

CHAPTER- 3: PROJECT MANAGEMENT

1. What is a project?

a. Project is an interrelated set of activities that has a definite starting and ending point resulting in to an unique product. few examples of project are-

- Constructing a bridge, dam, highway or building.
- Producing an aeroplane, missile or rocket.
- Introducing a new product.
- Installation of a large computer system.
- Construction of a ship.
- Maintenance of major equipment/plant.
- Commissioning of a power plant.
- Conducting national election.

2. Basic steps in project management

Managing a project (regardless of its size and complexity) requires identifying every activity to be undertaken and planning- when each activity must begin and end in order to complete the overall project in time. typically all projects involve the following steps:

- Description of the project.
- Development of network diagram.
- Insertion of time of starting/ending of each activity.
- Analysis of the network diagram.
- Development of the project plan
- Excetion of the project.
- Periodically assessment of the progress of project.

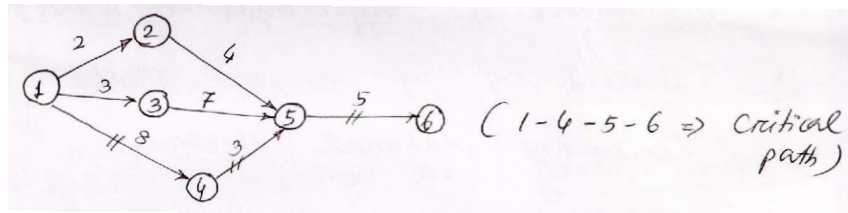
3. Terminologies used in network diagram

(i) **Activity:** An activity means work/job. it is a time consuming process. it is represented by an arrow (\rightarrow) in the network diagram. as shown below.

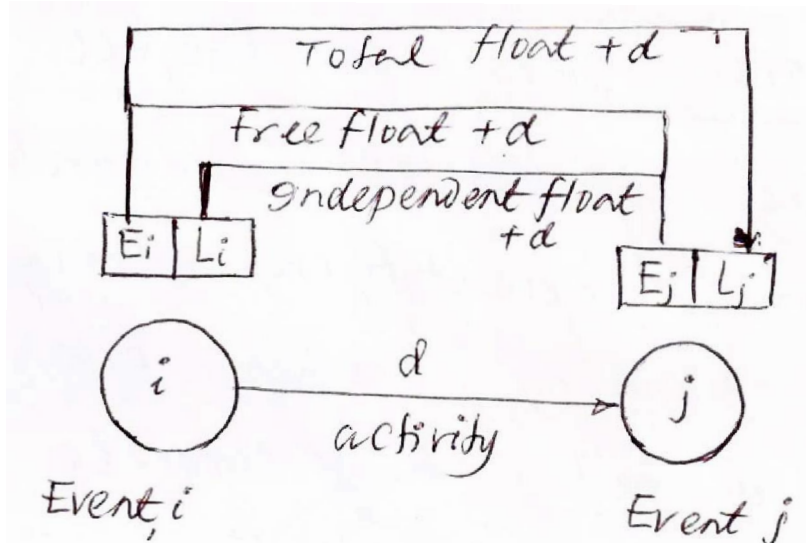
Tail \rightarrow head

(ii) **Event :** An event is a specific instant of time \rightarrow marks the "start" and "end" of an activity.

(iii) **Critical path:** It is the sequence of activities which decides the total project duration. Ex.



- (iv) **Duration (d)** : Duration is the estimated or actual time required to complete a task or an activity.



- (v) **Total project time**: time to complete the project. In other words, it is the duration of critical path.
- (vi) **Earliest start time (Ei)**: It is the earliest possible time at which an activity can start. It is calculated by moving from 1st to last event in the network diagram.
- (vii) **Latest start time (Li)** : It is the latest possible time by which an activity can start.
- (viii) **Earliest finish time (Ej)** : It is the earliest possible time at which an activity can finished/end.
- (ix) **Latest finish time (Lj)** : It is the last event time of the head event. It is calculated by moving backward in the network diagram.
- (x) **Float/slack** : Slack is with reference to an event. Float is with reference to an activity.
- (xi) **Total float** : (Latest finish time- Earliest start time) - Activity duration (Su fig. above)
- (xii) **Free float** : (Earliest finish time- Earliest start time) – Activity duration.

- (xiii) **Independent float** : (EST of head event – LST of tail event) – Activity duration.
- (xiv) **Optimistic time (to)** : Time estimate for fast activity completion.
- (xv) **Pessimistic time (tp.)** : Maximum time duration. that an activity can take.
- (xvi) **Most likely time (tm)** : best guess of activity completion time.
- (xvii) **Expected time (te)** : $\frac{to+4tm+tp}{6}$
- (xviii) **Variance of an activity time** : $\sigma_e^2 = \left(\frac{tp-to}{6}\right)^2$
- (xix) **CPM** – Critical path method
- (xx) **PERT**- Program evaluation & review technique.

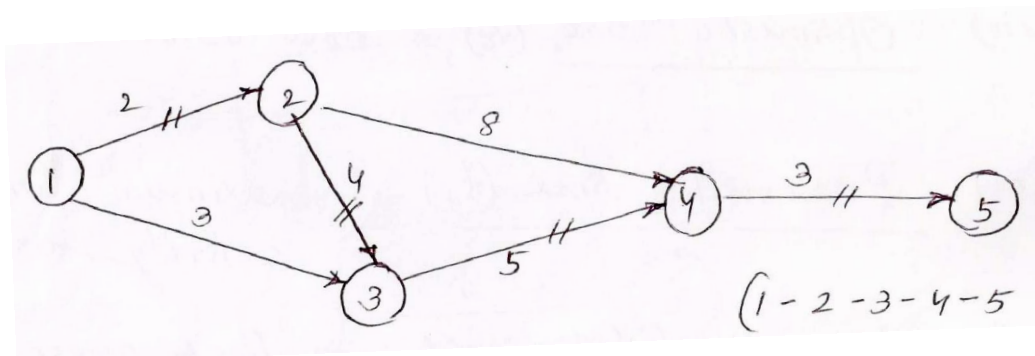
© Project management through PERT/CPM.

Project scheduling using Gantt chart was done from 1917. Till 1956. Between 1956-58 two new scheduling techniques were developed.

- (i) PERT
- (ii) CPM

Both are based on the use of a network/graphical model to depict the work tasks being scheduled. The popularity of network based scheduling can be attributed to its many benefits, especially its ease of use. Other benefits include the following.

- (1) It provides a visual display of needed task and their temporal ordering which makes it easy to see how the tasks should be sequenced as shown below.



This assist communication and cooperation among task teams because each team can see how its work affect other team.

- (2) It provides relatively accurate estimate of the time required to complete the project at the proposed resource level.
- (3) It identifies and highlights the tasks that are critical to keep the project on schedule.
- (4) It provides a method for evaluating the time-cost trade-offs resulting from reallocating resources among tasks.
- (5) It provides a method for monitoring the project throughout its life cycle. as the project progresses, PERT/CPM easily identifies changes in which tasks are critical and how the expected completion date is affected.
- (6) It provides a convenient method for incorporating uncertainty regarding task times into the schedule and it helps to evaluate the effect of this uncertainty on project completion time.

