LECTURE NOTE

ON

CONSTRUCTION MANAGEMENT

FOR

DIPLOMA IN CIVIL ENGINEERING

(6TH SEMESTER STUDENTS)

AS PER SCTE&VT SYLLABUS

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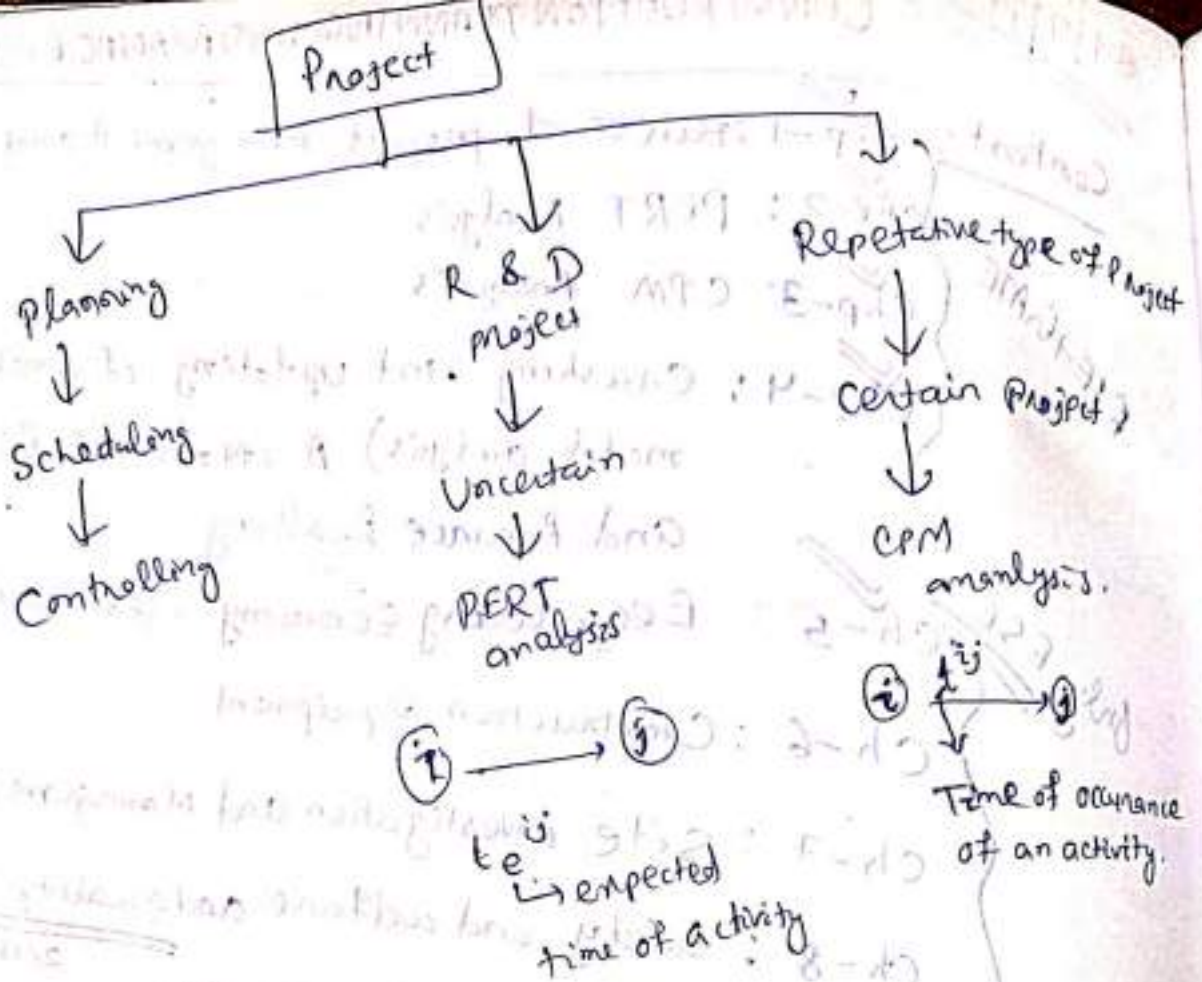
Intro:-



Project management:

It deals with material and human resources both to increase Productivity of efficiency.

For completion of a project two basic things are required:

(1) Material resources

(2) Man power "

Each project either it is big or small has 3 objectives:—

(i) project should be completed in min time.

(ii) It should use available man power & material resources without delay in project.

(iii) ~~It should use min^m of~~

(iii) Project should be completed in min^m of capital investment.

There 3 phases of project management.

① Project planning or planning. → This is the most imp. phase of project management. Planning involves defining the objectives of project, arrangement of job that must be performed, determining gross requirements for material, equipment, man power & preparing estimate of cost & durations for various jobs for satisfactory completion of the project.

IMPortance

→ It provides dirn.

→ It " performance std.

② Scheduling of project scheduling

Scheduling is the elongation of resources such as time, material, equipment, man power resources in appropriate manner such that it results in efficient working.

Scheduling also involves sequencing of activities.

Note In traditional techniques the term planning & scheduling are performed as one step.

③ Project Controlling :- It is the process to identify critical (running exactly on schedule but not complete). Subcritical (before) (before schedule) or non critical) or super critical (delayed) (late)

Critical → On time.

Activities.

The critical & super critical activities are given extra attention. So that network is updated.

Note Planning & scheduling are performed before execution of the project whereas controlling is carried out during execution of the project.

Work break down structure

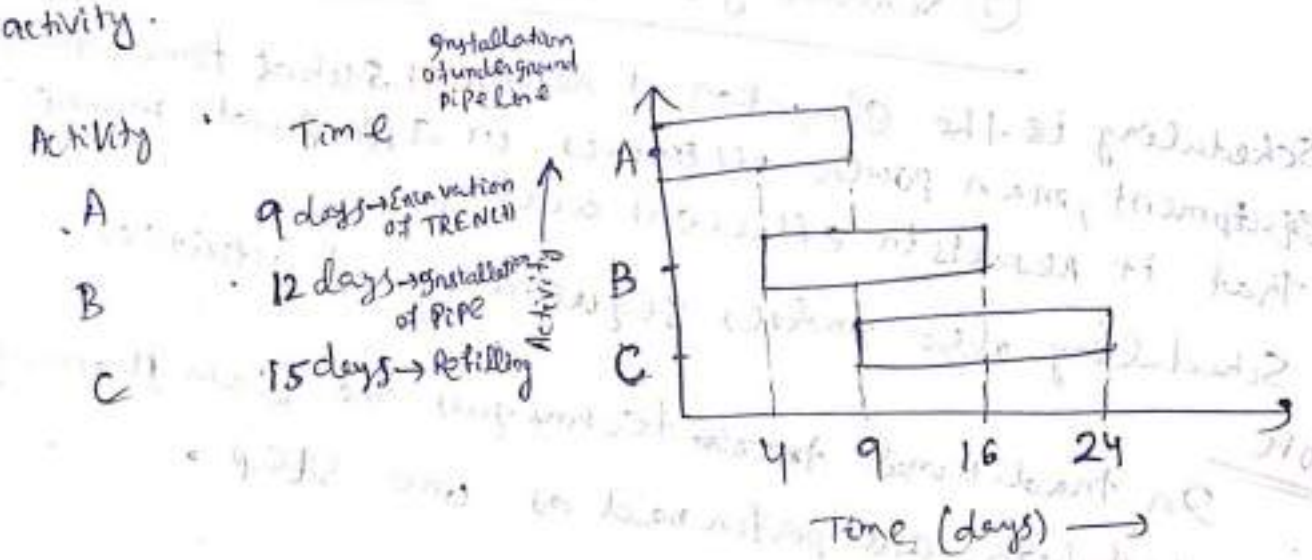
This is incremental & hierarchical decomposition of project phase. It is tree like structure. It is also called top-down approach. It is suitable for big & complex project.

Technique used in Project management :-

(1) Bar chart :-

This is the oldest technique of Project management and it was developed by Henry Gantt around 1900.

Hence it is also called Gantt chart. There are two co-ordinates on which horizontal axis represent time and vertical axis represent activity.



From the above bar chart, it is clear that activity C will start after completion of Activity A. But it is not clear that how activity A, B, C are interconnected to each other.

Limitation of bar chart

(1) Lack of degree of detail

In a bar chart only major activities are shown. Sub activities can not be represent hence it is difficult to carry out the control. So it is not used for controlling purpose.

WBS for construction of 5 km. village road (flexible pavement)

Earthwork
* Test of compaction by cone cutter.
* Watering & Compaction
* Soil levelling
* Soil cutting and filling
* Field survey.

Soil subgrade
* Test of compaction by sand replacement method
* watering & Rolling
* Installation of coarse sand on embankment.

Sub-base course
* Test of Compaction and test of grading by sieve analysis
* watering & Rolling
* Install mix on surface
* Prepare a mix of coarse sand and stone metal of flaky size.

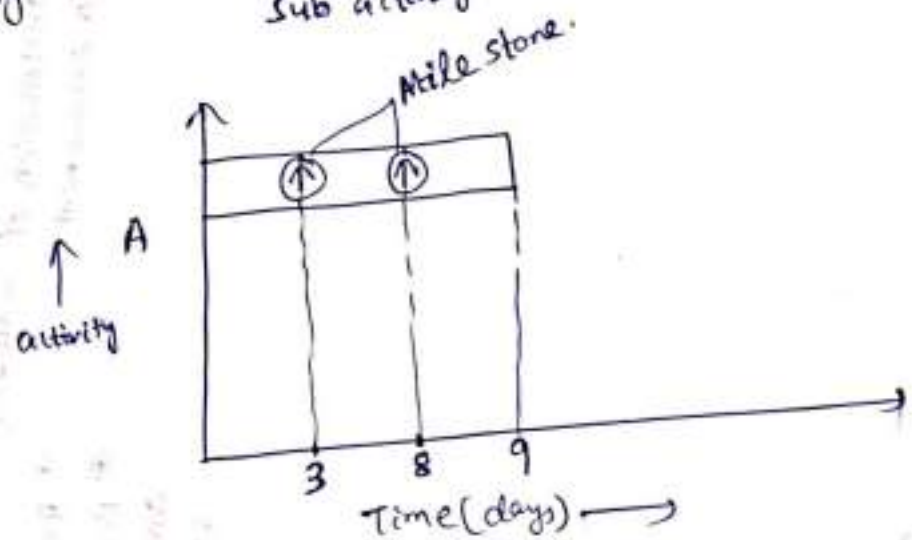
Base Course
* Test of compaction & gradation
* Watering & Compaction
* Install morum on surface
* Install stone metal on surface.

Surface Course
* Test of thickness of Bitumen layer.
* Seal coat & Compac
* Compaction by static Roller
* Tack coat & prem carpating (PMC)
* Prime Coat (SS1)
* Clening of surface by air Compresson

Remedy of bar chart :-

Activity A → Casting of roof slab → 9 days.

- Shuttering and centring — 3 days — Sub activity
- Bars bending or R/f. — 5 days — Sub activity
- Casting or concreting — 1 days — Sub activity.



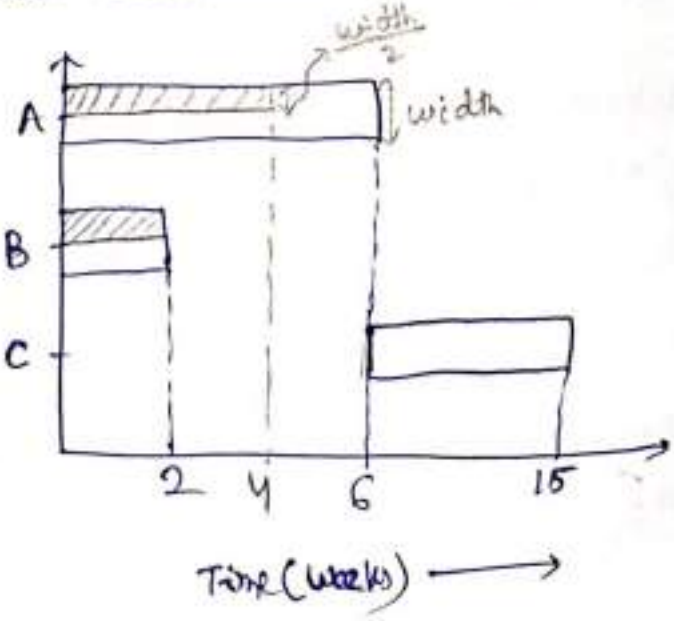
- Milestone represent an event of occurance of a sub activity at an intermediate stage of a activity.

(2) No provision to show project progress

Since project progress can't be shown hence bar chart can't be used as controlling mechanism.

Review after 8 weeks

Activity A is incomplete and it has only 4 week work which has done. So it requires 2 more weeks. So, Activity A will Complete at the end of 10 weeks. Activity C is completely dependent on A. So C will start after 10 weeks. So 'C' will finish in 19 weeks.



Activity B is Complete.

∴ Project is delayed by 4 weeks, Hence rescheduling of activity 'C' is required.

③ Lack of activity interrelationship.

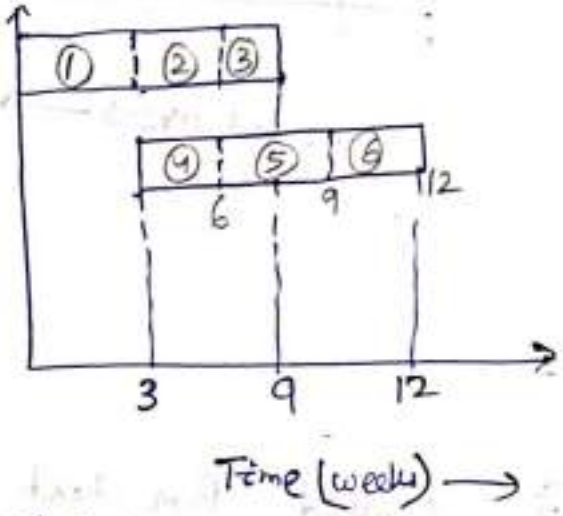
In bar chart, clear picture b/w activity relan ship is not available hence it is difficult to identify their interdependancy.

