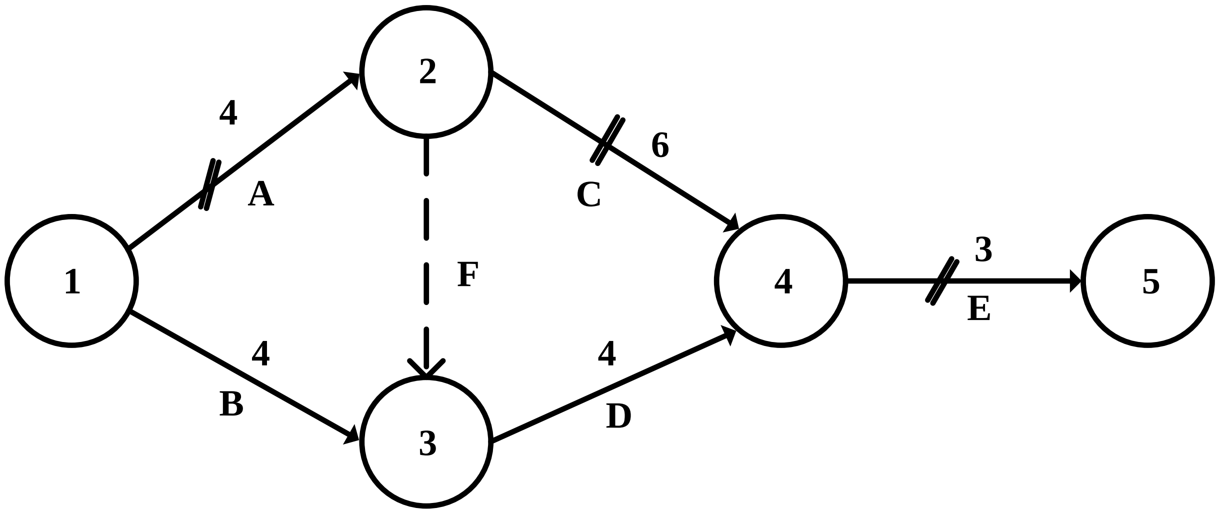
Terms related to network planning methods (AOA)



Critical path in network

- ***Network diagram** –It is a diagram which represents all the events and activities in sequence (in which they are required to be performed to complete the project), along with their inter relationships and with their interdependencies*.
- ***Event*** – An event is a specific instant of time which marks start or the end of an activity. Event consumes neither time nor resources. It is represented by a circle and the event number is written within the circle.
- ***Activity*** – Every project consists of a number of tasks which are called activities. Activities are classified as ***critical activities***, ***non-critical activities*** *and* ***dummy activities***.

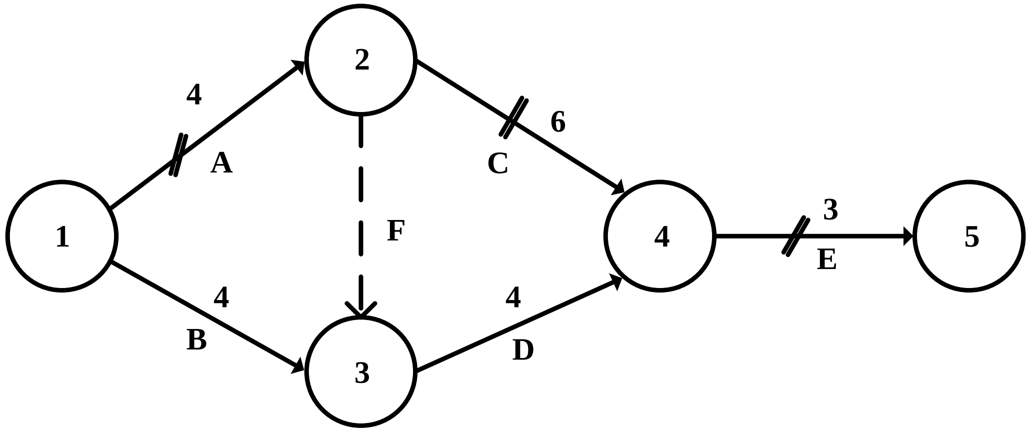
Terms related to network planning methods (AOA)



Critical path in network

- ***Critical activities*** – In a network diagram, critical activities are those, if consume more than their estimated time, the project will be delayed.
- ***Non-critical activities*** – Such activities have provision (float or slack), so that even if they consume time over and above the estimated time, the project will not be delayed.
- ***Dummy activity*** – When two activities start at the same instant of time the head events are joined by a dotted arrow and this is known as dummy activity.
- ***Critical path*** – It is that sequence of activities which decide the total project duration. Critical path is formed by critical activities.