Differences bet PERT & CPM

Sl No.	PERT	CPM
1.	PERT is a probabilistic model with uncertainty in activity duration. activity duration is calculated from t_o , t_p & t_m by relation $t_e = \frac{t_o + 4f_m + t_p}{6}$	1. CPM is a deterministic model with well known activity duration
2.	It is an event oriented approach	2. It is an activity oriented approach
3.	PERT terminology uses word like network diagram event and slack	3. CPM terminology uses word like arrow diagram nodes and floats
4.	The use of dummy activity is required for representing the proper sequencing	4. No dummy activity
5.	PERT basically does not demarcate between critical and noncritical activity	5. CPM marks the critical activity
6.	PERT is applied in projects where resources are always available	6. CPM is applied to projects where minimum overall cost is the prime importance.
7.	PERT is suitable in defence project & R & D, where activity time can't be readily predicted	7. Suitable for plant maintenance, civil construction projects etc. where activity duration is known.

Rules for Network Construction

1. The network should have a unique starting node (tail event) and unique completion node (head event).
 2. No activity should be represented by more than one arrow (\rightarrow) in the network.
 3. No two activities should have the same starting node and same ending node.
 4. Dummy activity is an imaginary activity indicating precedence relationship only. duration of dummy activity is zero.
 5. The length of arrow bear no relationship to activity time.
 6. The arrow in a network identifies the logical condition of dependence.
 7. The direction of arrow indicates the direction of work flow.
 8. All networks are constructed logically or based on the principal of dependency.
 9. No event can be reached in a project before the completion of precedence activity.
 10. Every activity in the network should be completed to reach the objective.
 11. No set of activities should form a circular loop.
- Network construction, CPM network calculation. (with the help of diff. types of problems)

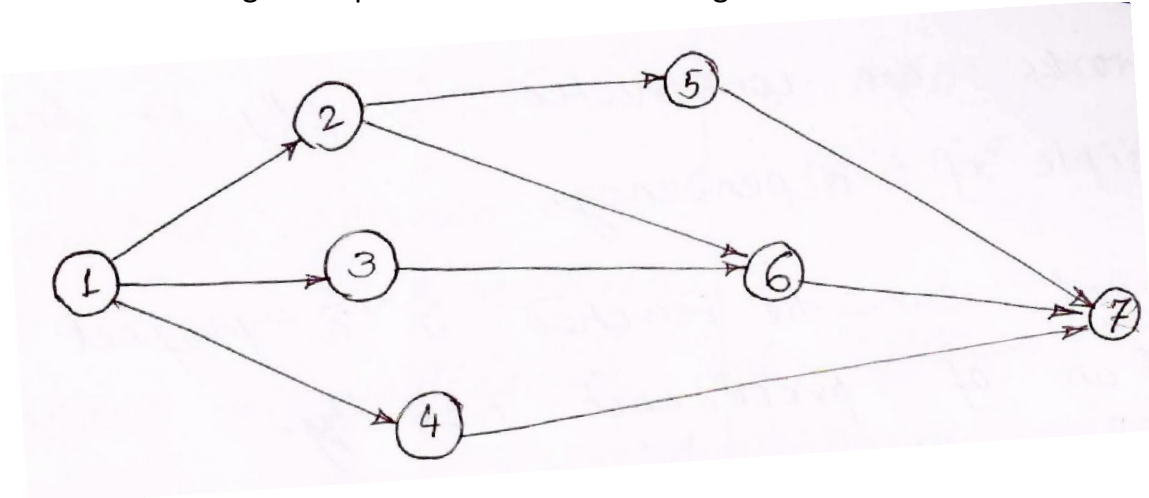
Prob- 1: A project consists of the following activities and time estimates

Activity	Least time/optimistic time (to), days	Greatest time/Pessimistic time (tp), days	Most likely time (tm), days
1-2	3	15	6
1-3	2	14	5
1-4	6	30	12
2-5	2	8	5
2-6	5	17	11
3-6	3	15	6
4-7	3	27	9
5-7	1	7	4
6-7	2	8	5

Construct the network. determine the expected task time. show the critical path. what is the project duration?

Solutions

The network diagram is presented in the following

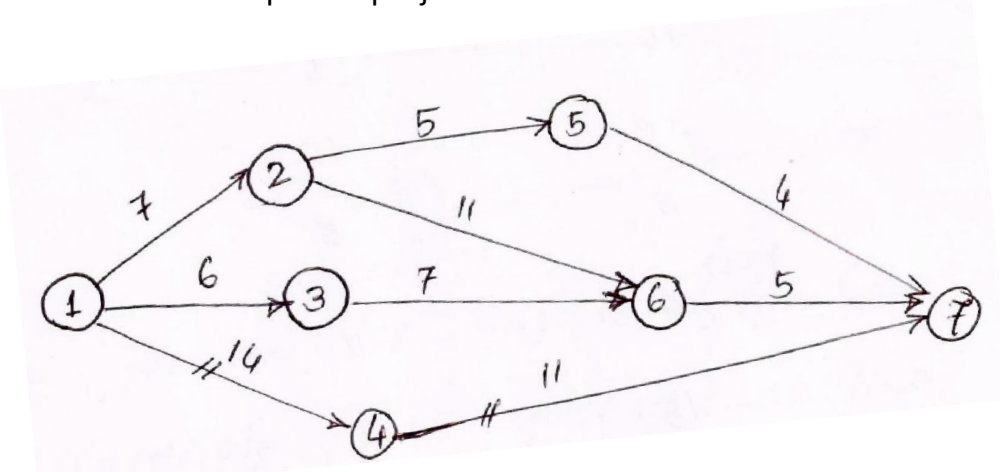


The formula for expected task time $(t_e) = \frac{t_0 + t_p + 4 t_m}{6}$

Accordingly the expected task times for different activities are as follows:

<u>Activity</u>	<u>(t_e) values, days</u>
1-2 →	7
1-3 →	6
1-4 →	14
2-5 →	5
2-6 →	11
3-6 →	7
4-7 →	11
5-7 →	4
6-7 →	5

The expected task times are shown on the network diagram to determine the critical path & project duration.



From this network diagram 1-4-7 represents the critical path and the duration for project completion = total time along the critical path = 14+11 = 25 days

Problem-2

A project consists of the following activities and time estimates.

Activity	Optimistic time (t ₀), day	Pessimistic time (t _p), day	Most likely time (t _m), day
1-2	3	15	6
1-3	2	14	5
1-4	6	30	12
2-5	2	8	5
2-6	5	17	11
3-6	3	15	6
4-7	3	27	9
5-7	1	7	4
6-7	2	8	5

- a) What is the project duration?
- b) What is the probability that the project will be completed in 27 days?