Remedy:

This difficulty can be partially removed by breaking each activity into a no. of sub secns. So that succeeding sub secn will depend on completion of preceeding sub secn.

Breaking each activity into a number of equal sub activity.

Sub-secn 4 will start after completion of sub secn ①



④ No provision to account for time uncertainty hence it is not suitable for new or Research and development types of project.

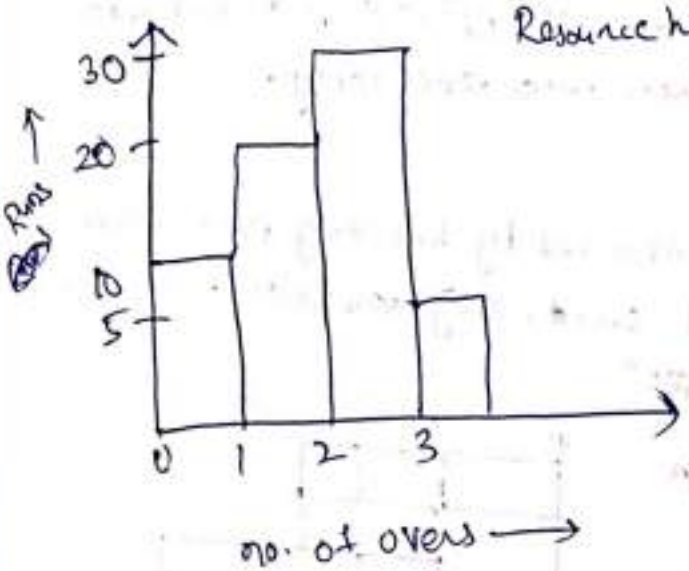
⑤ It is difficult to identifies critical activity & difficult to find Critical path. So that bar chart can't be used as controlling mechanism.

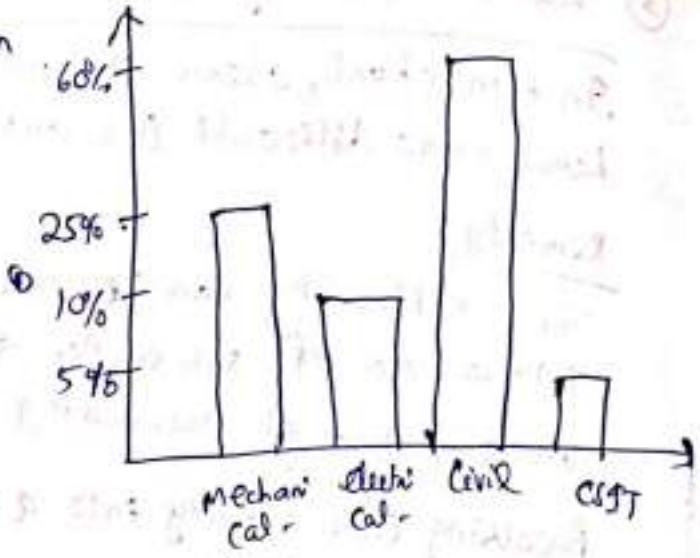
Milestone chart:

This is imp. to over gantt chart controlling. can be better achieved with the help of mile stone chart.

Resource histogram

Bar chart and resource histogram both are similar. The only diff.: is that the continuous data and each column represent quantitative variable of particular group.





Bar chart

Bar chart represent data of a diff. grp.

(4) Linked Bar chart

→ The end of preceeding activity is connected to the start of succeeding activity.

* It provides clear picture of activity rel^n ship.

Dotted arrow (Dummy) are used to established their inter rel^n ship.

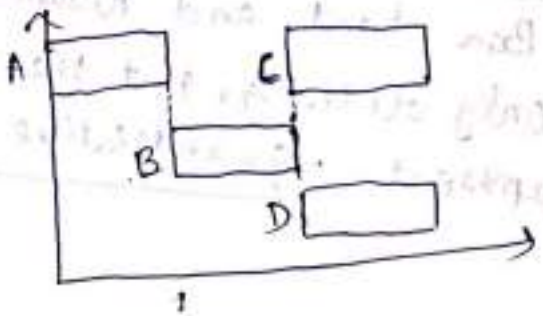
(Freedom) Floats → Can be easily calculated.

There is no need to monitor separate milestone.

It is easy to understand.

It can be used for controlling purpose.

Activity B will start after completion of activity A.



* Resources for individual Activities can be easily planned.

Drawback :

→ Un-certainty can't be accounted hence not suitable for new or research & development type of project

→ Critical path can't be calculated.

Network diagram

This is improvement over milestone chart & it is to be used for big project under complex cond^{n}s.

All limitations of bar chart are eliminated here.

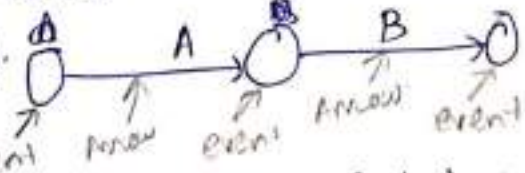
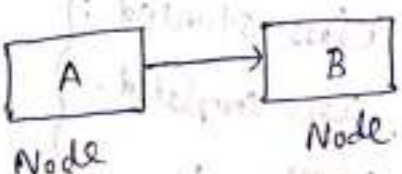
Network is a pictorial representation of all activities in which activities and their interrelnship are shown & dummies may be used to show their interrelnship if required

Types of Network :

A - O - A

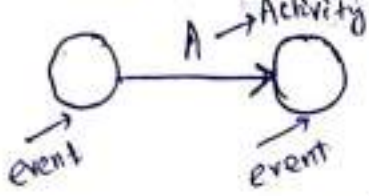
A - O - N

Diff. b/w. A - O - A & A - O - N Network

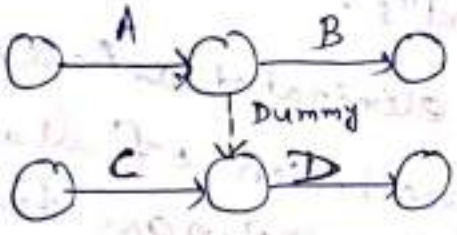
A - O - A	A - O - N
1. Activities are represented by Arrows.	1. Activities are represented by Nodes.
e.g. 	e.g. 
A & B are activity which is on Arrow.	Activity A & B are inside the node.
2. The no. of arrow is exactly equal to no. of activity in a network.	2. The no. of arrow will not be equal to no. of activity.

e.g. No. of activity = no. of arrow = 2
in above Network.

3. Events are represented by Nodes.



4. Dummy are used to establish logical Rel^{n}ship, if required.



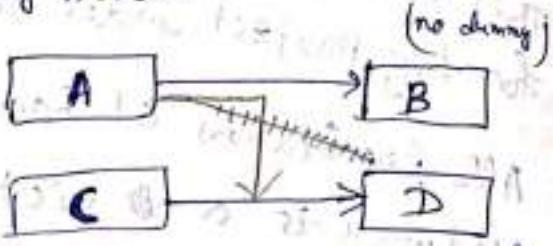
5. It is used for both PERT as well as CPM based project.
(Continued project)

6. Suitable for both R & D and repeatative type of project.

e.g no. of activity ≠ no. of arrow
no. of arrow = 1
no. of activity = 2 in above network

3. Events have no place.

4. There is no role of dummy however there rel^{n}ship is represented by Arrow.



5. It is used only for CPM based project.

6. Suitable for only repeatative type of project.

ELEMENTS OF A-O-A Network

(1) Event :→ An event is either start or Completion stage of an activity. It doesn't need any resources and any time for its occurance.

Exp Class started
Class completed
CTPM "
Slab casted
} event.

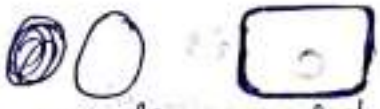
Types of event

(1) Start event
(2) finish "
(3) intermediate event or ideal role event.

event (2) is finish event for activity A.

event (2) " start " " " B.

∴ " (2) " "dual role".

An event is represented by  Circle Oval shape.

* In a network diagram there is only one start event & only one finish event & remaining alls are dual role event.

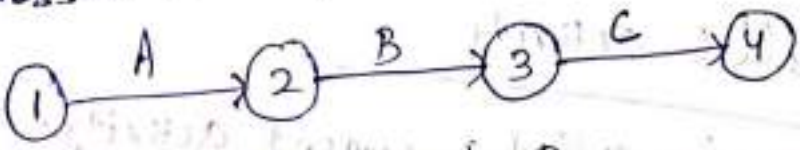
(2) Activity →

It is the actual performance of work which requires time & resources both for its completion. e.g. Class is going on. slab is casting found" is going on

Types of activities

(1) Predecessor Activity:

Activities that are required to be performed before another activites is called predecessor activity.

e.g: 

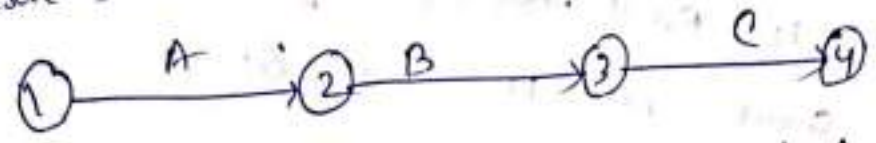
Activity A is predecessor of activity B

" B " " " C.

Note: Never say: activity (A) & activity (B) are predecessor of activity (C) for the above network.

(2) Successor activity

Activity that are required to be performed after another activity is called successor activity.

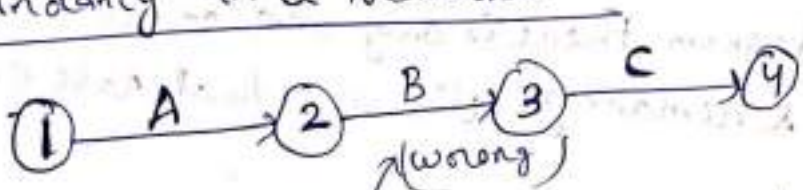


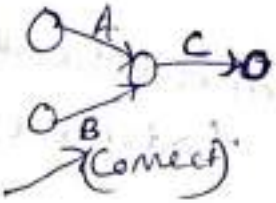
Activity B is successor of Activity A.

" " C is " " B.

(unwanted elements)

* Redundancy in a Network





Activity A & B are predecessor of activity C.

(just immediate)

successor (just front)

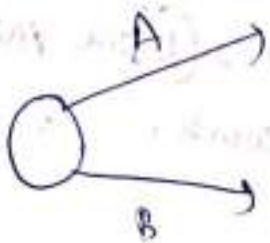
If more than one network is possible for a given statement then Redundancy will exist in a network.

Predecessor means immediate predecessor.

& successor " " successor

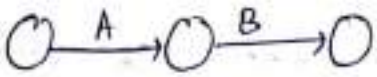
(3) Parallel activity

This is also called Concurrent activity. If more than one activity will start at the same time then it is called Concurrent activity or parallel activity.



Activity A & activity B are Concurrent

(4) Serial Activity.



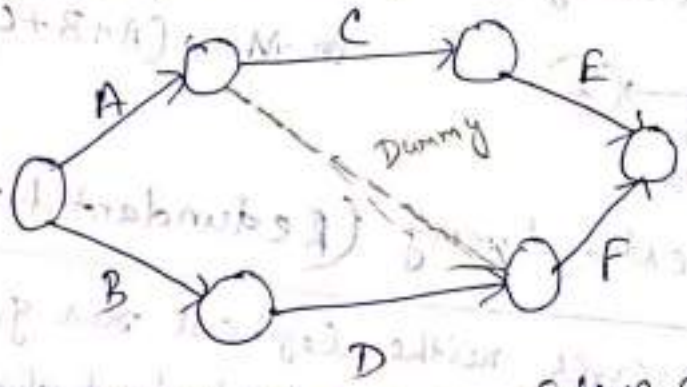
If one activity will start after completion of another activity than it is called serial activity.

(5) Dummy activity

It is an activity which require neither resources nor time for its completion. It is used to establish a logical relnship b/w two activities. Also dummies are used for grammatical purpose.

(6) Logical Purpose.

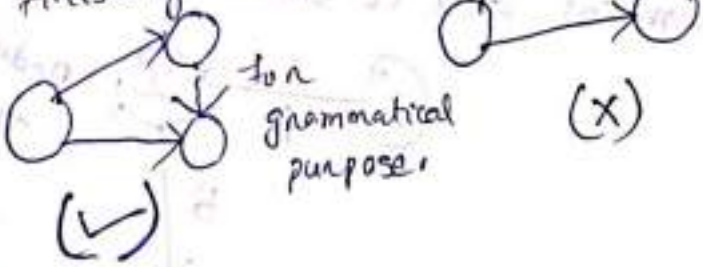
Dummies are use to establish interrelnship b/w two activities in a logical way.



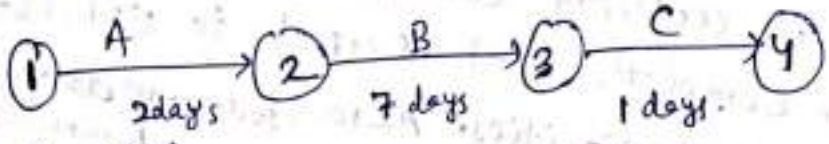
* Activity F will depends on completion of activity A & D.
* A preceeds 'c' but restrain the occurance of F.
* F succeeds D but restrained by occurance of A.

Grammatical Purpose:

Acc^n to Network Rule more than one activity can't have common starting and finishing loady.



Note: If events are added or removed than there will be no change in resources and time for completion of a project. But if activities are removed than time & resources both will change, hence activities can neither be added nor be removed from a network.



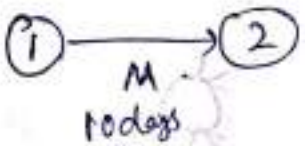
Casting of roof slab

A → shuttering & centering

B → Bar activity

C → Concreting

M → casting of roof slab.