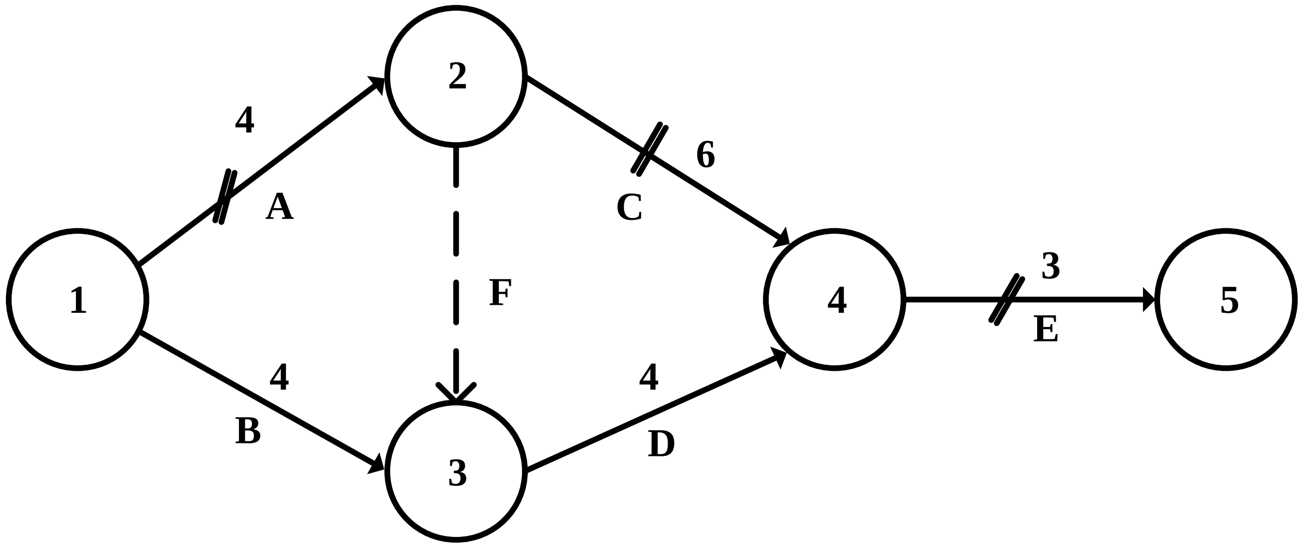
Terms related to network planning methods (AOA)



Critical path in network

- ***Duration*** – Duration is the time required to complete a task or an activity.
- ***Earliest Start Time (EST)*** – It is the earliest possible time at which an activity can start and is calculated by moving from first to last event in a network diagram.
- ***Earliest Finish Time (EFT)*** – It is the earliest possible time at which an activity can finish.
- ***Latest Finish Time (LFT)*** – It is the latest time by which the operation must be completed so that scheduled date for the completion of the project may not be delayed.
- ***Latest Start Time (LST)*** – It is the latest possible time by which an activity can start.
- ***Float** or **Slack*** – Float or slack means spare time or extra time over and above duration which a non-critical activity can consume without delaying project.

Numbering of events – Fulkerson's rule

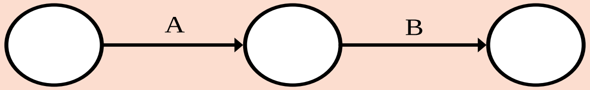
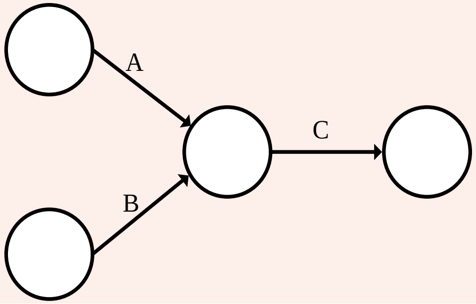
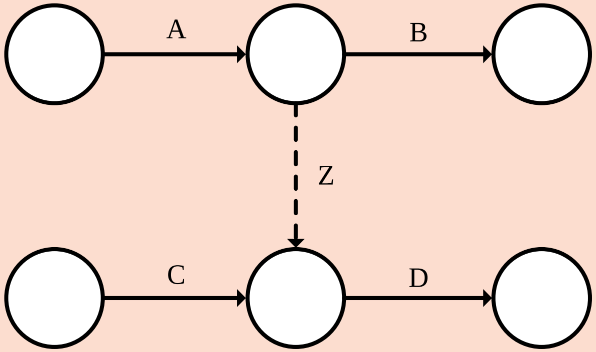


Critical path in network

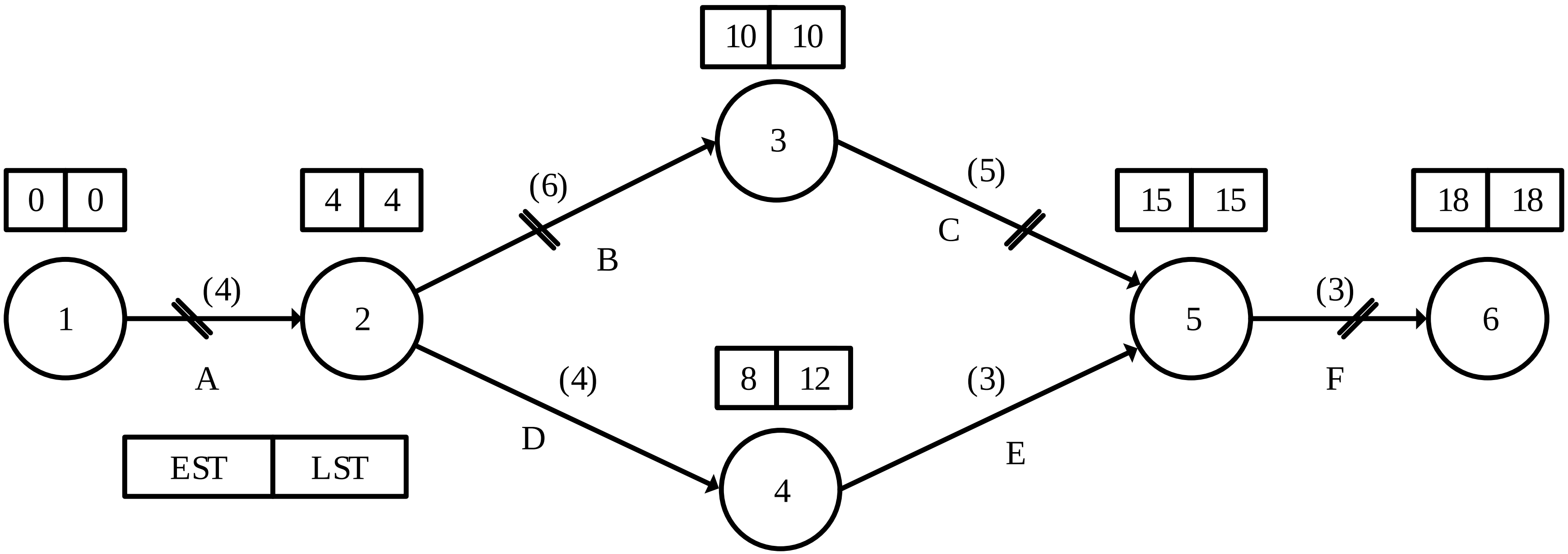
The steps involved in numbering of the events as per the ***Fulkerson's rule*** are :-