Solution:

In order to find out the project duration, the expected task time for each activity is to be determined using the formula $\rightarrow t_e = \frac{t_0 + t_p + 4 t_m}{6}$

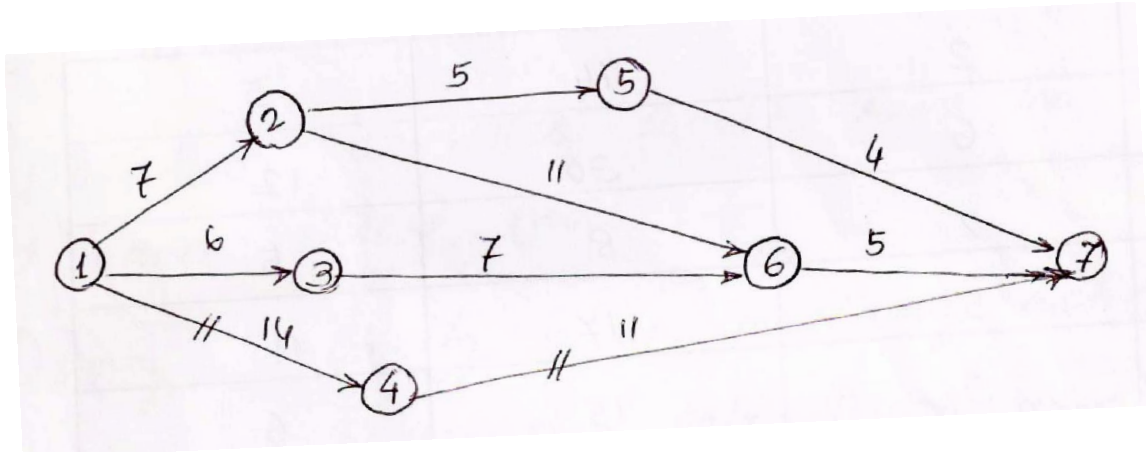
In order to find out the probability of completion in a given day, standard deviation (σ) for the critical path is to be determined using the formula

$$\sigma^2 = \left(\frac{t_p - t_0}{6}\right)^2$$

So the required data are presented in the following

Activity	t_0	t_p	t_m	t_e	σ^2
1-2	3	15	6	7	4
1-3	2	14	5	6	4
1-4	6	30	12	14	16
2-5	2	8	5	5	1
2-6	5	17	11	11	6
3-6	3	15	6	7	4
4-7	3	27	9	11	16
5-7	1	7	4	4	1
6-7	2	8	5	5	1

Using the expected time (t_e) value, the network is drawn as shown below.



a) 1-4-7 is critical path. The duration of project = 14+11= 25 days.

b) The sum of variances along the critical path = 16+16 = 32.

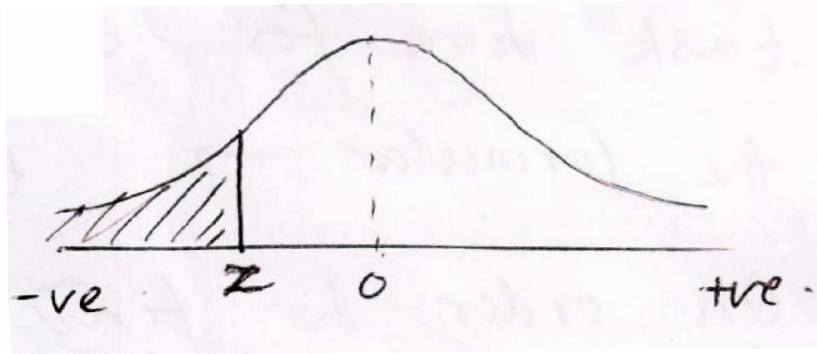
Now the standard deviation, $\sigma = \sqrt{\sigma^2} = \sqrt{32} = 5.656$

Expected project duration, $T_e = 25$ days,

Given $D = 27$ days,

With reference to Normal Distribution Curve

$$Z = \frac{D - T_e}{\sigma} = \frac{27 - 25}{5.656} = 0.35$$



From Normal Distribution Table, for $Z = 0.35$, the fraction of (shadow) area = 0.637 i.e., 63.7%

So probability of completion of project in 27 days is 63.7%

[Note: If probability of completion of project will be given and the due date (D) will be asked to find out, then backward calculation can give the result].

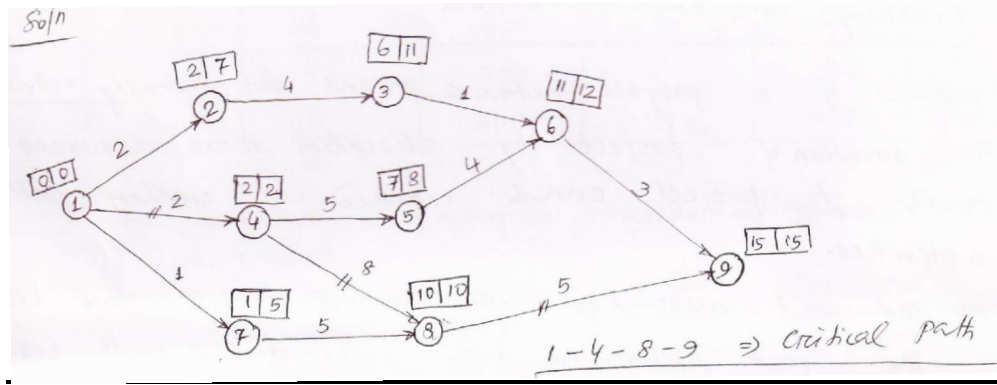
Problem-3:

A project schedule has the following characteristics →

Activity	1-2	1-4	1-7	2-3	3-6	4-5	4-8	5-6	6-9	7-8	8-9
Duration, day	2	2	1	4	1	5	8	4	3	5	5

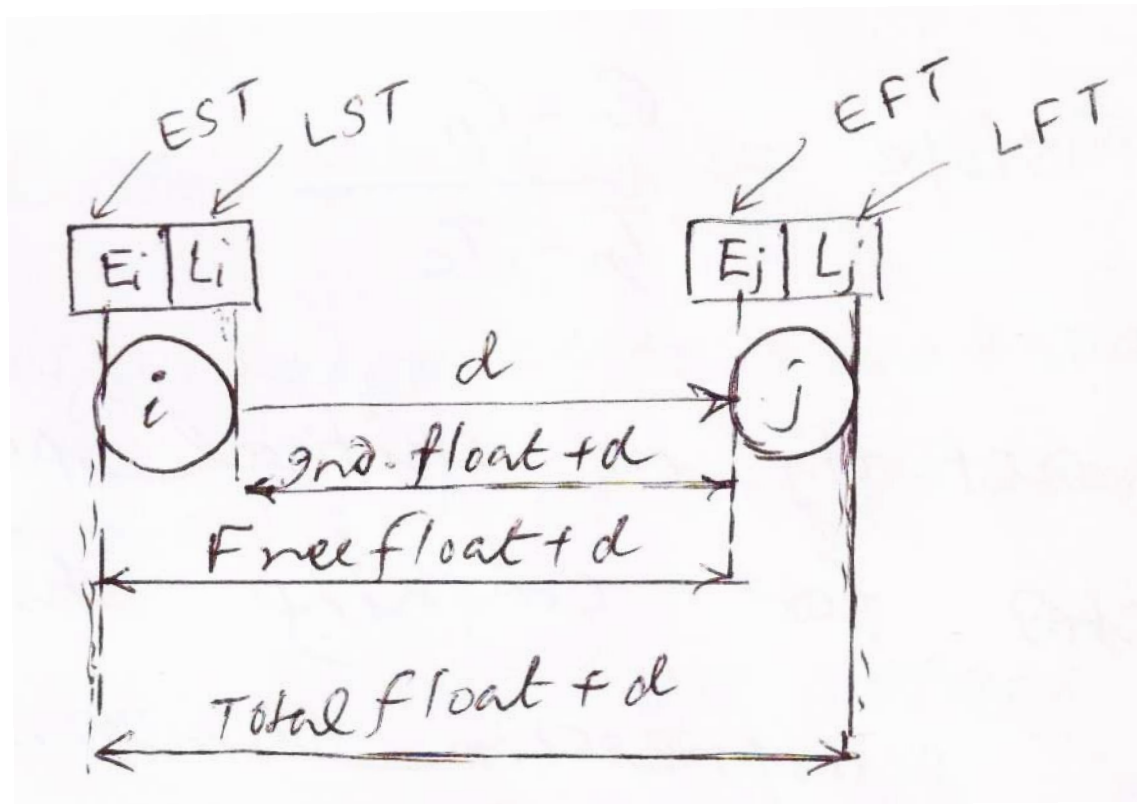
Construct the network and locate the critical path. Calculate the various time estimates and floats.