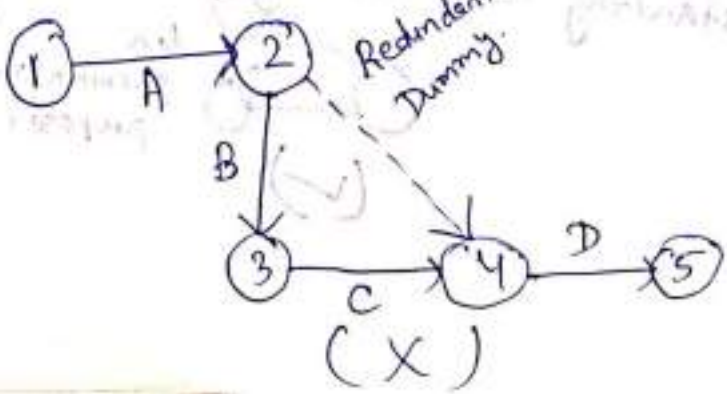
M → (A+B+C)

Removal of extra dummy (Redundant dummy)

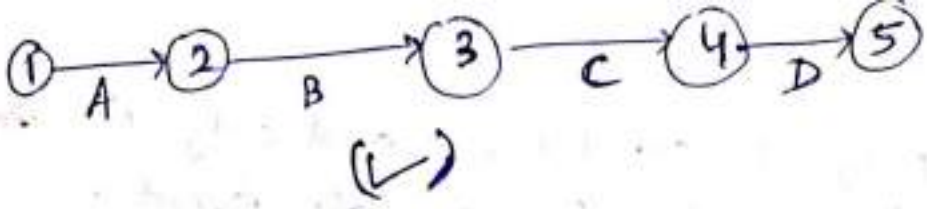
If dummy serves neither logical nor grammatical purposes hence such a dummy is called redundant dummy & it should be removed from a network.

Guidelines for removal of Redundant Dummy:

1. If dummy show the predecessor rel^n in a network but that rel^n is already established in a network then that dummy is redundant and it should be removed.

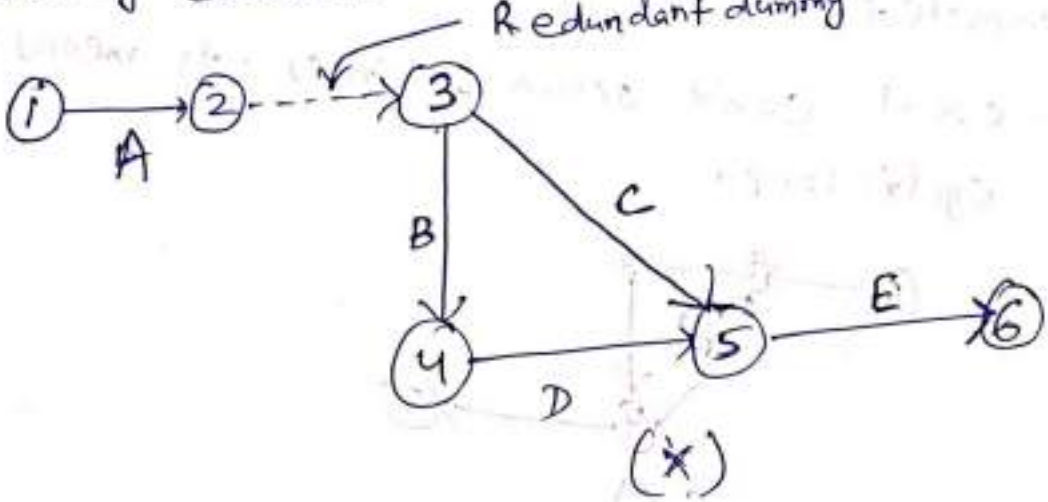


(X)

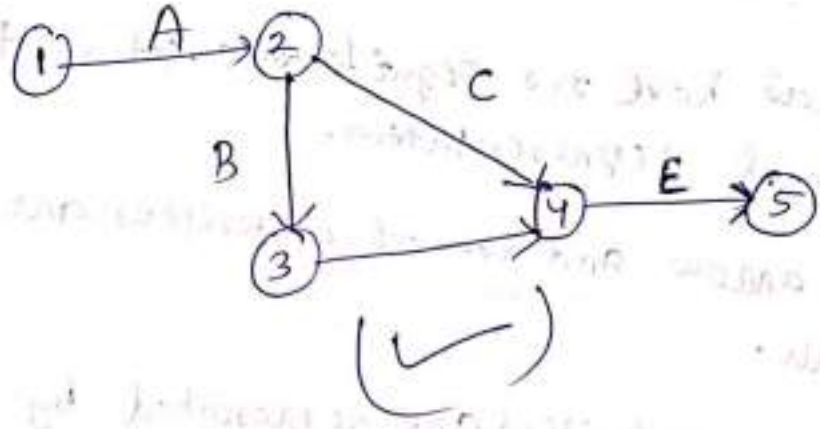


(✓)

2. If dummy is the only incoming arrow to an event a then it should be removed provided diagrams are logically and grammatically correct.

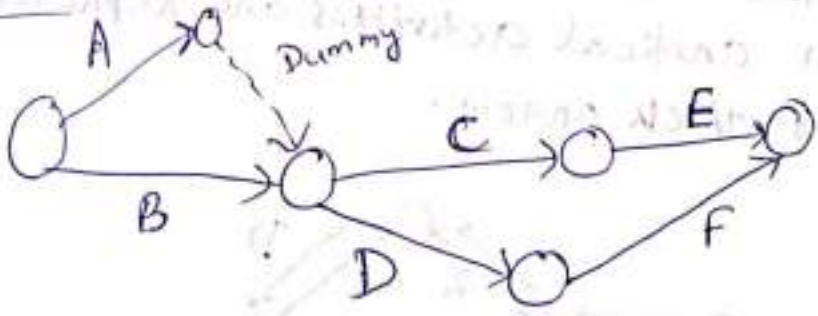


(✗)



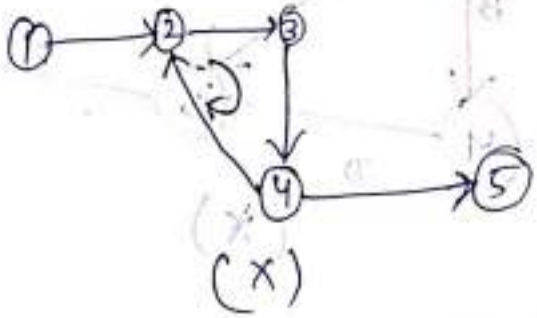
(✓)

Logical purpose



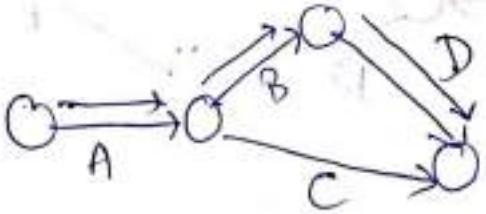
Network rule

1. There can be only one start event and only one finish event remaining all are dual role event.
2. An event can't occur till all preceded ing activities are completed.
3. An event can't occur 2 times. It means that there can't be cyclic loop.



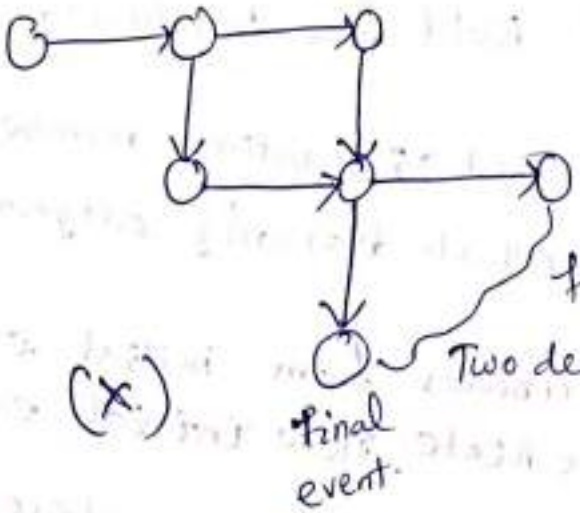
(X)

4. Length of arrow have no significance. It is taken only acc^n to pictorial representation.
5. The no. of arrow and no. of activities are equal in A-O-A network.
6. The non-critical activities are represented by single arrow whereas critical activities are represented by double arrow or thick arrow.



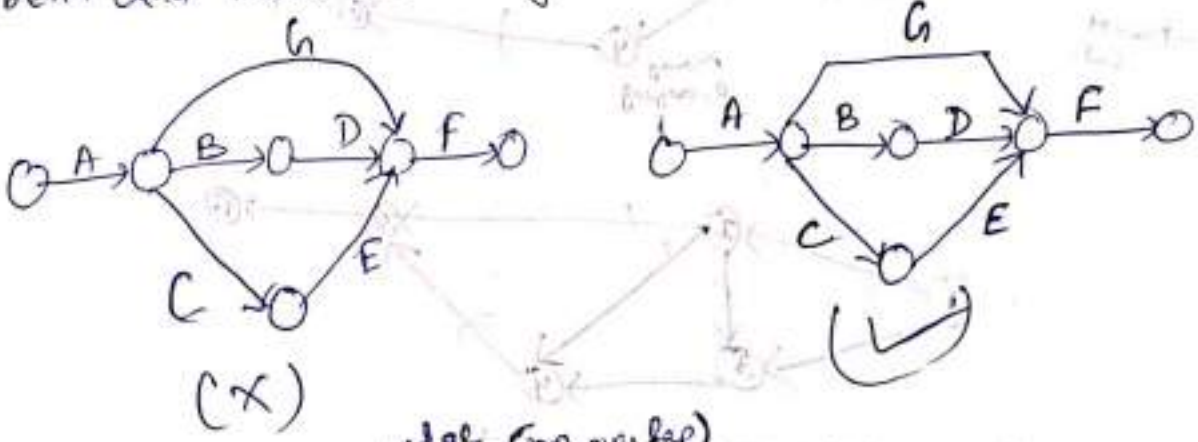
Activity A, B & D are critical activity.

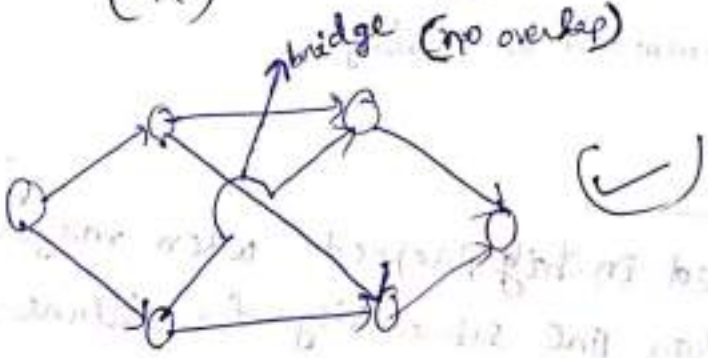
7. In a network there can be only one dead end of final event.



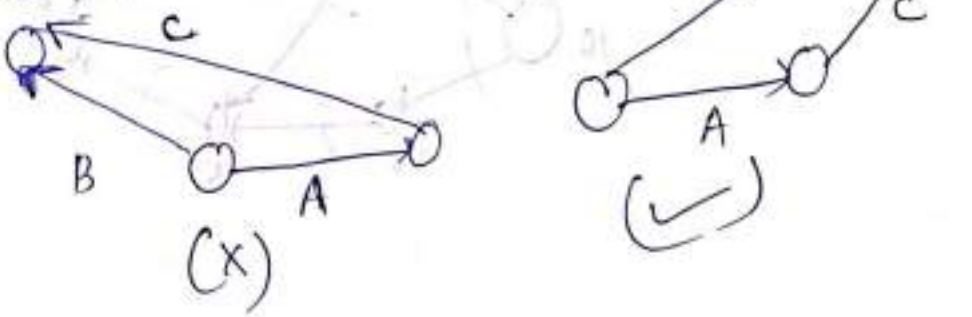
Conventions of network

1. As far as possible arrow should be a straight and their crossing should be avoided, but if not possible then arrow should be bent and their crossing should be bridged.



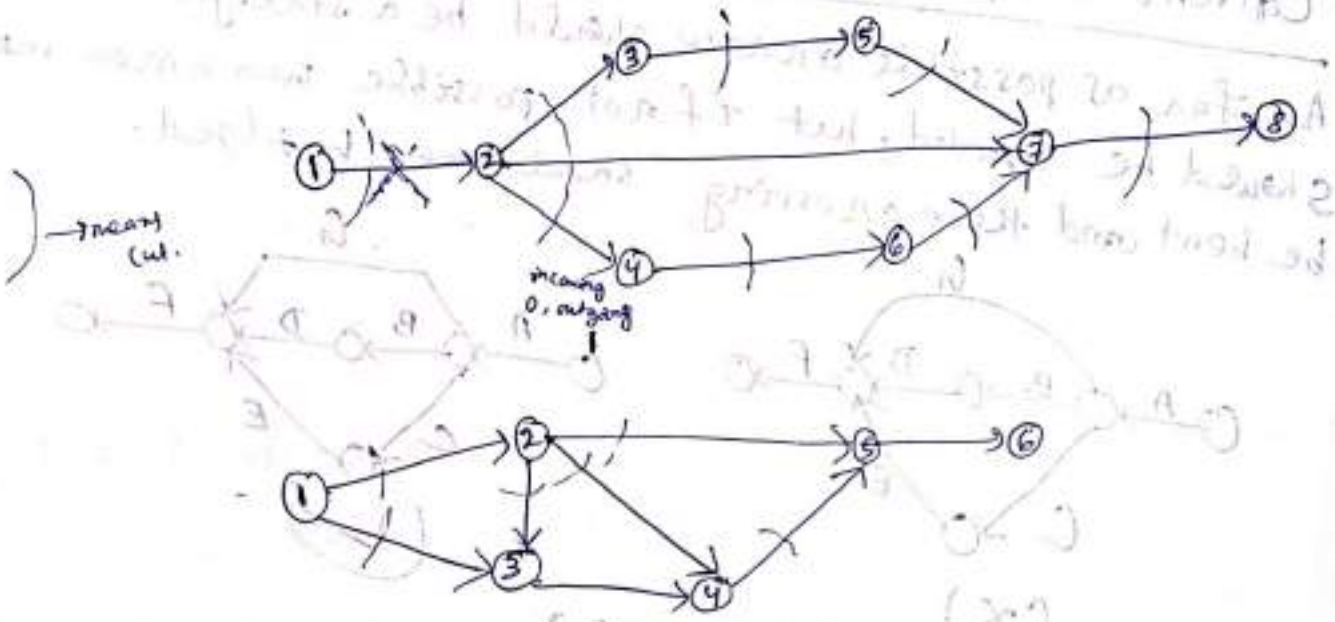


2. As far as possible, with the flow of time, dirn of arrow should be from left to right.



D.R. FULKERSONS RULE for Numbering the event.