1. *The initial event, which has all outgoing arrows and no incoming arrow, is numbered as 1.*
2. *Delete all the arrows coming out from the node just numbered (i.e., 1). This step will create some more nodes (at least one) into initial events. Number these events in ascending order (i.e., 2, 3, etc.).*
3. *Continue the process until the final or terminal node which has all arrows coming in, with no arrow going out, is numbered.*

Some of the common combination of activity in a project

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 ‘D’ cannot begin until both A and ‘C’ is completed. But, ‘B’ can start after ‘A’ is completed. The activity ‘Z’, represented by dashed arrow, is a dummy activity. This does not consume any resource i.e., have zero time to complete.

Example :



Network diagram

Problems on construction of network diagram

1. Construct the network diagram for the following set of sequential activities for installation of water supply by digging well and installation of pump given below.

SL. 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

Problem 1: Solution

SL. No.	***Activity***	***Symbol***	***Preceding activity***	***Time (Days)***
1.	Site selection	A	——	7
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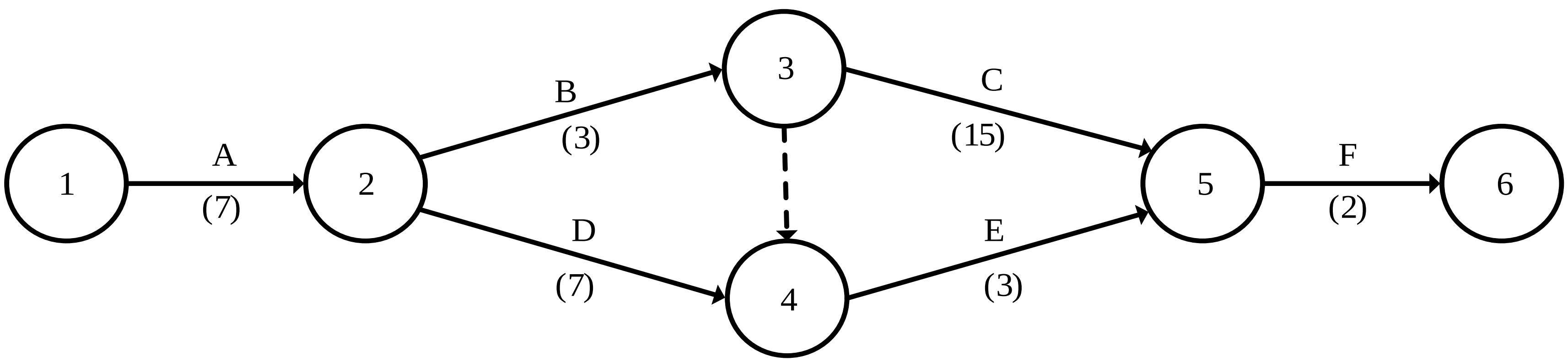


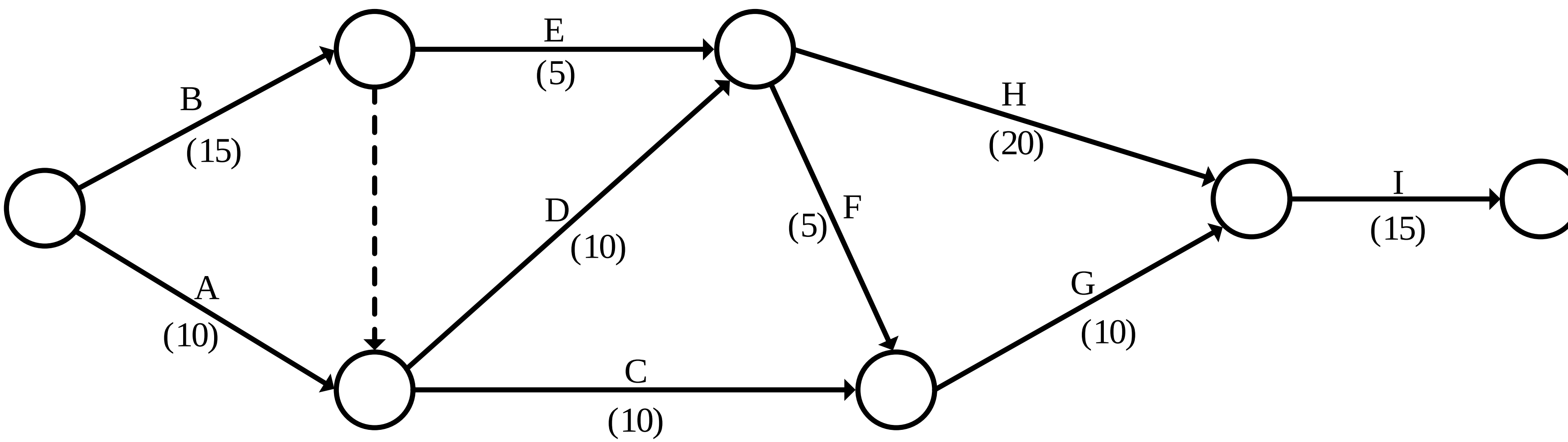
Problem 2 :

2. A project consists of 9 jobs with the following precedence relations and time estimates. Draw the project network and identify the critical path.