Solution:



The earliest start time (EST), the latest start time (LST) the earliest finish time (EFT) and latest finish time (LFT) are shown above at each node point by square block in the network diagram.

The various floats can be calculated w.r.t. the following figure :-



Activity	Duration	EST	LST	EFT	LFT	Total float	Free float	Independent float
1-2	2	0	0	2	7	5	0	0
1-4	2	0	0	2	2	0	0	0
1-7	1	0	0	1	5	4	0	0
2-3	4	2	7	6	11	5	0	-5
3-6	1	6	11	11	12	5	4	-1
4-5	5	2	3	7	8	1	0	-1
4-8	8	2	3	10	10	0	0	-1
5-6	4	7	8	11	12	1	0	-1
6-9	3	11	12	15	15	1	1	0
7-8	5	1	5	10	10	4	4	0
8-9	5	10	10	15	15	0	0	0

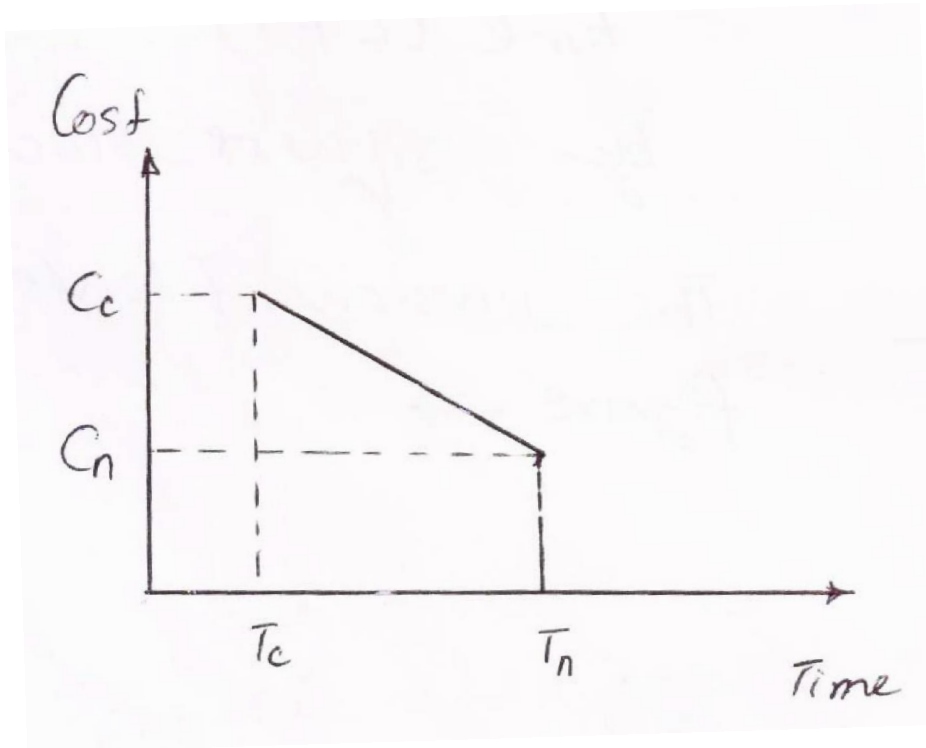
(C) Crashing of Project Network

Crashing of a project network means intentionally reducing the duration of project by allocating more resources to it. A project can be crashed by crashing critical activities.

The cost associated with normal time → normal cost

The cost associated with crashed time → crash cost.

It is obvious that the crash cost should be more than the normal cost.



The slope of crashing an activity is given by :

$$\text{Slope} = \frac{C_c - C_n}{T_n - T_c}$$

The activity on critical path selected for crashing should have minimum slope and for compression limit = min [crash limit, free float limit]

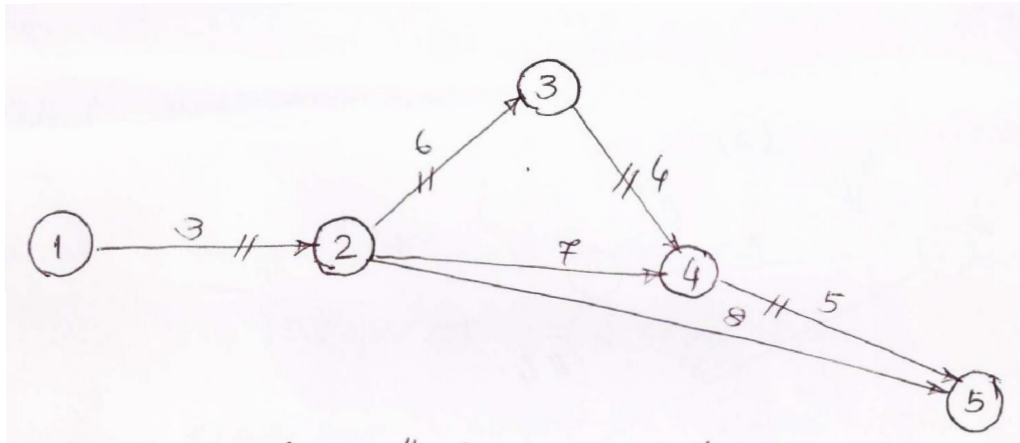
Typical Example on Crashing

For a network shown below, normal time, crash time, normal cost, crash cost are given in table. Contract the network by crashing it to optimum value and calculate optimum project cost. Indirect cost = Rs 100/- per day.

Activity	Normal		Crash	
	Time in days	Cost in Rs	Time in days	Cost in Rs
1-2	3	300	2	400
2-3	6	480	4	520
2-4	7	2100	5	2500
2-5	8	400	6	600
3-4	4	320	3	360
4-5	5	500	4	520

Solution:

By using the network diagram as shown below



The critical path → 1-2-3-4-5.

The project duration = 3+6+4+5 = 18 days.