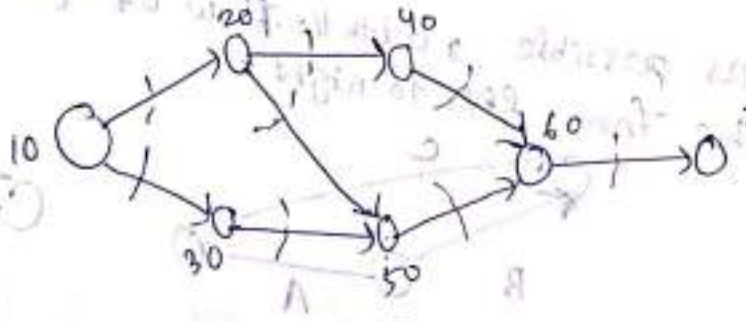
1. Initial event is numbered as starting number. Initial event is that which has only outgoing arrows.
2. Ignore all outgoing arrows from initial event which has already numbered & create new initial event which will assign next no.
3. Repeat Step (2) till all events are numbered.



If there is an incoming arrow then no numbering.

Skip Numbering

This is generally used in big project when major activities are divided into more than one sub activity for future opportunities.

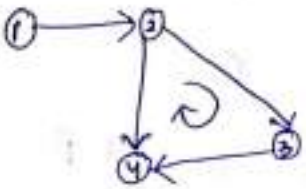


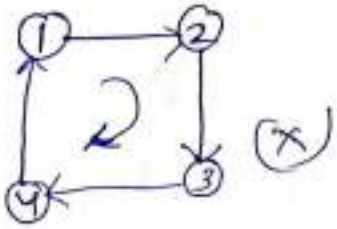
Errors in Networks

5/7/19

→ 1. Looping error or cyclic error

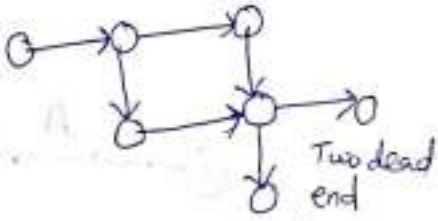
An event can't occur two times in a network so that there can't be cyclic ~~typing~~ loop in a network.





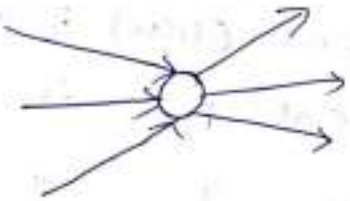
2. Dynamic error

In a network there can't be more than one dead end or can't be more than one final event.



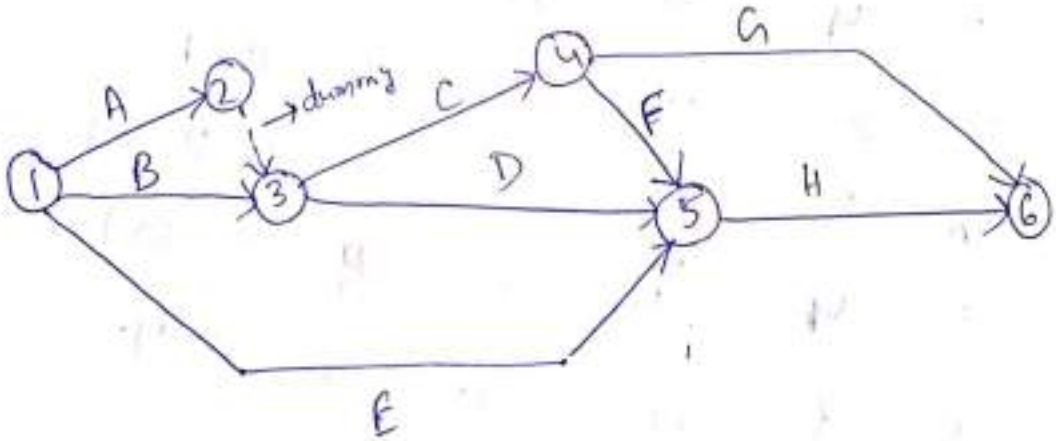
3. Wagon wheel error

In a given network more than 3 activity completed at the same time and more than 3 activity ~~one~~ stated at the same time. It is practically not possible, hence such type of error is called Wagon wheel error.

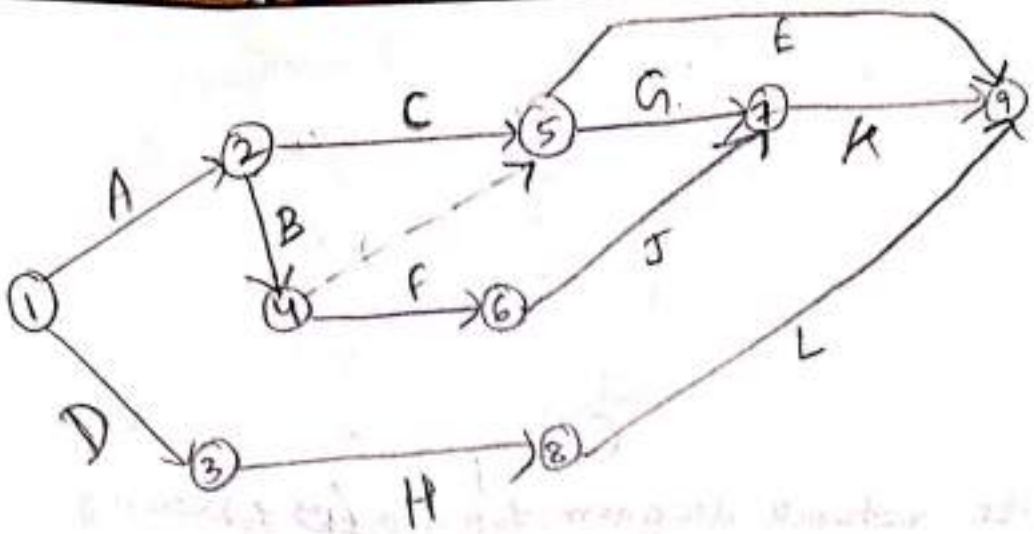


WB
Ch-2

10

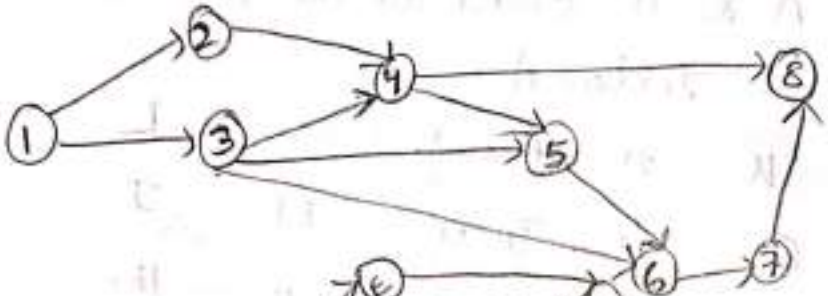


Q. In a particular project the following rel^n ship occur draw the events.

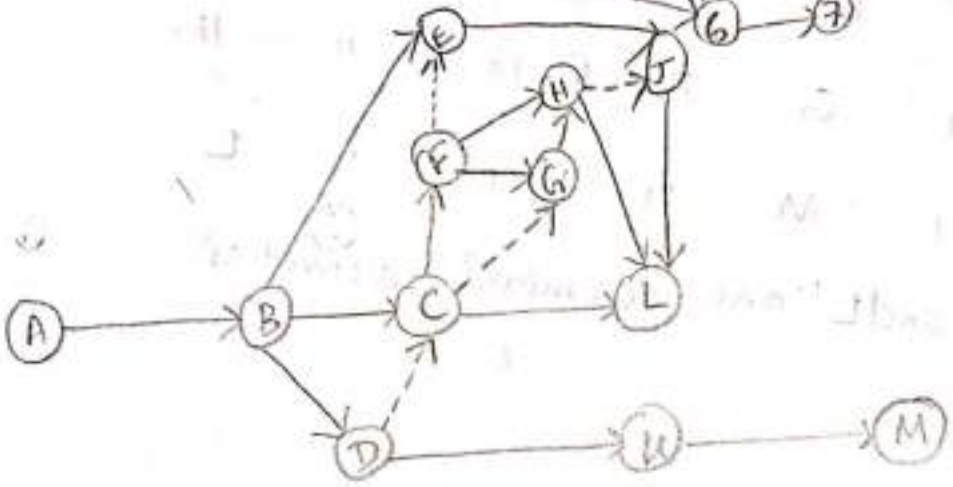


WB ch-2

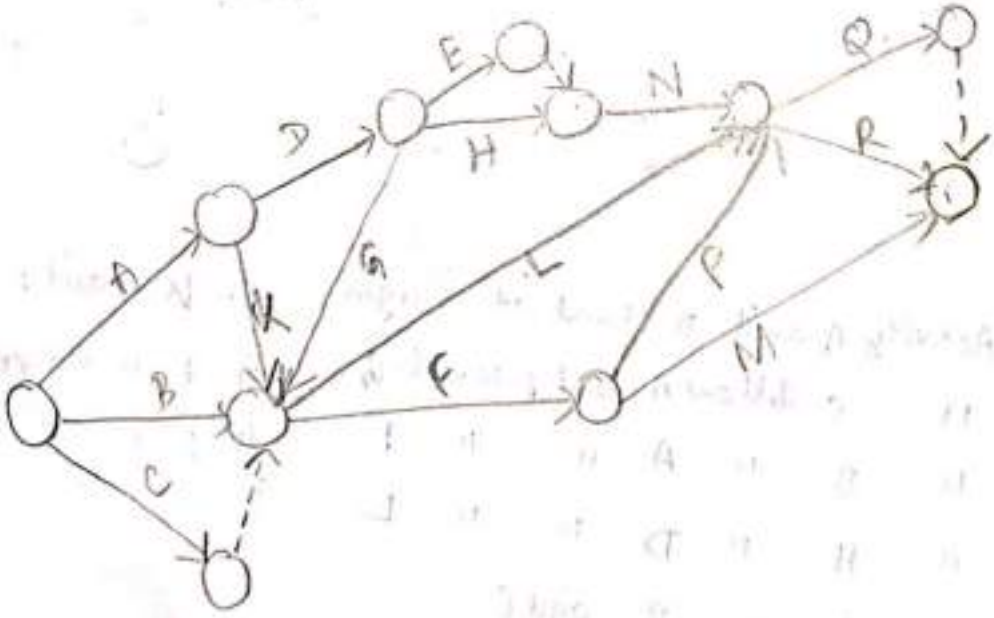
11.



T2.



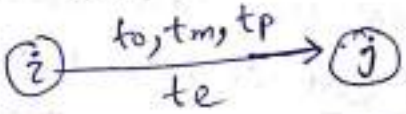
12



PERT

1. It stands for programme evaluation and review technique. It was first developed by U.S Navy department in 1958 for development of missiles.

2. It is based on three time estimates for completion of an activity.
   (1) Optimistic Time (to)
   (2) Pessimistic time (tp)
   (3) (te or tm) Most likely time



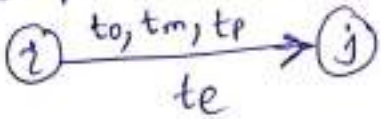
Based on the above three time estimates, mean expected completion time of an Activity is given by

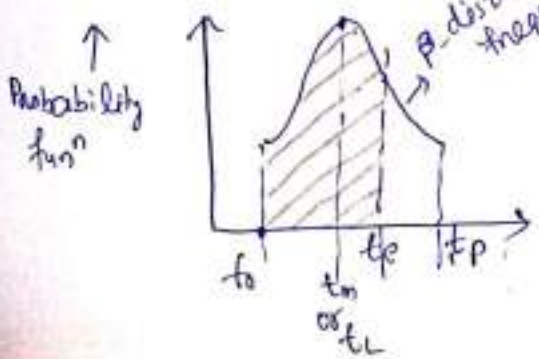
$$te = \frac{to + 4\,tm + tp}{6}$$

te → expected / mean time for completion of an activity.

Based on the mean expected time (te) probability of Completion of an activity is only 50%.

3. In PERT each activity is assumed to follow β-distribution of frequency

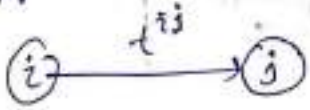




CPM

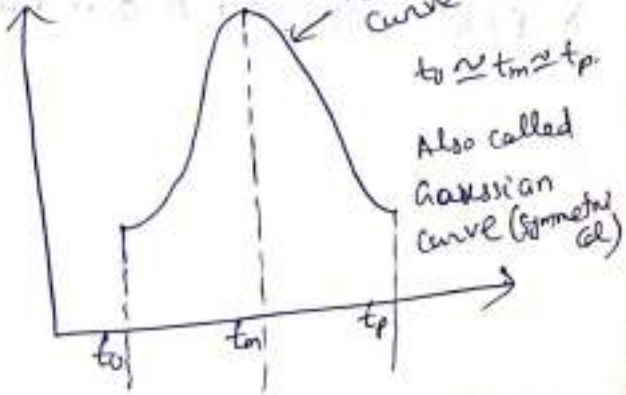
1. It stands for critical path method. It was first developed in 1956 by Kelly and walker when a German company wanted to construct a chemical factory.

2. Only one time estimates for completion of each activity and probality of Completion of an activity in this time is 100%.