Job	***Predecessor***	***Time (Days)***
A	——	15
B	——	10
C	A, B	10
D	A, B	10
E	B	5
F	D, E	5
G	C, F	20
H	D, E	10
I	G, H	15

Problem 2: Solution

Job	***Predecessor***	***Time (Days)***
A	——	15
B	——	10
C	A, B	10
D	A, B	10
E	B	5
F	D, E	5
G	C, F	20
H	D, E	10
I	G, H	15

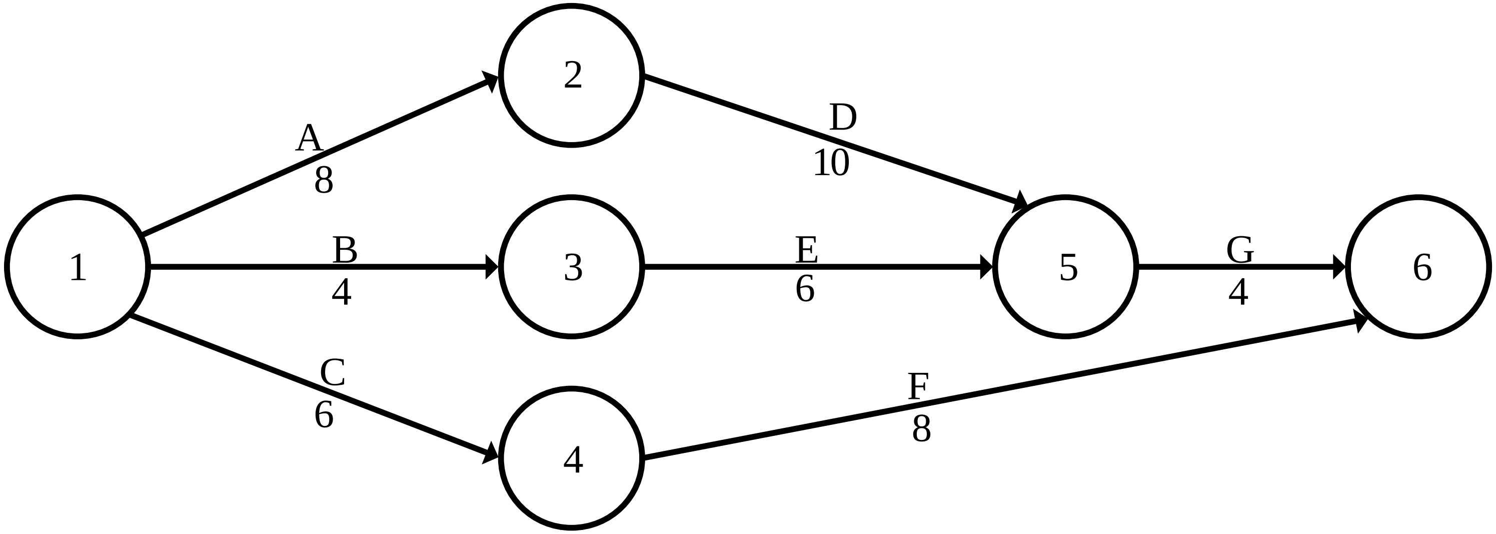


Critical Path Method (CPM)

- CPM is a technique used for planning and controlling the logical and economic sequence of operations for accomplishing a project.
- CPM model of the project includes the following.
  1. A list of all activities required to complete the project,
  2. The time (duration) that each activity will take to completion, and
  3. The dependencies between the activities.
- Using these values, the longest path of planned activities to the end of the project, and the earliest and latest time that each activity can start and finish without making the project longer is calculated.
- This process determines which activities are '***critical***' (i.e., on the longest path) and which have '***float***' (i.e., can be delayed without making the project longer).