On this path, crash time = 2+4+3+4 = 13 days

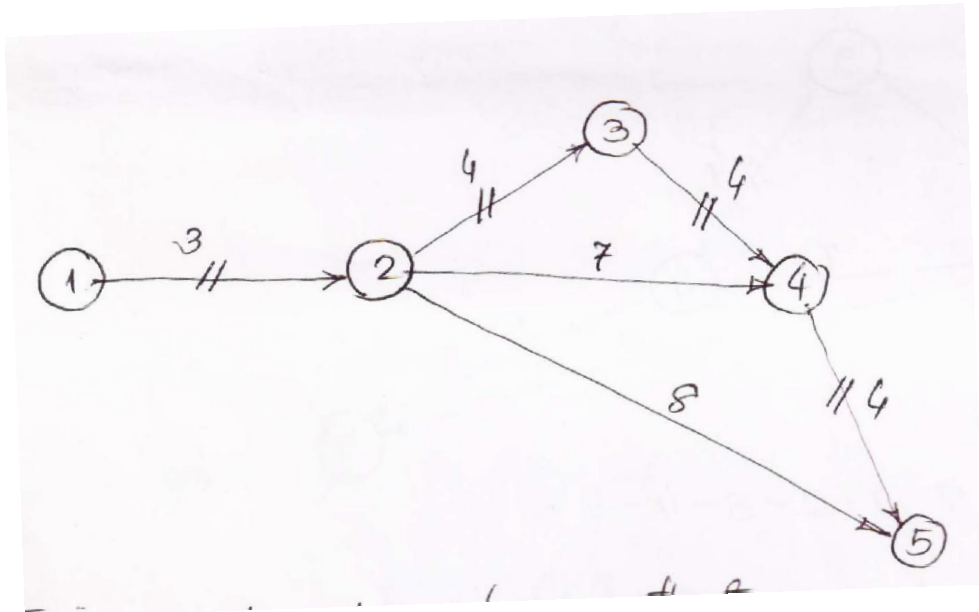
Normal cost = 300+480+2100+400+320+500 = Rs 4100/-

Crash cost = 400+520+2500+600+360+520 = Rs 4900

To contract the network in the 1st stage we should identify the activities on the critical path having lowest cost slope. For this purpose, the cost slopes are calculated as follows:

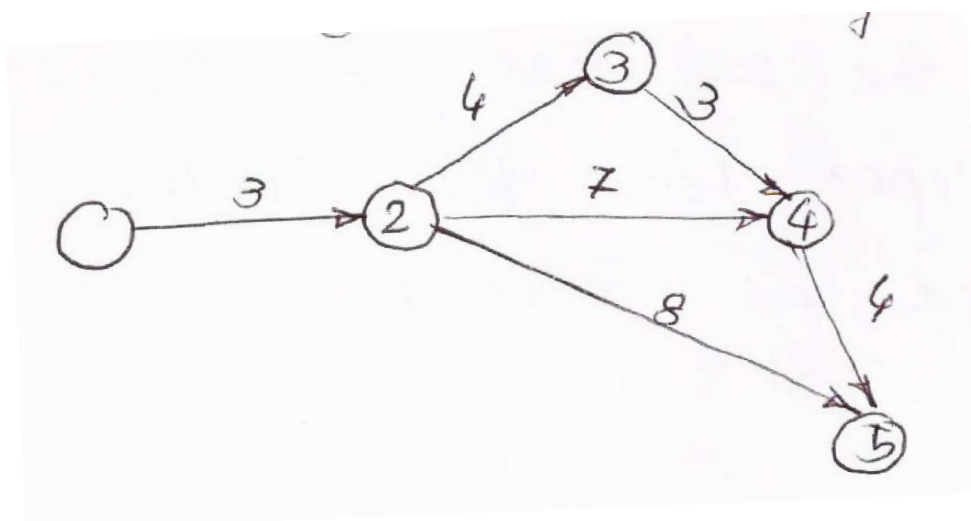
Activity	Normal		Crash		ΔC	ΔT	$\frac{\Delta C}{\Delta T}$
	Time, days	Cost, Rs	Time, days	Cost, Rs			
1-2	3	300	2	400	100	1	100
2-3	6	480	4	520	40	2	20
2-4	7	2100	5	2500	400	2	200
2-5	8	400	6	600	200	2	100
3-4	4	320	3	360	40	1	40
4-5	5	500	4	520	20	1	20

It is observed from the above table that, the critical path activities 2-3 & 4-5 have least cost slope. Therefore, these activities are 1st crashed. The modified network is drawn in the following.



This network shows that after crashing activity 2-3 by 2 days and activity 4-5 by 1 day, the critical path is same i.e. 1-2-3-4-5 and the project duration = 15days.

Now, in the 2nd stage, the least cost slope in the remaining activities is for activity 3-4 on the critical path. By crashing this activity, the new network diagram becomes:



Now 2 paths become critical path i.e. 1-2-4-5 and 1-2-3-4-5 and the duration = 14days.

Now we see that there is no other activity on both the critical paths which has cost slope less than indirect cost (i.e., Rs 100/-). This shows that this is the optimum network and hence optimum project duration = 14days.

Total direct project cost for this optimum condition = Direct cost for all activities on the network = Sum of costs of activities 1-2 , 2-3, 3-4, 4-5, 2-4, 2-5 = $300+520+360+520+2100+400 = \text{Rs } 4200/-$

Indirect cost for 14 days = $14 \times 100 = 1400/-$

Total project cost after crashing = $4200+1400 = \text{Rs } 5600/-$

Whereas, total cost with all normal activities = $4100+18 \times 100 = \text{Rs } 5900/-$

So b crashing cost is reduced and time is also reduced.

(C) **Project scheduling with limited resources**

Usually the resources in project are:

- ❖ Manpower
- ❖ Equipments
- ❖ Money

These resources are limited. Hence the objective is to adjust noncritical activities between their EST & LFT such that the peak resource requirement is reduced. There are 2 types of problems under this category.

- (1) Resource leveling (to minimize the peak requirement and smooth out period to period variation).
- (2) Resource allocation (adjust the noncritical activities such that the resource requirement in each period is within the available range).