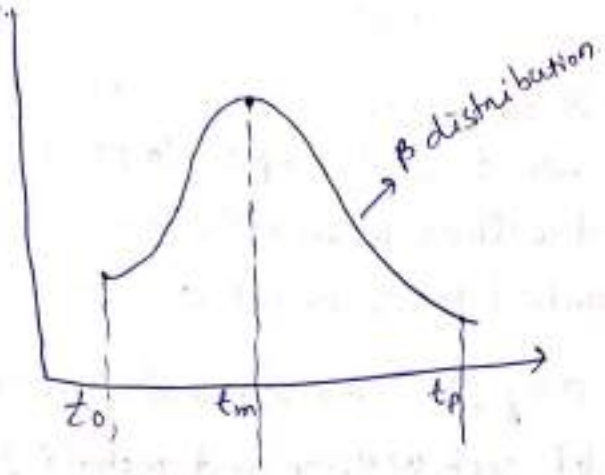


t^{ij} → Time of completion of an activity

(3) In CPM, each activity is assumed to follow Normal distribution of frequency



4.



std. deviation,

$$\sigma = \frac{t_p - t_o}{6}$$

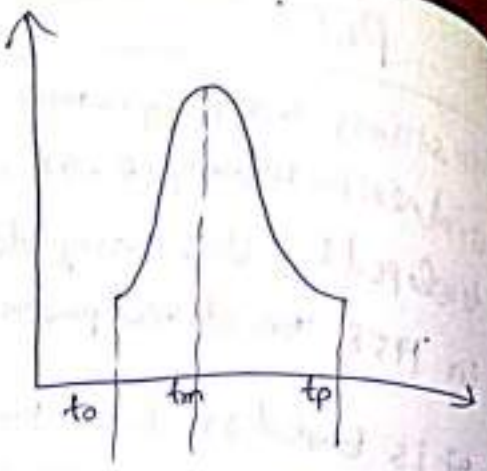
5. In PERT, time is directly proportional to cost therefore to minimise the cost, time of completion should be minimum

6. PERT is generally used for New or Research and development type of project

7. PERT was event oriented Network.

8. PERT uses only A-O-A Network

4.

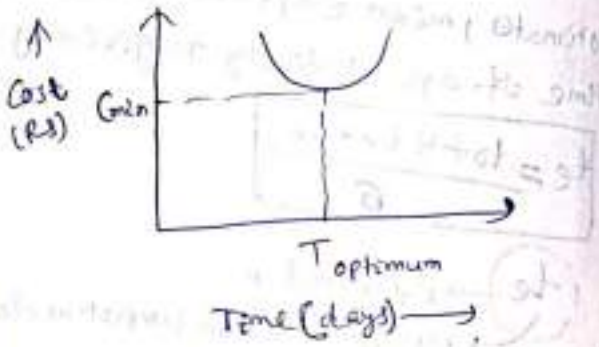


$(t_m - t_o) \simeq (t_p - t_m)$

$\sigma = 0$

i.e. Certain Project.

5. In CPM, time cost model is analysed and min^m cost of project is obtained corresponding to optimum time.

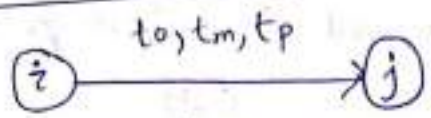


6. CPM is generally used for repetitive type of projects. Such as Civil engineering Construction project or Mechanical engineering production project.

7. CPM uses activity oriented Network

8. CPM uses both A-O-A and A-O-N Network

PERT ANALYSIS



* It is based on three time estimates for each activity.

(i) Optimistic time (t_o): It is the min. time in which an activity is expected to complete when cond^n are most favourable.

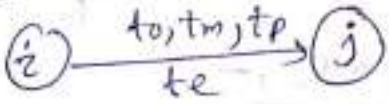
(ii) Pessimistic Time (t_p): It is the max^m time in which an activity is expected to complete under adverse cond^{n}s or when cond^{n}s are most unfavourable.

Note: while estimating pessimistic time natural climatic anomaly, earthquake, floods, droughts, fire etc. are not considered.

(iii) Most Likely time (t_m or t_L)

It is the normal time in which an activity is expected to complete under normal cond^{n}s.

It reflects mode on β-distribution of frequency curve.

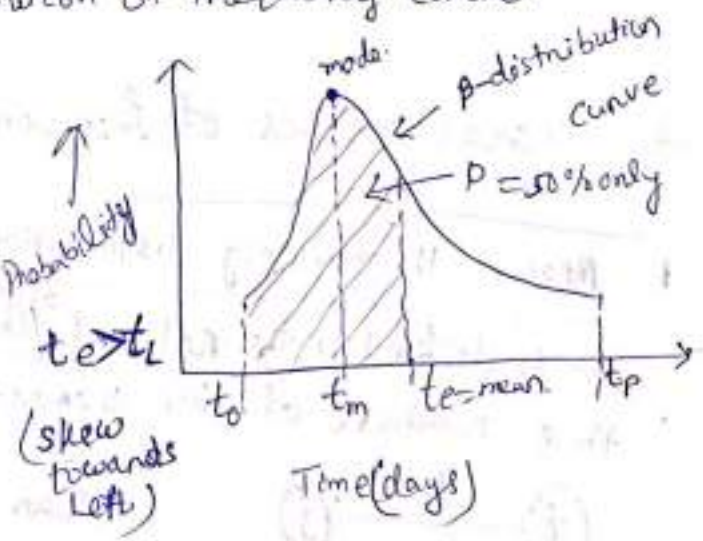


Based on above three time estimates mean expected completion time is taken is weighted avg of all three times.

$$\therefore t_e = \frac{1 t_o + 4 t_m + 1 t_p}{1 + 4 + 1}$$

$$\therefore \boxed{t_e = \frac{t_o + 4 t_m + t_p}{6}}$$

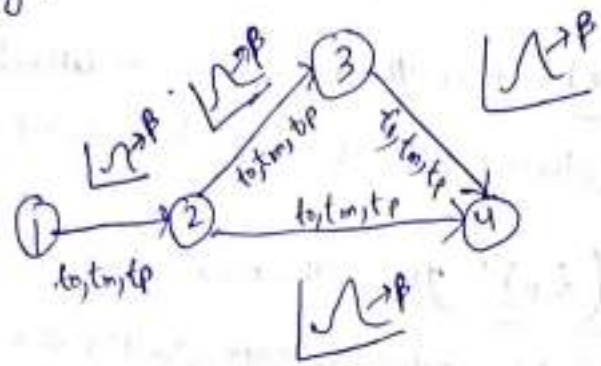
→ expected / mean time.

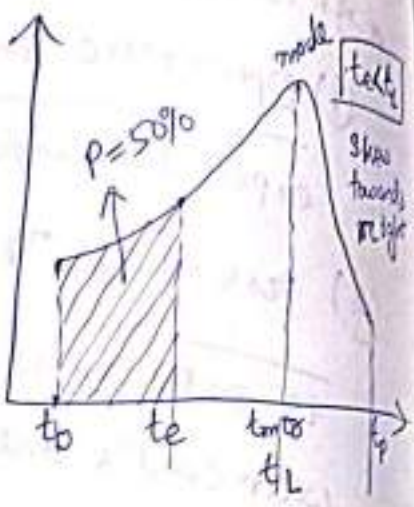


The probability of completion of an activity in time t_e is only 50%.

* In β-distribution of frequency mean and mode are different.
* In PERT analysis each activity is assumed to follow β-distribution of frequency.

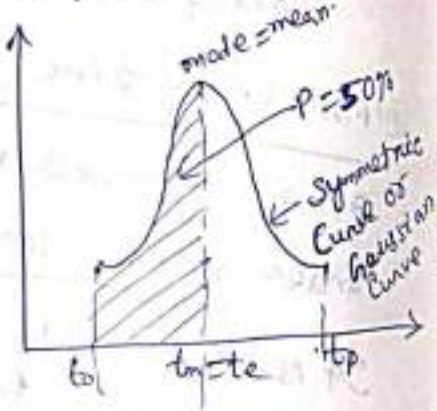
Note





Note

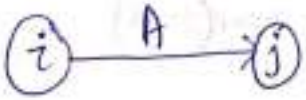
If mean and mode of a frequency curve coincide than such a frequency curve is called Normal frequency distribution Curve



* Characteristics of frequency curve :-

1. Mean of the frequency distribution:

It is defined as the ratio of the algebraic sum of the time req. for completion of an activity to the number of time the activity is analysed.



t_1 = 1st time
t_2 = 2nd time
t_3 = 3rd time
⋮
t_n = n time

Mean time, $t_{mean} = \frac{t_1+t_2+\dots+t_n}{n}$

$\therefore$ $\boxed{t_{mean} = \frac{\sum_{i=1}^{n} t_i}{n}}$ Basic formula.

t_{mean} = Expected completion time of an activity

$$\boxed{t_{mean} \simeq te \simeq \frac{to+4t_L+tp}{6}}$$

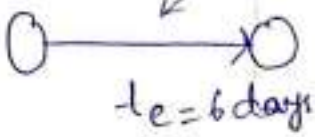
2. deviation (δ) (Not the xm)

It is defined as the diff. of time reqd. for completion of an activity with the mean of that activity.

once cancel in xm

$$\delta = (t_i - t_{mean}) \quad ****$$

e.g.



$\therefore \delta = (10-6) = 4$ days.

3. Variance (σ^2)

* It is defined as mean of square of deviation.
* It is used to represent uncertainity or variability in completion of an Activity.
* It is square of standard deviation.
* Greater variance means greater uncertainity in completion of an activity. ✓ obj.

Variance, $$\sigma^2 = \frac{\sum (t_i - t_{mean})^2}{n} \quad **** \text{ IES 95}$$

$$\sigma^2 = \left(\frac{t_p - t_o}{6}\right)^2 \quad **** \text{ for numerical.}$$

e.g. Casting of roof slab ESE-97

Tender

Contractor A
$\sigma^2 = 10$
Uncertainity less

Contractor B
$\sigma^2 = 15$
most uncertainity

Prefer Contractor A over Contractor B

Standard deviation (σ)

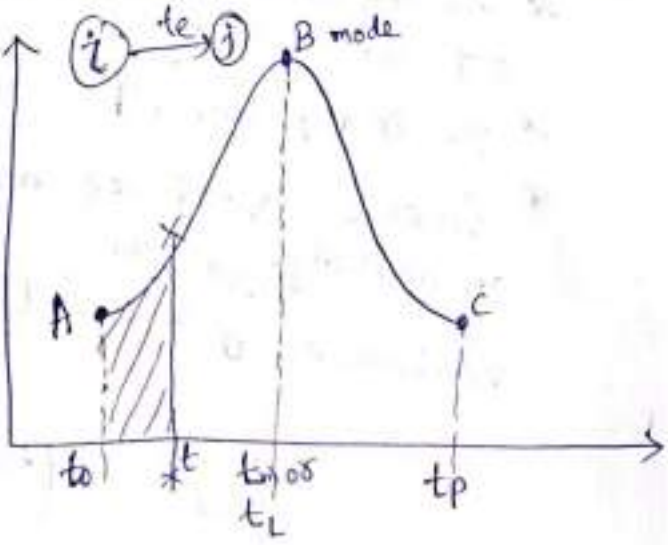
* It is square root of variance and its significance is similar to that of variance.
* It also represents uncertainity or variability in completion of an activity.

$$\sigma = \sqrt{\text{variance}}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(t_i - t_{mean})^2}{n}}$$

* Probability Distribution Curve

Probability distribution curve is similar to frequency curve which is standarised in such a way that Area bounded by the curve is 1 unit.



Area bounded b/w ABC = 1 unit

Probability of completion of an activity in time 't' is given by,

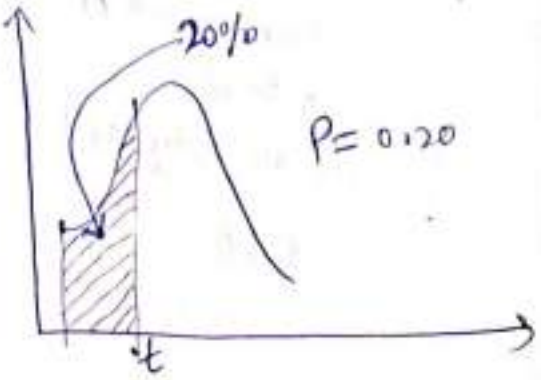
$$P = \frac{n(E)}{n(S)}$$

$$= \frac{\text{Area bounded b/w } \Delta x}{\text{Area bounded b/w ABC}}$$

$$= \frac{\text{Area bounded b/w } \Delta x}{1}$$

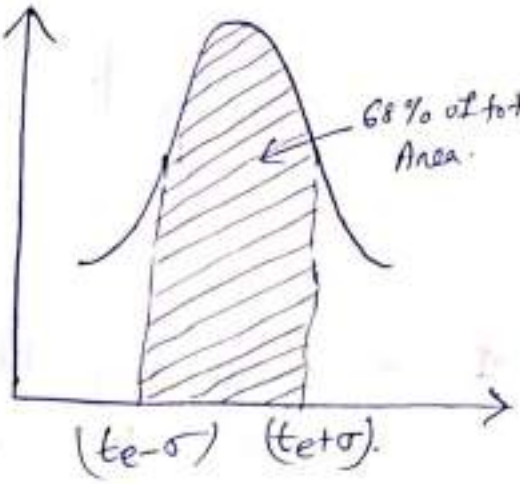
Probability Completion in time t = Area bounded b/w Δx ****

e.g.

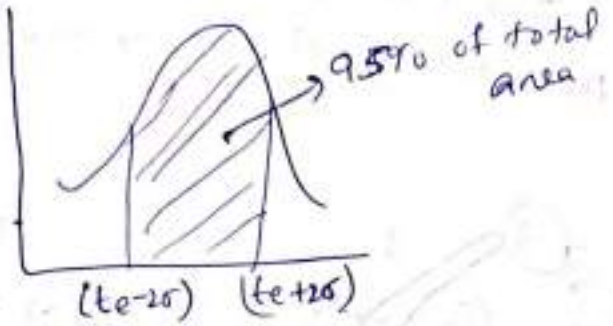


Properties of probability Distribution Curve:-

* Area bounded b/w $(te-\sigma)$ to $(te+\sigma)$ is 68% of total area.



* Area bounded b/w $(te-2\sigma)$ to $(te+2\sigma)$ is 95% of total area.



* Area bounded b/w $(te-3\sigma)$ to $(te+3\sigma)$ is 99.7 % of total area.