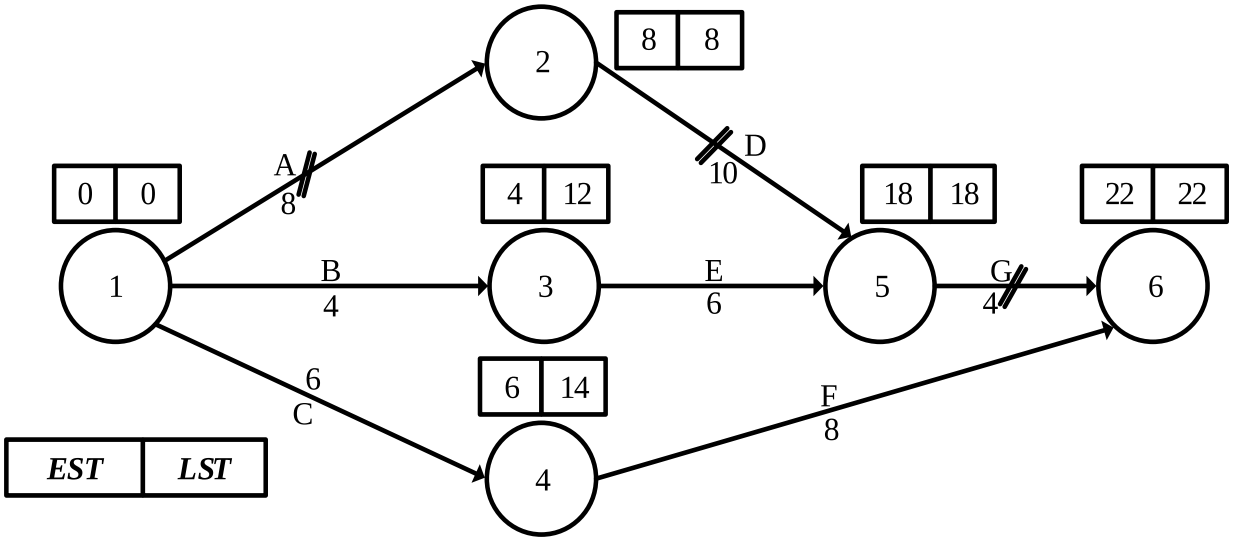
CPM-Problems : #1

1. Mark the critical path and find total project duration for the network diagram shown below. Also, calculate *EST, LST, EFT, LFT* and floats.



CPM-Problem-1

CPM-Problems : #1



CPM-Problem-1-Solution

Activity	*Duration (Days)*	*EST*	*EFT*	*LST*	*LFT*	*Float = LST-EST*
A(1-2)	8	0	8	0	8	0
C(1-4)	6	0	6	8	14	8
B(1-3)	4	0	4	8	12	8
D(2-5)	10	8	18	8	18	0
E(3-5)	6	4	10	12	18	8
G(5-6)	4	18	22	18	22	0
F(4-6)	8	6	14	14	22	8

Program (or Project) Evaluation Review Technique (PERT)

- ***Program*** (or ***Project***) ***Evaluation Review Technique***, commonly abbreviated as ***PERT***, is a model for project management designed to analyze and represent the tasks involved in completing a given project.

Steps involved in PERT

1. The project is broken down into various activities systematically.
2. Arrange all activities in logical sequence.
3. Construct the network diagram.
4. Events and activities are numbered.
5. Using three time estimate, the expected time for each activity is calculated.
6. Standard Deviation and variance of each activity are calculated.
7. ***EST*** and ***LFT*** are calculated.
8. Expected time, earliest starting time and latest finishing times are marked on the network diagram.
9. Slack is calculated.
10. Critical paths are identified and marked on the network diagram.
11. Length of critical path or total project duration is found out.
12. Lastly the probability that the project will finish at due date is calculated.

Program (or Project) Evaluation Review Technique (PERT)

Estimation of activity times in PERT

1. t_o (*optimistic time*)
2. t_m(*most likely time*)
3. t_p(*pessimistic time*)
4. t_e(*estimated time*), $t_e = \dfrac{t_o + (t_m \times 4) + t_p}{6}$

Estimation of variability of activity times

$$S_t(\text{standard deviation}) = \frac{t_p - t_o}{6}$$

$$V_t\ (\text{variance}) = \left[\frac{t_p - t_o}{6}\right]^2$$

Length of the critical path or ***the total project duration***

Total project duration = Sum of the duration of each critical activity.

Variance of the critical path

$$\textit{Variance of the critical path} = \textit{Sum of the variance of the each critical activity.}$$

$$\textit{Standard deviation, } S_t = \sqrt{\textit{Variance of the critical path}}$$

Program (or Project) Evaluation Review Technique (PERT)

The probability that the project will meet the schedule *or* ***the due date***

- The probability of completing the project within the scheduled time may be obtained by using the *standard normal variate*, where '*D*' is the expected time of project completion.

$$Z = \frac{D - T_e}{S_t}$$

where, Z = Normal deviation (Standard normal variate)

D = Due or schedule date (time) (desired time)

S_t = Standard deviation

T_e = Total project duration

- Probability of completion of project that corresponds to '*Z*' is obtained from the ***standard normal table***.

PERT-Problems : #1

1. The data regarding the activities in a project are given below. It is given that the schedule date of completion of project is 38 days. Draw the network diagram, find the critical path and find the probability that project can be completed at schedule time.

Activity	t_o *(Optimistic time)*	t_m *(Most likely time)*	t_p *(Pessimistic time)*
1-2	2	5	14
1-6	2	5	8
2-3	5	11	29
2-4	1	4	7
3-5	5	11	17
4-5	2	5	14
6-7	3	9	27
5-8	2	2	8
7-8	7	13	31

PERT-Problems : #1

Solution :