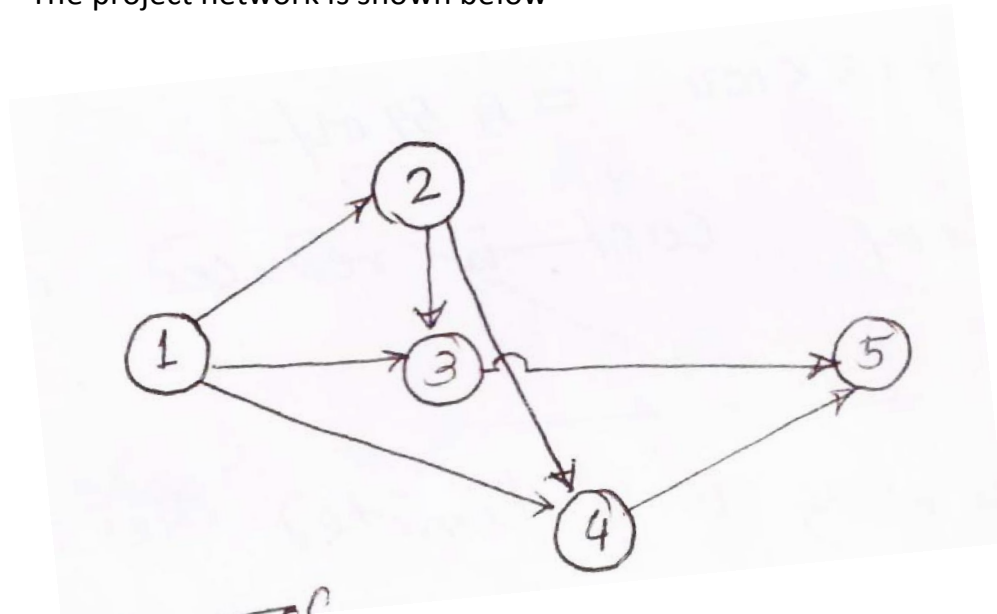
(1)Resource Leveling Technique

Ex: Consider the following problem of project scheduling to obtain a schedule which will minimize the peak manpower requirement and smooth out period to period variation of manpower requirement.

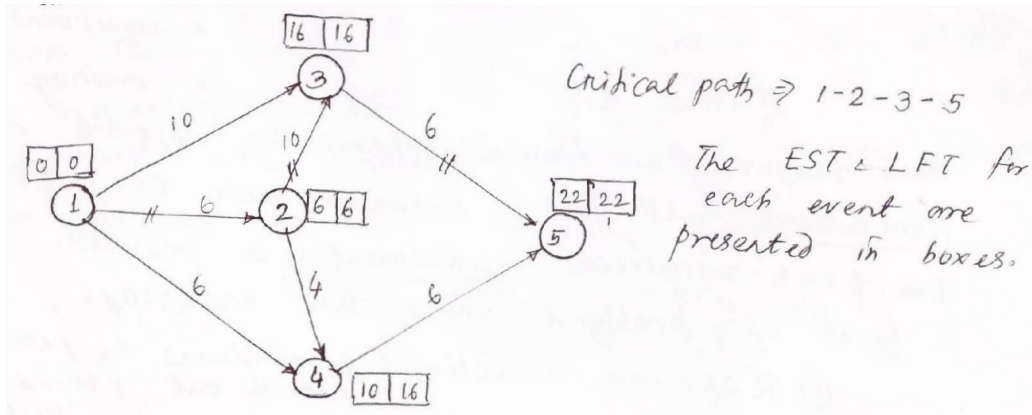
Activity	Duration	Manpower requirement
1-2	6	8
1-3	10	4
1-4	6	9
2-3	10	7
2-4	4	6
3-5	6	17
4-5	6	6

Solution:

The project network is shown below



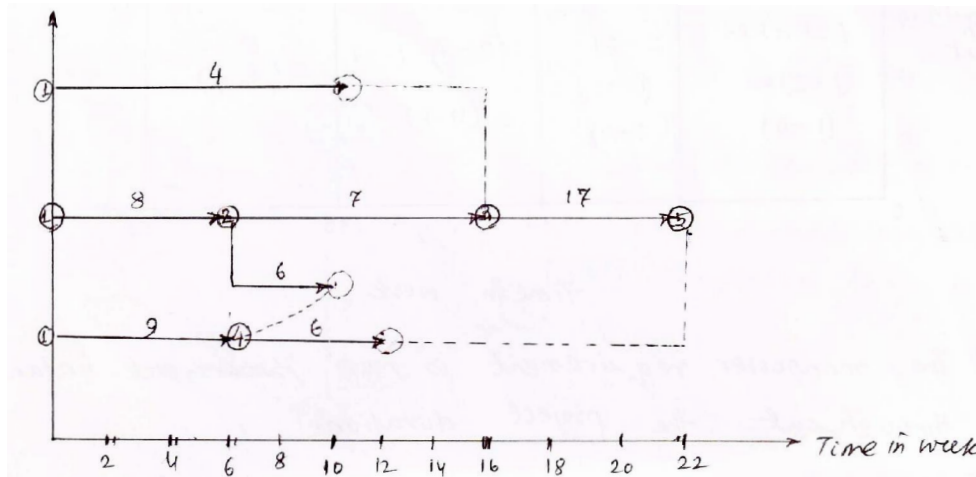
A better form of network will be obtained if event (3) will be above (2) and it is shown below.



Critical path = 1-2-3-5

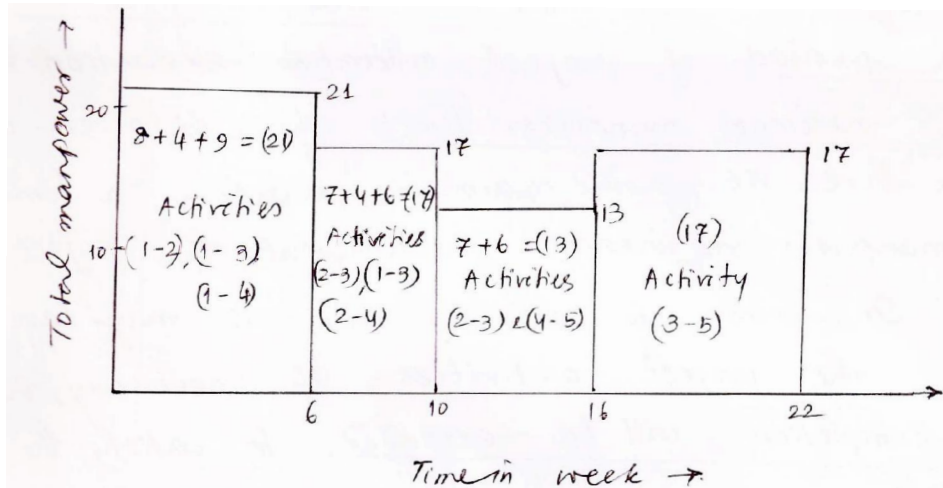
The EST & LFT for each event are presented in boxes.

The activities representation on a time state and corresponding manpower requirements are presented on the top of arrow as follows:

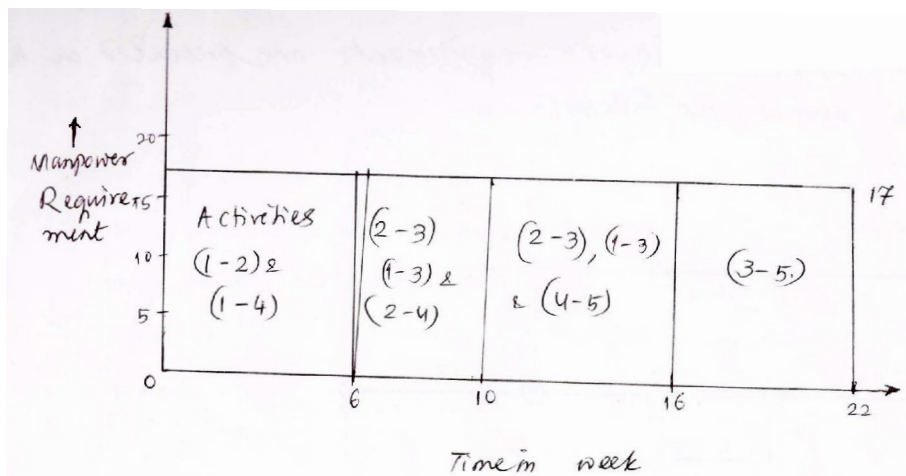


The corresponding manpower requirement histogram is as follows:

(shifting 4-5 towards right)



The peak manpower requirement is 21 and it occurs between 0-6 weeks. The activities which are scheduled during this period are: (1-2), (1-3) and (1-4). The activity 1-2 is a critical activity. So it should not be disturbed. Between activities (1-3) and (1-4), the activity (1-3) has a slack of 6 weeks. Hence it should be postponed to maximum extent (i.e., it can be started at the end of 6th week). The corresponding modification is shown in the following histogram.