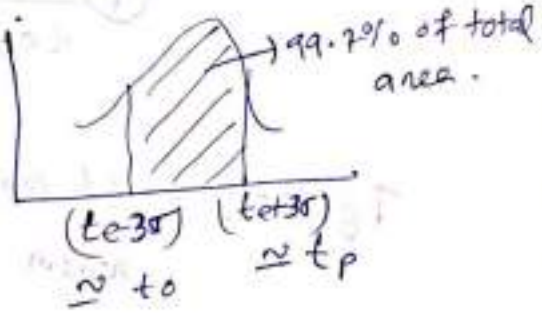
$to = (te-3\sigma)$

$tp = (te+3\sigma)$

$\therefore tp - to = (te+3\sigma) - (te-3\sigma)$

$= 6\sigma$

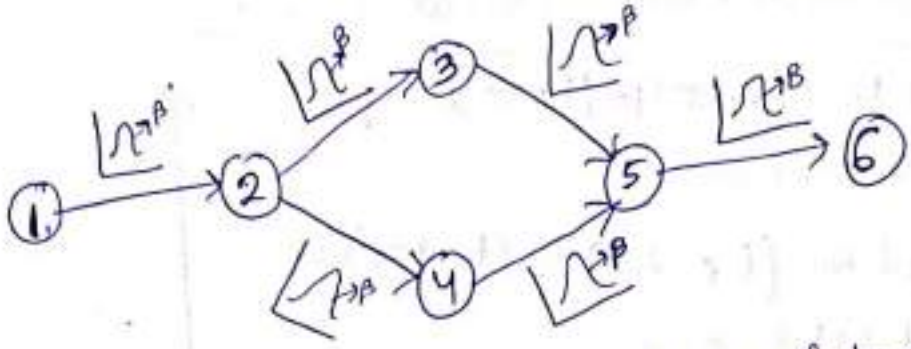
$\therefore \boxed{\sigma = \left(\frac{tp-to}{6}\right)}$ ****



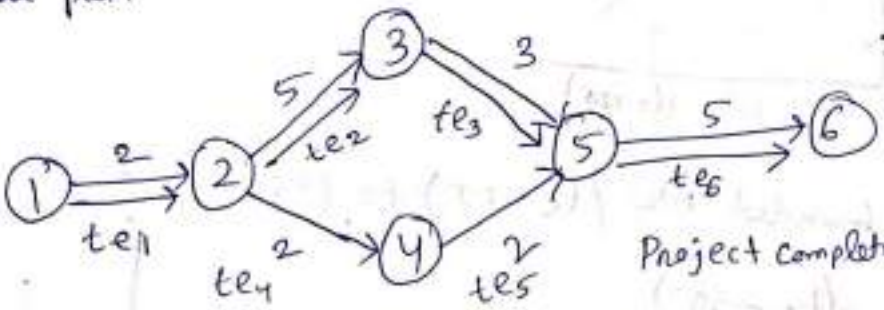
* Normal range of time for completion of an activity is $(te-\sigma)$ to $(te+\sigma)$
* Max. Range of time for completion of an activity is $(t-3\sigma)$ to $(t+3\sigma)$

Central limit Theorem:

① If there are various activities on a project network which having β-distribution of frequency then entire project as whole will have normal distribution of frequency.



(2) The total expected project duration is equal to sum of expected completion time of those activities which are critical and located along critical path.



Project completion time = 15 days

T_E = 11 days → if project completion time is 11 days than some activity will remain incomplete.

∴ Activity ① – ②, ② – ③, ③ – ⑤ & ⑤ – ⑥ are critical activity.

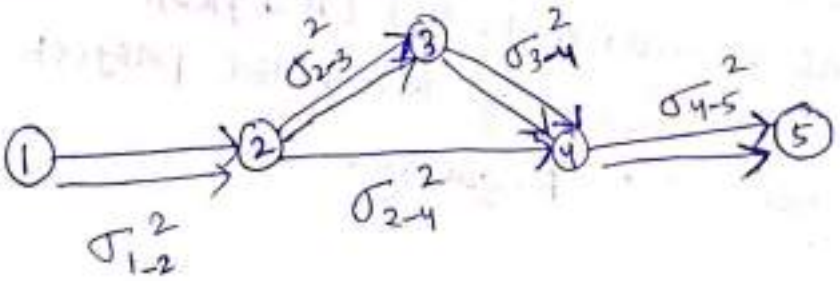
and 1-2-3-5-6 is critical path.

∴ $\boxed{T_E = te_1 + te_2 + te_3 + te_6}$ = 2+5+3+5 = 15 days

T_E = expected completion duration of project

Probability of completion of a project in time T_E is only 50%.

(3) The variance of the project is equal to sum of variances of all critical activities which are located along critical path.



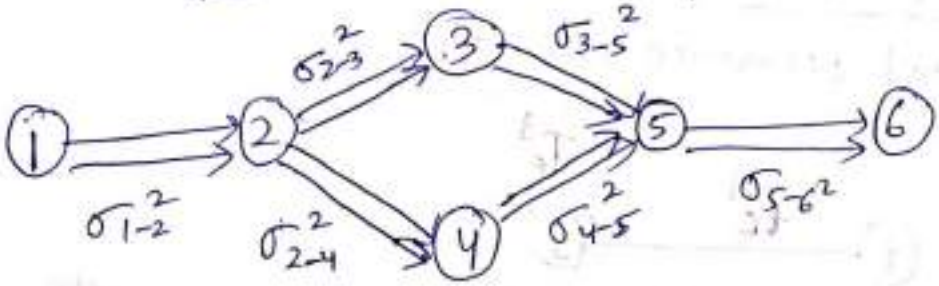
Let's consider Path, 1-2-3-4-5 is critical.

Variance of the project, $\sigma^2 = \sigma_{1-2}^2 + \sigma_{2-3}^2 + \sigma_{3-4}^2 + \sigma_{4-5}^2$ Along critical path.

standard deviation of project, $\sigma = \sqrt{\sigma^2}$

$\therefore \sigma = \sqrt{\sigma_{1-2}^2 + \sigma_{2-3}^2 + \sigma_{3-4}^2 + \sigma_{4-5}^2}$ along critical path

Imp $\sigma \neq \sigma_{1-2} + \sigma_{2-3} + \sigma_{3-4} + \sigma_{4-5}$



Variance along critical path ① [1-2-3-5-6]

$$\sigma_1^2 = \sigma_{1-2}^2 + \sigma_{2-3}^2 + \sigma_{3-5}^2 + \sigma_{5-6}^2$$

Variance along critical path ② [1-2-4-5-6]

$$\sigma_2^2 = \sigma_{1-2}^2 + \sigma_{2-4}^2 + \sigma_{4-5}^2 + \sigma_{5-6}^2$$

If $\sigma_1^2 < \sigma_2^2$

path ① is less uncertain.

path ② is most uncertain. select Take most certain path as critical path.

If there are more than one critical path then priority is given to that part which have greater value of variences. bcz this path is most uncertained, hence extra attention are required for this path.

All critical path having same project duration.

Critical Path :- Critical path is time wise longest path connecting start event to finish event.

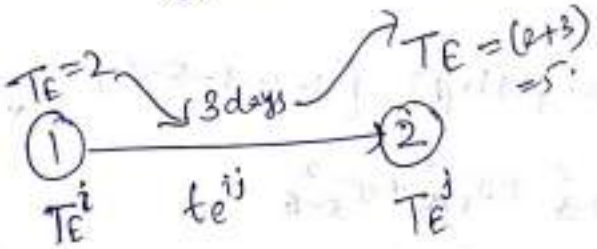
In a network there may be one critical path but all critical path having same project duration.

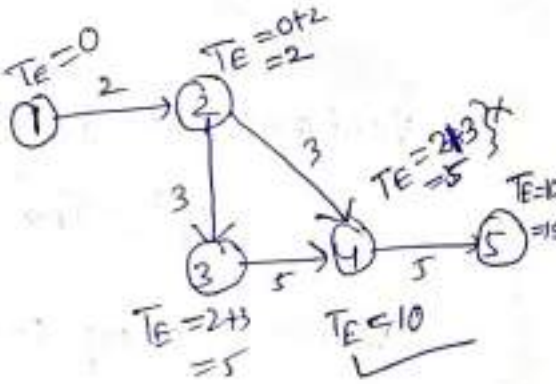
Along the critical path each activity has just proper resources hence any delay in any activity will result in delays of the project. Hence along the critical path each activity and each event are critical. Hence total float for each activity is zero and slack for each event is zero.

Time calculation for event :→

① Earliest expected occurance time (T_E)

e.g.





$$T_E^j = T_E^i + te^{ij}$$

$$T_E^j = (T_E^i + te^{ij})$$

$$T_E^j = (T_E^i + te^{ij})_{max}$$

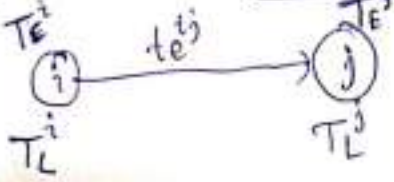
if more than one path it is called by forward path.

If T_E for the start event is not given than it is taken as zero.

It is the time in which an event is expected to occur as early as possible.

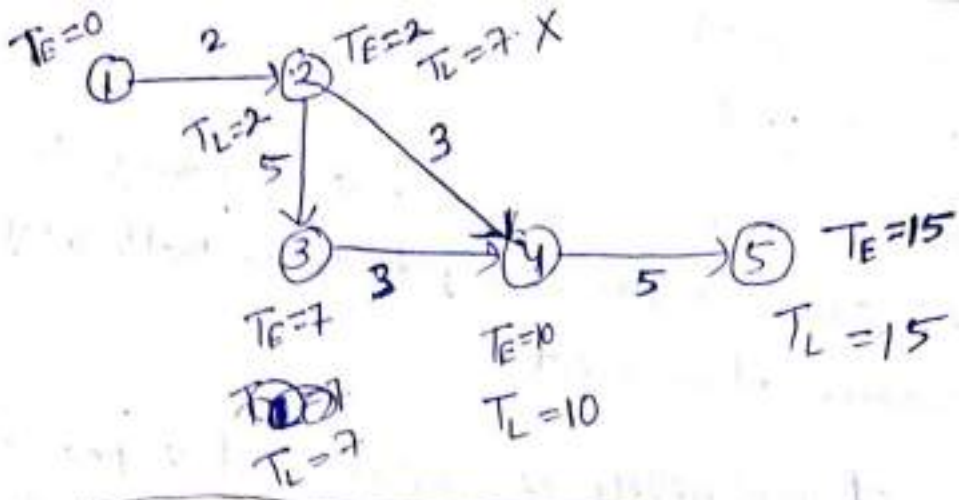
② Latest allowable occurance time

It is the time in which an event is expected to occur as late as possible



$$T_L^i = T_L^j - te^{ij}$$

e.g.



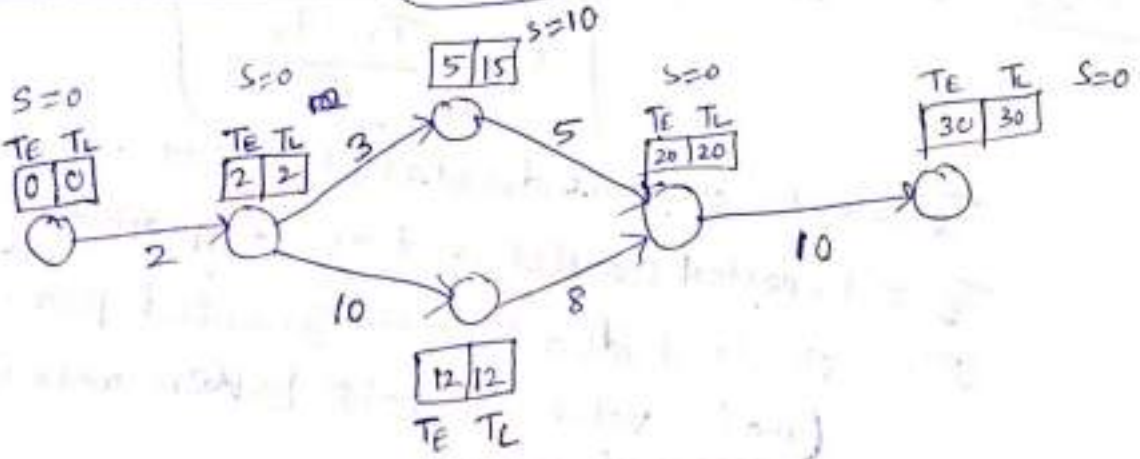
$$T_L^i = T_L^j - t_e^{ij})_{min^m}$$ if more than one path.

$$T_L^i = T_L^j - te^{ij}$$

Calculated by backward path.

(backward) SLACK(S) :→

Slack of an event represent the excess time which may be available to delay the occurance of an event without affecting total project duration.



slack = freedom of event. $slack = T_L - T_E$ **

Case ① - If $slack = 0$

then event is critical. Activity for occurance of such event have just adequate resources. So any delay will result in delay of the project.

Case - ② - If $slack > 0$

- than event is sub critical, than activity having enough resources for occurance of such an event. (degree of freedom > 0 so that delay of this event

will not delay the project).

Case-③ If slack < 0

than event is supercritical than activity having improper resources So occurance of event has already delayed. that's why no freedom for late occurance of an event.

* Calculation of probability of completion of a project :→

step① Draw PERT Network and find T_E and T_L for each event.

step② · Find stack for each event and than identify critical path. Paths connecting critical event (event of zero slack) is called critical path.

step③ Cal. variance / S.D of project along critical path.

step④ Cal. Probability factor Z.

$$Z = \frac{T_S - T_E}{\sigma}$$

T_S = given schedule duration of project.

T_E = Expected completion time of project.

σ = Standard deviation along critical path. (max^m)
(max^m value of σ is taken when more than one critical path)

Step⑤: Cal. probability of completion of project from value of probability factor (given)

Z	P
0	50%
1	84.13%
2	97.72%
3	99.87%

Z	P
0	50%
−1	15.57%
−2	2.28%
−3	0.13%

Intermediate value can be calculated by linear interpolation.

6/7/19

OB Ch-9

Q25. $t_o = 25$ min

$t_p = 48$ min

t_m or $t_L = 35$ min.

expected completion time,

$t_e = \frac{t_o + 4t_m + t_p}{6} = 35.5$ min Ans.