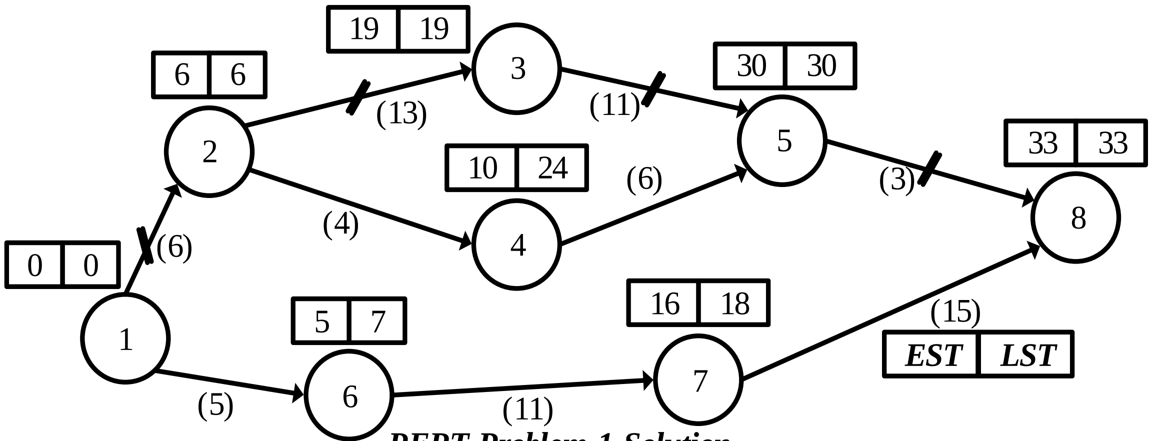
We know, $t_e = \dfrac{t_o + (t_m \times 4) + t_p}{6}$, $S_t = \dfrac{t_p - t_o}{6}$, $V_t = \left[\dfrac{t_p - t_o}{6}\right]^2$

Estimated time, standard deviation and variance for the rest of the activities are computed and tabulated in the table below.

Activity	***t_e (Estimated time)***	***S_t (Standard deviation)***	***V_t (Variance)***
1-2	6	2	4
1-6	5	1	1
2-3	13	4	16
2-4	4	1	1
3-5	11	2	4
4-5	6	2	4
6-7	11	4	16
5-8	3	1	1
7-8	15	4	16

PERT-Problems : #1

Network diagram is drawn as below.



PERT-Problem-1-Solution

Values LST, EST, EFT and LFT of other activities are calculated and are tabulated in the table below.

Activity	*EST*	*LST*	*Total slack = LST–EST*
1-2	0	0	0
1-6	0	2	2
2-3	6	6	0
2-4	6	20	14
3-5	19	19	0
4-5	10	24	14
6-7	5	7	2
5-8	30	30	0
7-8	16	18	2

PERT-Problems : #1

Length of the critical path or the total project duration =

= Sum of the duration of each critical activity = 6 + 13 + 11 + 3= 33 days.

Variance of the critical path = Sum of the variance of each critical activity

= 4 + 16 + 4 + 1 = 25

$$Standard\ deviation,\ S_t = \sqrt{Variance\ of\ the\ critical\ path} = \sqrt{25} = 5$$

The probability that the project will meet the schedule or the due date

D = the due or schedule date(time) (Desired Time) = 38 days

Total project duration = T_e = 33

Substituting different values in the equation, we get,

$$Z = \frac{D - T_e}{S_t} = \frac{38 - 33}{5} = 1$$

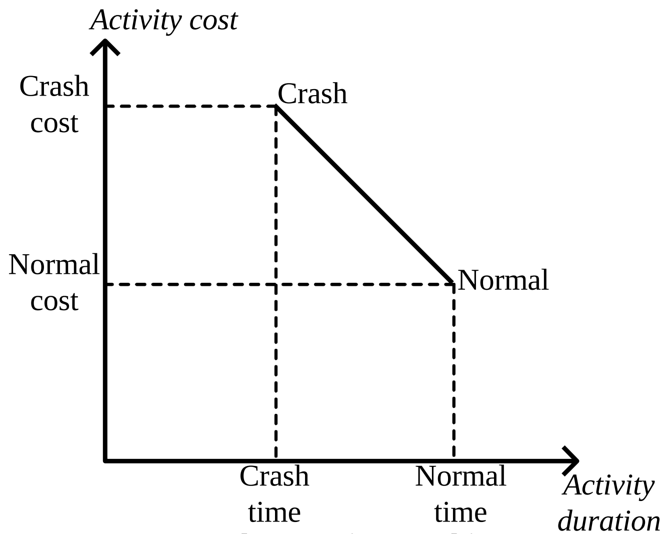
The corresponding value of probability can be read from the *normal distribution table* and is 0.841.

Project crashing

- The process of reducing the time of the project by reducing the scheduled time of some of the activities is called ***crashing***.

- Project crashing is accomplished by subcontracting, overtime, extra shifts, increasing the number of workers, additional capacity installation, etc.

Important terms used in project crashing



Cost slope-Project crashing

1. ***Normal time*** – It is the time taken by an activity when it is performed in the normal way.
2. ***Normal cost*** – It is the cost for carrying out an activity when it is performed in the normal way.
3. ***Crash time*** – The crash time refers to the shortest possible time to complete an activity with additional resources.
4. ***Crash cost*** – The crash cost refers to the activity cost under the crashing activity time.
5. $$\textbf{\textit{Crash cost per period}} = \frac{\textbf{\textit{Crash cost}} - \textbf{\textit{Normal cost}}}{\textbf{\textit{Normal time}} - \textbf{\textit{Crash time}}}$$