The manpower requirement is now balanced/smothered throughout the project duration.

(2) Resource Allocation Technique

The objective of resource allocation is to reschedule the project activities so that the manpower requirement in each period of project execution is

within the maximum manpower limit which is given as a constraints. Here we should aim to maintain a limit on the manpower requirement throughout the project duration. In order to achieve this, we may have to reschedule the project activities. If necessary, the project completion will be extended to satisfy the constraints on manpower limit.

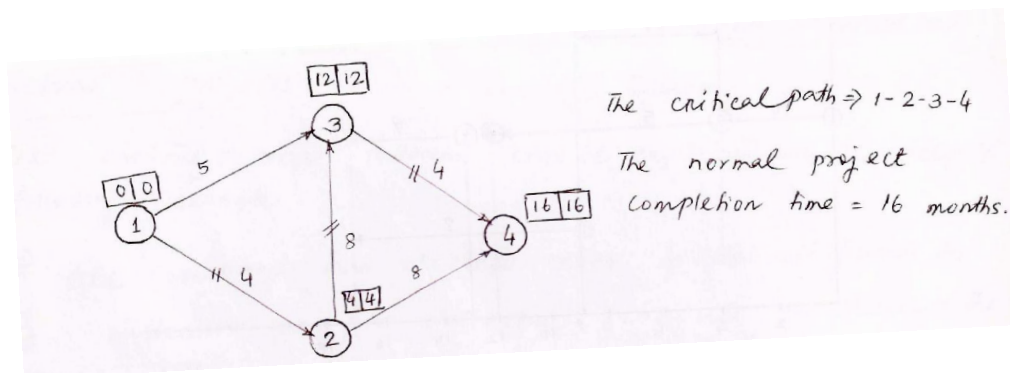
Ex. Consider the following problem

Activity	Duration in month	Manpower requirement
1-2	4	10
1-3	5	4
2-3	8	5
2-4	8	2
3-4	4	7

Reschedule the activities of the project with a maximum limit on the manpower requirement = 10

Solution:

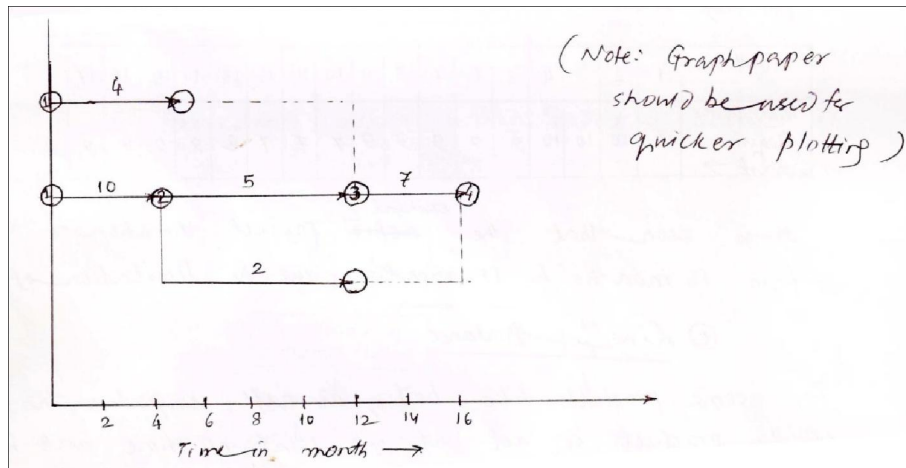
The project network and the various time values are shown below.



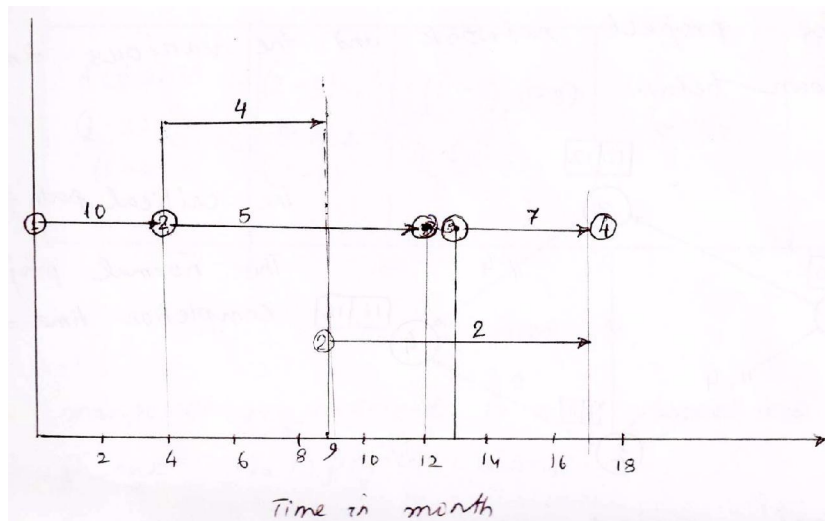
The critical path = 1-2-3-4

The normal project completion time = 16 months.

The normal project scheduling with manpower requirement (on the top of arrow) is shown below.



If the actual manpower allocated as per the project schedule is more than the upper limit of 1, then the non-critical activities are postponed with the most slack value so that the actual manpower on that month is less than or equal to the maximum limit. In spite of this if the total manpower goes beyond the maximum limit, then the critical activity is to be postponed by some period such that total manpower is within the maximum limit. It is shown in the following.



Now the manpower requirement with month is presented in the following table.

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Manpower requirement	10	10	10	10	9	9	9	9	9	7	7	7	2	9	9	9	9

It is seen that the project duration is changed from 16 months to 17 months due to limitation of resource.

(C) Line of Balance

For some products like boiler, aircraft, computers, the delivery of the product is not at one point of time is spread over a time interval. For scheduling and control of these products, a graphic technique called Line of Balance (LOB) is quite essential.

For Line of Balance, the following information are required

- i. Contracted schedule of delivery.
- ii. Key operations in making the product (which need to be controlled).
- iii. The sequence of key events.
- iv. The expected/observed lead time with respect to delivery of final product.