Variance, $\sigma^2 = \left(\frac{t_p - t_o}{6}\right)^2 = \left(\frac{48-25}{6}\right)^2 = 14.69$ Ans

$\therefore$ Standard deviation, $\sigma = \sqrt{14.69} = 3.83$ min.

Time allowed, $= (t_e - 3\sigma)$ to $(t_e + 3\sigma)$

$= (35.5 - 3\times3.83)$ to $(35.5 + 3\times3.83)$

$= 24.01$ min to 46.94 min Ans

Imp ESE

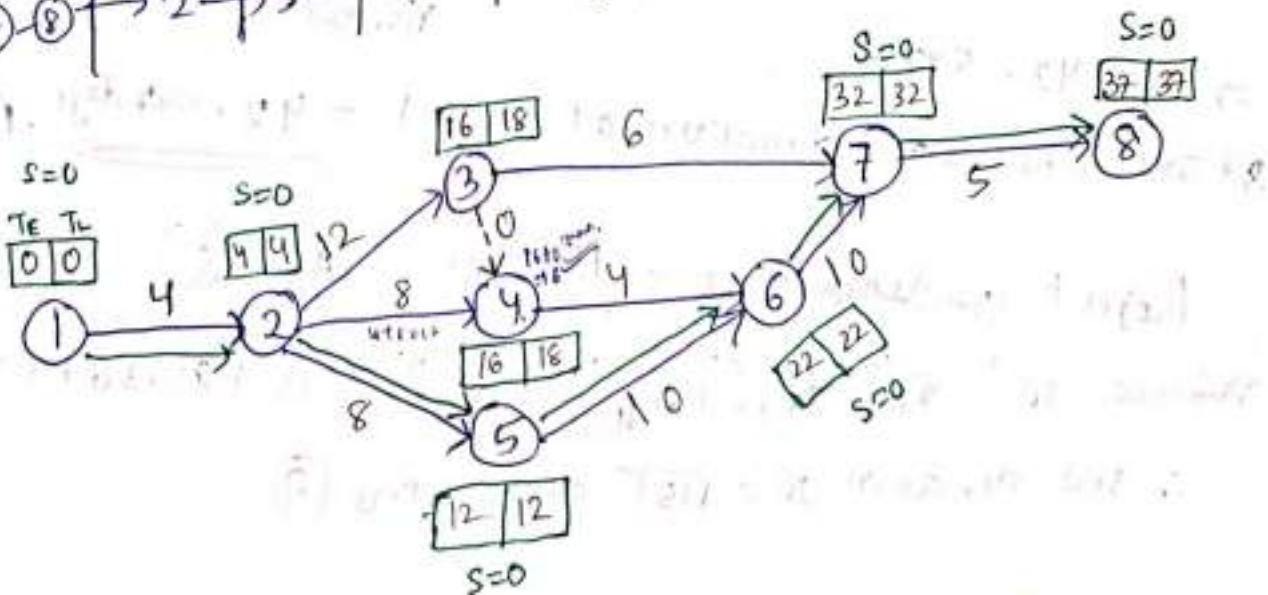
Q. Following is the activity relnship with their 3 time estimates. Draw a PERT network dig. & find,

① critical path

② variance

③ what time did you allow. so that prob. of completion is 90%.

Activity	t_o	t_i	t_p	$t_e = \frac{t_o + 4t_m + t_p}{6}$	Std. deviation (σ)
①-②	2	4	6	4	0.67
②-③	8	11	20	12	2
②-④	4	7	16	8	2
②-⑤	3	67	17	8	2.33
④-⑦	3	5	13	6	1.67
③-④	0	0	0	0	0
④-⑥	2	3	10	4	1.33
⑤-⑥	4	9	20	10	2.67
⑥-⑦	7	10	13	10	1
⑦-⑧	2	5	8	5	1



(iii) Ans

(i) Critical path is **1-2-5-6-7-8** Ans

(ii) Variance for the project = Sum of all variances along Critical path

$\Rightarrow \sigma^2 = \sigma_{1-2}^2 + \sigma_{2-5}^2 + \sigma_{5-6}^2 + \sigma_{6-7}^2 + \sigma_{7-8}^2$

$= (0.67)^2 + (2.33)^2 + (2.67)^2 + 1^2 + 1^2 = 15.0067$

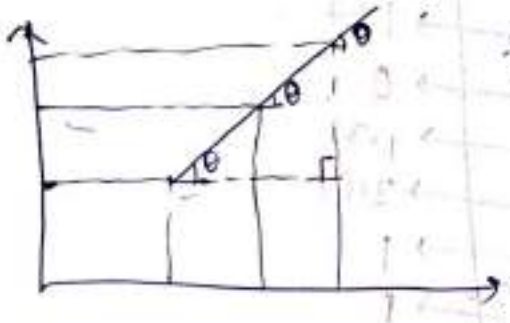
$\therefore$ **Variance = 15.0067** Ans

(iii) Probability of completion = 90% probability) $T_S = ?$

Project duration, $T_E = 37$ days.

Project factor z for 90% probability is calculated by linear interpolation

z	P
0	50%
1	84.13
?	90%
2	97.72



$$\tan\theta = \frac{97.72-84.13}{2-1} = \frac{90-84.13}{2-1}$$

$\therefore z = 1.432$

$\therefore z = \frac{T_S - T_E}{\sigma}$

$\Rightarrow 1.432 = \frac{T_S - 37}{\sqrt{15.0067}}$

$\Rightarrow T_S = 42.547$ days.

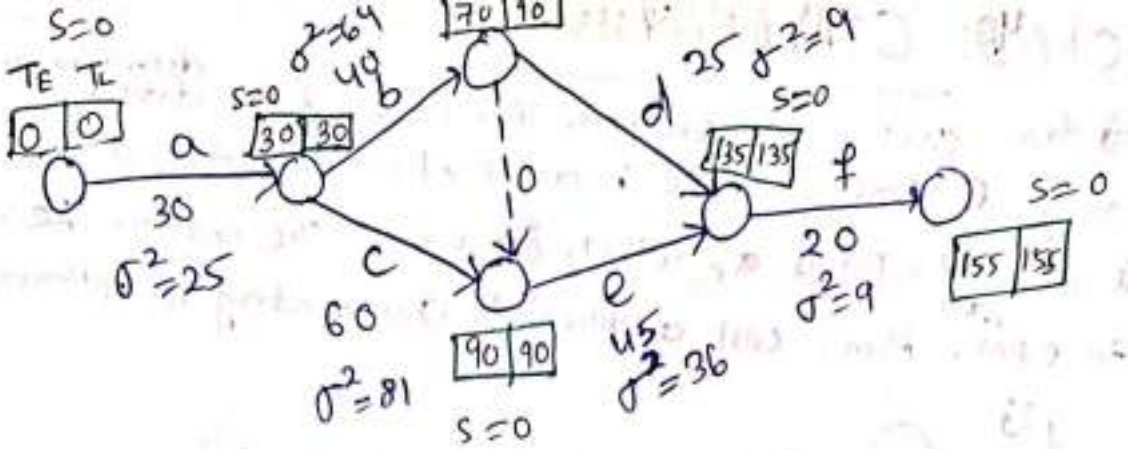
Gate 2020 Q.8

scheduled duration of project = 42.547 days. Ans.

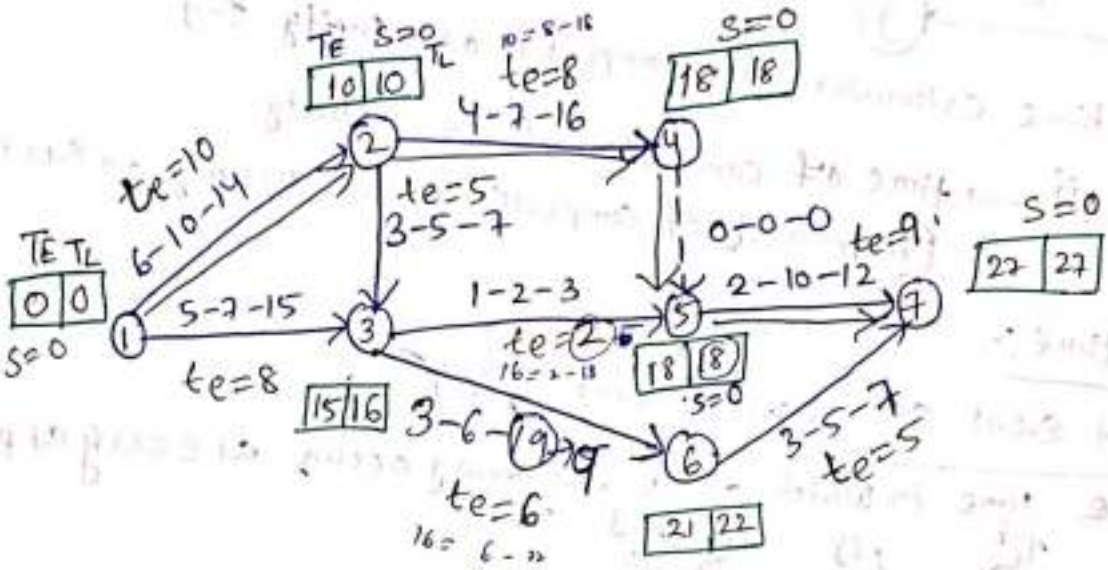
Project completion time = 155 days Ans (8)

Variance $\sigma^2 = \sigma_{1-2}^2 + \sigma_{2-1}^2 + \sigma_{4-5}^2 + \sigma_{5-6}^2 = 25 + 81 + 36 + 9 = 151$

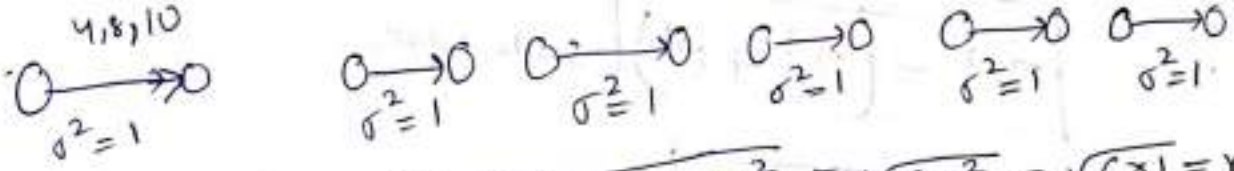
$\therefore$ Std. deviation $\sigma = \sqrt{151}$ days. Ans (9)



Q 26

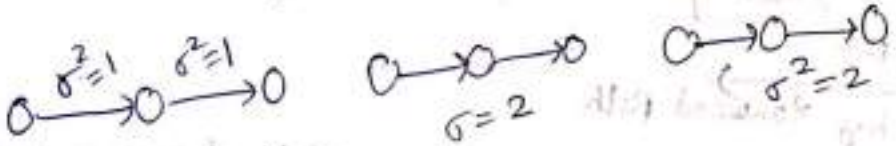


Q.19



Std. deviation, $\sigma = \sqrt{\sigma^2+\sigma^2+\cdots+\sigma^2} = \sqrt{6\sigma^2} = \sqrt{6\times1} = \sqrt{6}$

$\therefore X_1 = \sqrt{6}$

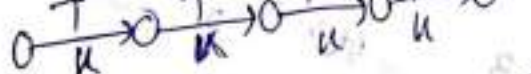


Variance $= \sigma^2+\sigma^2+\sigma^2 = 2+2+2 = 6$

$\therefore$ Std. deviation $= \sqrt{\text{variance}} = \sqrt{6} = X_2$

Ratio $= \frac{X_1}{X_2} = \frac{\sqrt{6}}{\sqrt{6}} = 1$

Q3



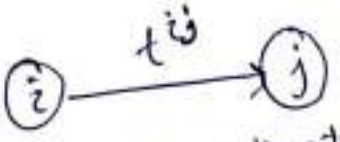
$T_E = 4T$

$\sigma = \sqrt{u^2+u^2+u^2+u^2} = \sqrt{4u^2} = 2u$

$T_E - 3\sigma$ to $T_E + 3\sigma$ $= 4T-6u$ to $4T+6u = 4T \pm 6u$ Ans (d)

Chp-4: CPM ANALYSIS

CPM stands for critical path method. This is based on deterministic approach in which only one time estimate is made for completion of each activity. The network diagram in CPM is activity or event. The cost is the most imp criteria in CPM. Min. cost is obtained corresponding to optimum time.



one time estimates for completion of Activity i-j

t^{ij} → time of completion of an activity.
(Probability of completion of an activity in this time is 100%)

Event time:-

1. Earliest event occurance Time (T_E)

It is the time in which an event may occur as early as possible.

$$T_E^j = \left(T_E^i + t^{ij}\right)$$ single activity

forward path.

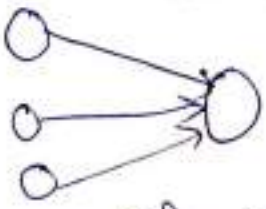
$$T_E^j = \left(T_E^j + t^{ij}\right)_{max}$$ many activity

If more than one path

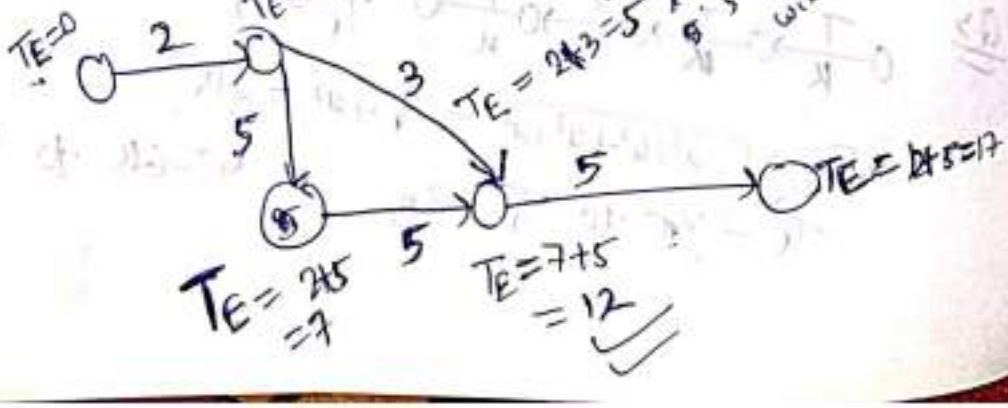
Calculated by forward path.