Problems on project crashing : #1

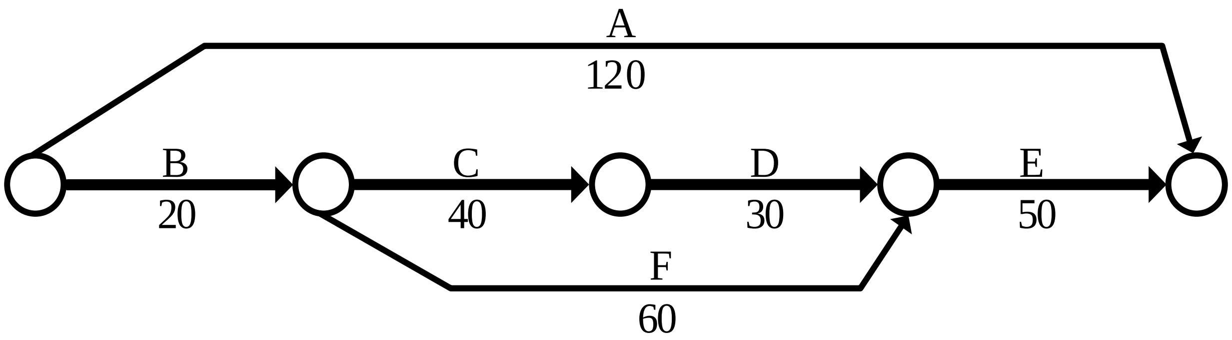
1. The table given below summarizes the time-cost information for the activities. The owner wants to finish the project in 110 days. Find the minimum possible cost for the project to finish it on 110 days.

Activity	Preceding activity	Normal duration (days)	Crash Duration (days)	Normal cost	Crash cost
A	–	120	100	₹12000	₹14000
B	–	20	15	₹1800	₹2800
C	B	40	30	₹16000	₹22000
D	C	30	20	₹1400	₹2000
E	D, F	50	40	₹3600	₹4800
F	B	60	45	₹13500	₹18000

Problems on project crashing : #1

Solution :

From the given data, the network diagram is drawn as below (*Crashing problem-1-Stage-1*).

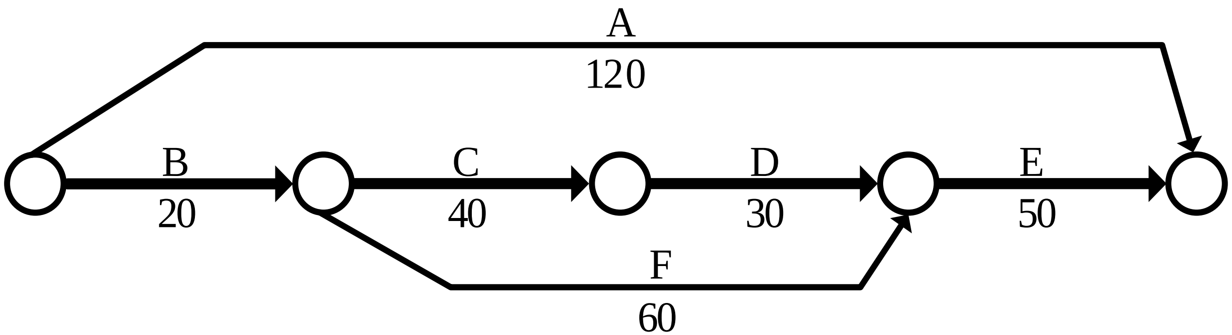


Crashing problem-1-Stage-1

$$\text{We have, } Crash\ cost\ slope\ = \frac{Crash\ cost - Normal\ cost}{Normal\ time\ -\ Crash\ time}$$

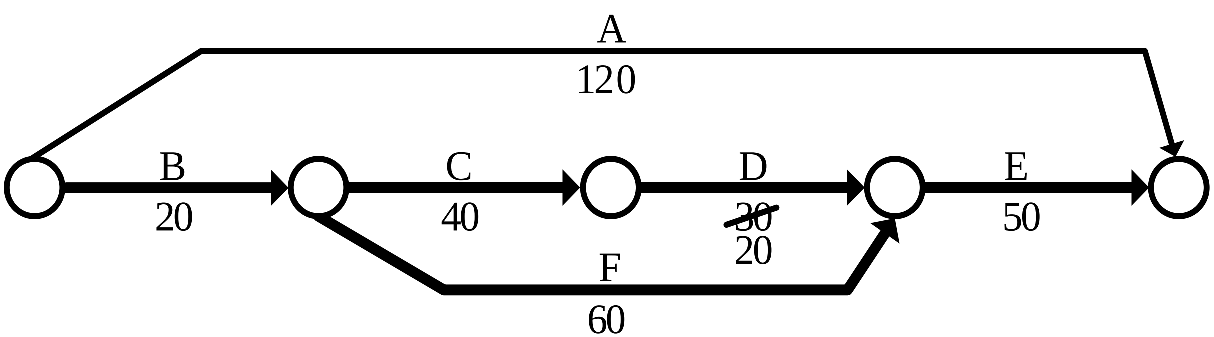
Activity	Crash cost slope
A	100
B	200
C	600
D	**60**
E	120
F	300

Problems on project crashing : #1



Crashing problem-1-Stage-1

The normal cost for the project is ₹48300 and the normal duration is the duration of activities in the critical path, which is 140 days. Activity having least-cost slope is activity D. Maximum of 10 days can be cut from this activity by reducing the duration of activity D to the crash duration of 20 days.