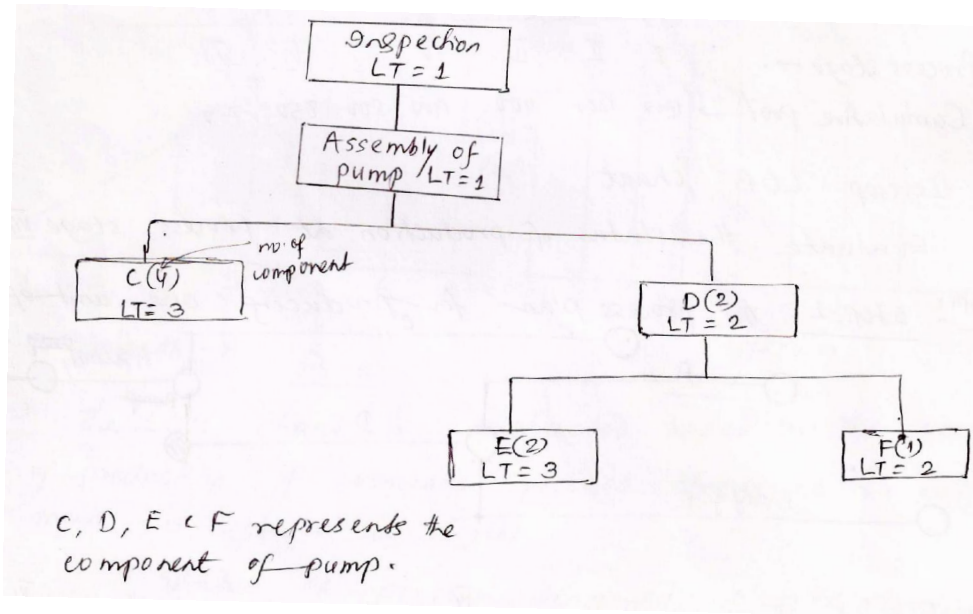
Based on the above information, a diagram is plotted which compress pictorially between the planned progress and actual progress → Line of Balance.

The various steps followed can be explained with the help of following example.

Ex: ABC company has received order to deliver pumps to its customers as per delivery schedule as shown in the following table.

Month	1	2	3	4	5	6
Quantity	100	200	200	200	300	400

The product structure explaining the subassemblies, inspection and test procedure along with lead time details is presents in the following figure.



The above information is presented in tabular form as presented in the following.

Sl. No.	Process stage	Components/subassembly	No. of components	Lead time in weeks
1	I	E	2	3
2	II	F	1	2
3	III	C	4	3
4	IV	D	2	2
5	V	Assembly of pump.	1	1
6	VI	Inspection	1	1
7	VII	Final product	1	-

The production schedule is for 6 months. After 4 months of production schedule, the cumulative number of units proceed at each process stage is shown below.

Cumulative production at the end of 4th month

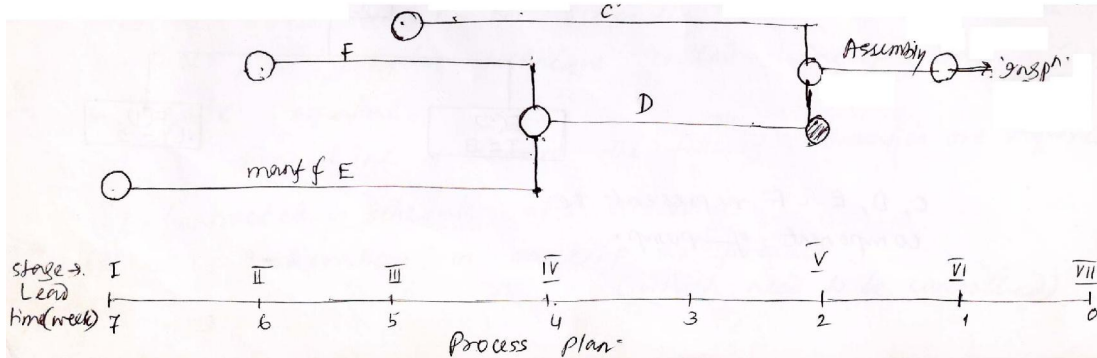
Process stage	I	II	III	IV	V	VI	VII
Cumulative production	1300	1200	1100	900	800	750	700

- Develop LOB chart
- Evaluate the status of production at process stage VII.

SOLUTION:

Step-1

The process plan for producing one unit of pump →



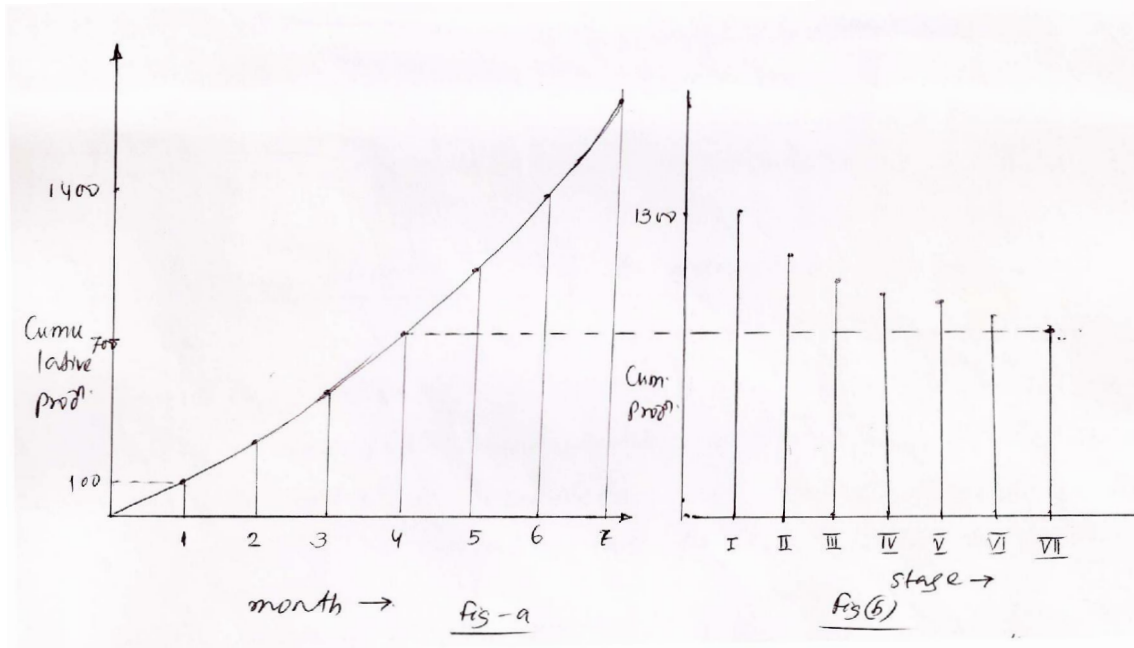
Step-2

The cumulative delivery schedule is computed as shown below.

Month	Quantity	Cumulative quantity
1	100	100
2	200	300
3	200	500
4	200	700
5	300	1000

6	400	1400
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The cumulative delivery chart can be plotted as shown below.



Step-3

The LOB chart is constructed based on the cumulative no. of production of various process stages at the end of 4th month is shown in fig(b).

Status of process stage VII after 4th month, in order to determine this, a horizontal line is plotted corresponding to cumulative production volume at 4th month and producing this line on to the VII stage graph as shown in the previous page. If it touches the tip of cumulative production of stage VII, then it has perfect LOB.