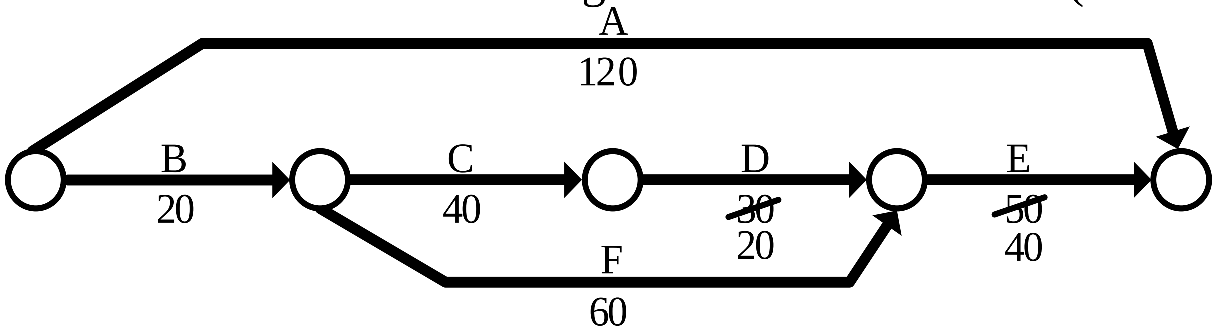


Crashing problem-1-Stage-2

Now, the overall duration is 130 days and there are multiple critical paths, viz., B-F-E and B-C-D-E. Total project cost at this stage is the normal cost of ₹48300 plus the cost of crashing the activity D by 10 days (₹2000–₹1400), which gives the value ₹48900.

Problems on project crashing : #1

The next activity to be crashed would be the activity E, since it has the least-cost slope (₹120 per day) of any of the activities on the critical path. Activity E can be crashed by a total of 10 days. Crashing the activity E by 10 days will cost an additional ₹120 per day or is ₹1200. Modified network diagram is drawn as below (*Crashing problem-1-Stage-3*).

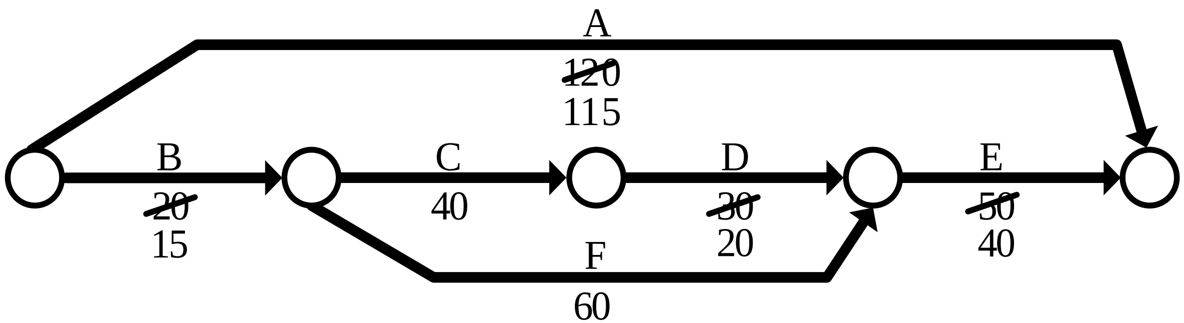


Crashing problem-1-Stage-3

The project duration is now 120 days and the total project cost is ₹50100. There are now three critical paths (A, B-C-D-E, and B-F-E). Activity A is paired with each of the other activities to determine which has the least overall cost slope, i.e., activity A and activity B are combined and crashed we get the least-cost slope, i.e., Activity A (₹100/day) + Activity B (₹200/day) = ₹300/day.

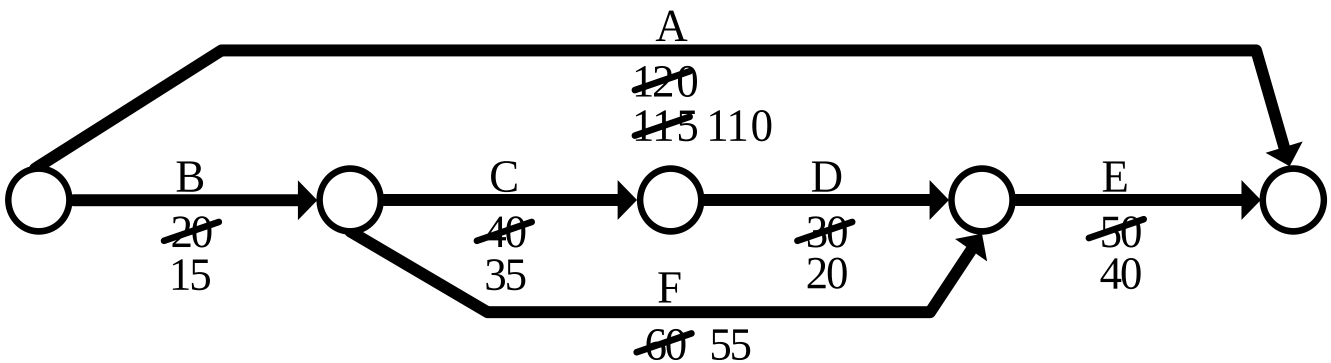
The least-cost slope will be activity A plus activity B for a cost increase of ₹300 per day. Reducing the project duration by 5 days will add 5 x 300 = ₹1500 crashing cost and the total project cost would be ₹51600.

Problems on project crashing : #1



Crashing problem-1-Stage-4

Final step in crashing the project to 110 days would be accomplished by reducing the duration of activity A by 5 days to 110 days, reducing activity C by 5 days to 35 days, and reducing activity F by 5 days to 55 days. The combined cost slope for the simultaneous reduction of activity A, activity C, and activity F would be ₹1000 per day. For 5 days of reduction this would be an additional ₹5000 in total project cost.



Crashing problem-1-Stage-5

Discussions

1. Explain the concept and objectives of network analysis. What are its different stages? Discuss its advantages and limitations.
2. Explain PERT and its importance in network analysis?
3. Define organizing and explain the importance of organizing in the present business environment.
4. Explain the concepts of crashing and dummy activity in project management.
5. Differentiate between CPM and PERT.