Imp. If T_E for initial event is not given than it is taken as zero.

e.g.

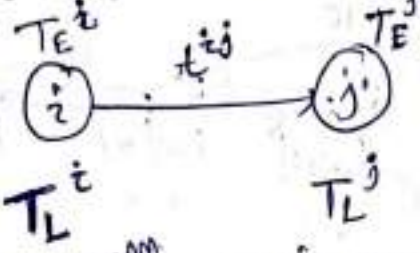


$$T_E^j = \left(T_E^j + t^{ij}\right)_{max}.$$

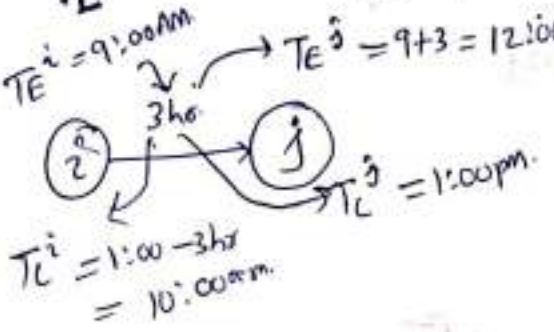


② Latest allowable occurrence Time (T_L)

It is the latest (most) time by which an event may occur as late as possible without delay in project completion time.



e.g.



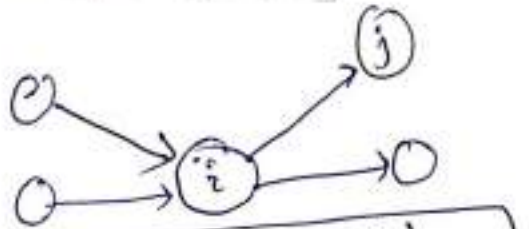
We have 4hr. from 9:00 AM to 1:00 PM.
We have to take 3hr. of class.

T_E^i = initial event = 9:00

$T_E^j = 9+3 = 12:00$

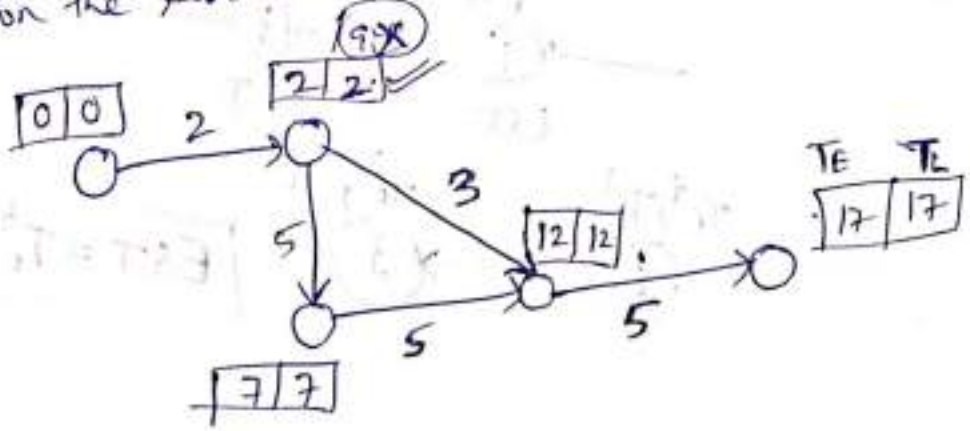
$T_L^j = 1:00$ PM.

$T_L^i = 1:00$ PM $- 3hr = 10:00$ A.M.

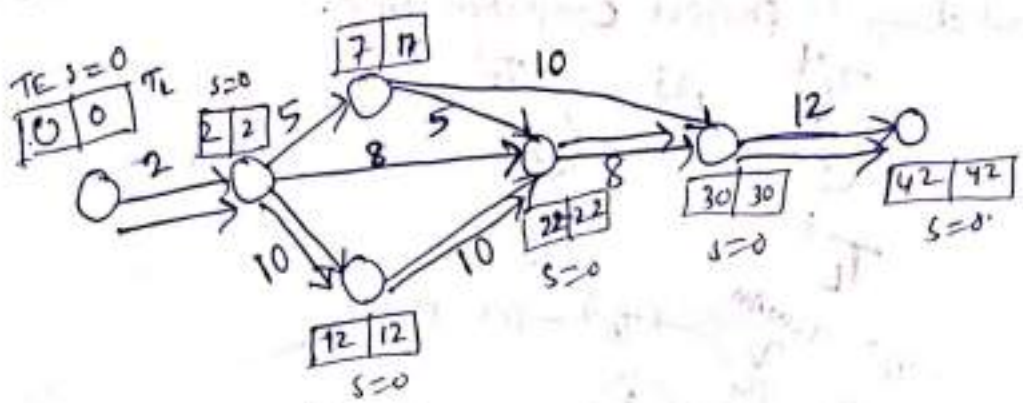


$$T_L^i = (T_L^j - t^{ij})_{min}$$

T_L for the last event is taken as T_E for the last event.

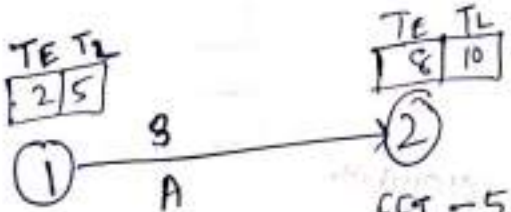


9(8) If we will take 9 than project will complete in 24 days, 30 min time 2 days is considered for no delay in project.



⟹ is critical path.

Activity time.



EST = 2 = T_E^i

LST = 10 − 3 = 7 = $T_L^j - t^{ij}$

EFT = 5 = 2 + 3 = $T_E^i + t^{ij}$

LFT = 10 = T_L^j

$EST = T_E^i$

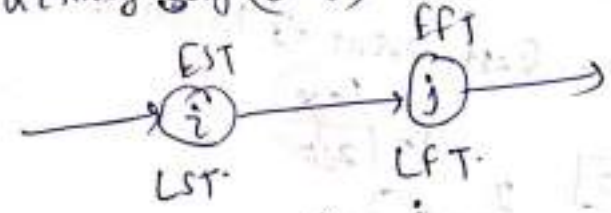
$EFT = T_E^i + t^{ij}$

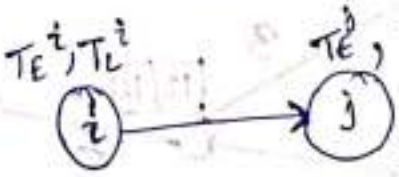
$LFT = T_L^j$

$LST = T_L^j - t^{ij}$

There are 4 activity time

(1) Earliest start time (EST) → It is the earliest possible start time for an activity say (i−j).





$EST = T_E^i$

(2) Earliest finish time (EFT) → It is the earliest possible finish time for an activity. For EFT an activity should start at EST.

$$EFT = T_E^i + t^{ij}$$

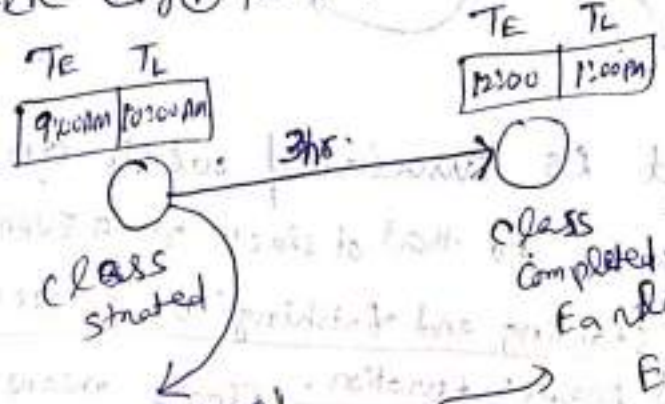
(3) Latest finish time (LFT) :→ It is the time in which an activity may allow to finish as late as possible without delay in project duration time.

$$LFT = T_L^j$$

(4) Latest start time (LST) → It is the latest start time for an activity, so that an activity should be completed as late as possible without delay in project completion time.

$$LST = T_L^j - t^{ij}$$

✓ e.g. Refer eg ① prev. page.



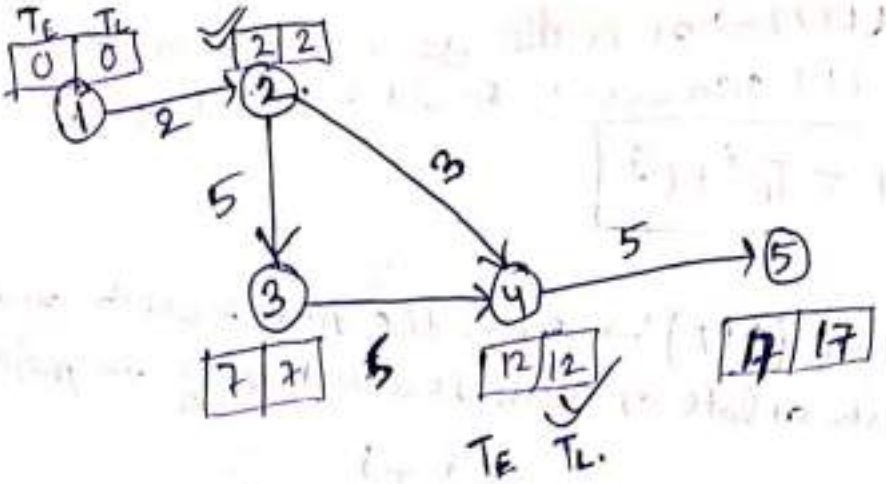
Earliest start time for class (EST) = 9:00AM.

Earliest finish time for class,
EFT = 9:00AM + 3hr = 12:00
$EFT = (EST + t^{ij})$

Latest start time for class
LST = 1:00 − 3hr = 10:00 AM
$LST = LFT - t^{ij}$

Latest finish time for class,
LFT = 1:00 PM.

Q//



Find EST, EFT, LFT and LST for activity ② - ④

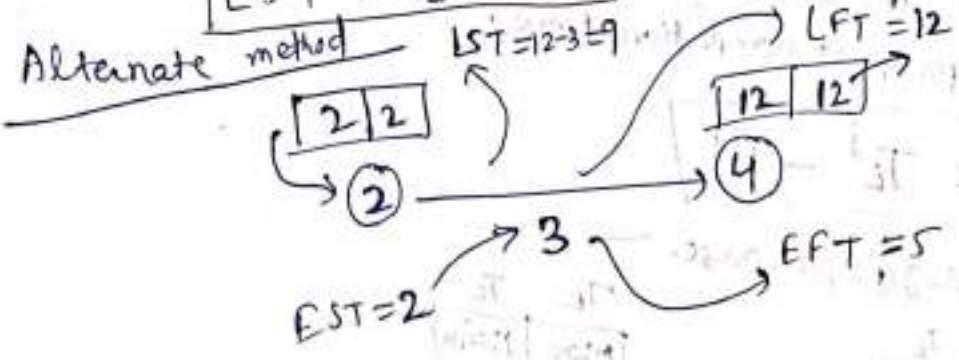
$EST = T_E^i = 2$

$EFT = T_E^i + t^{ij} = 2+3 = 5$

$LFT = T_L^j = 12$

$LST = T_L^j - t^{ij} = 12-3 = 9$

Alternate method

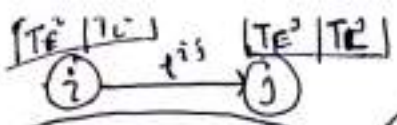


* **Float :→** A float is associated with an activity and its significance is similar to that of slack in a event. Float denotes the range within which the starting and finishing of an activity may varies without affecting total project duration. (Floats means freedom of activity)

* Types of Float

1. Total float (F_T)
2. Free float (F_F)
3. Independent float (F_{ID})
4. Interfering " (F_{IN})

(1) Total float (F_T):→ It is the max^m time by which either starting or Completion of an activity may delay without affecting schedule duration of project.



$EST = T_E^i$

$LST = (T_L^j - t^{ij})$

$EFT = T_E^i + t^{ij}$

$LFT = T_L^j$

Freedom = LST − EST (starting delay) = starting delay.

Completion delay = LFT − EFT

$= T_L^j - T_E^i - t^{ij}$

$\therefore F_T = T_L^j - T_E^i - t^{ij}$

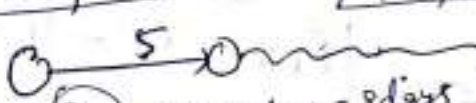
$\therefore$ Time float = starting delay of freedom

$= LST - EST$

$= T_L^j - t^{ij} - T_E^i =$

$T_L^j - T_E^i - t^{ij}$

e.g.



Freedom = 8 days

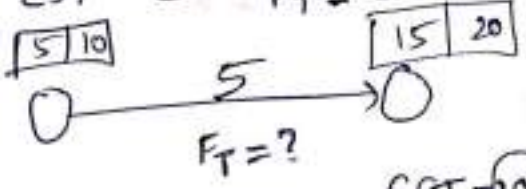
F_T = 8 days

Formula method

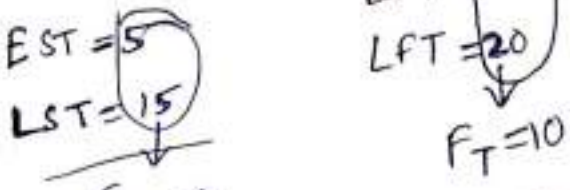
$F_T = T_L^j - T_E^i - t^{ij}$

$= 15 - 2 - 5 = 8$ days.

Q.



$F_T = 10$?

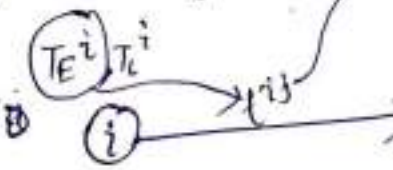


(2) Free float (F_F) :→

It is that portion of +ve total float which can be used by an activity for completion delay without affecting total project Duration. (TPD)

For Cal of free float all activities must be started at their earliest start time.

free float is always +ve → (T_E^j, T_L^j) → Freedom = $f_F = T_E^j - (T_E^i + t^{ij})$

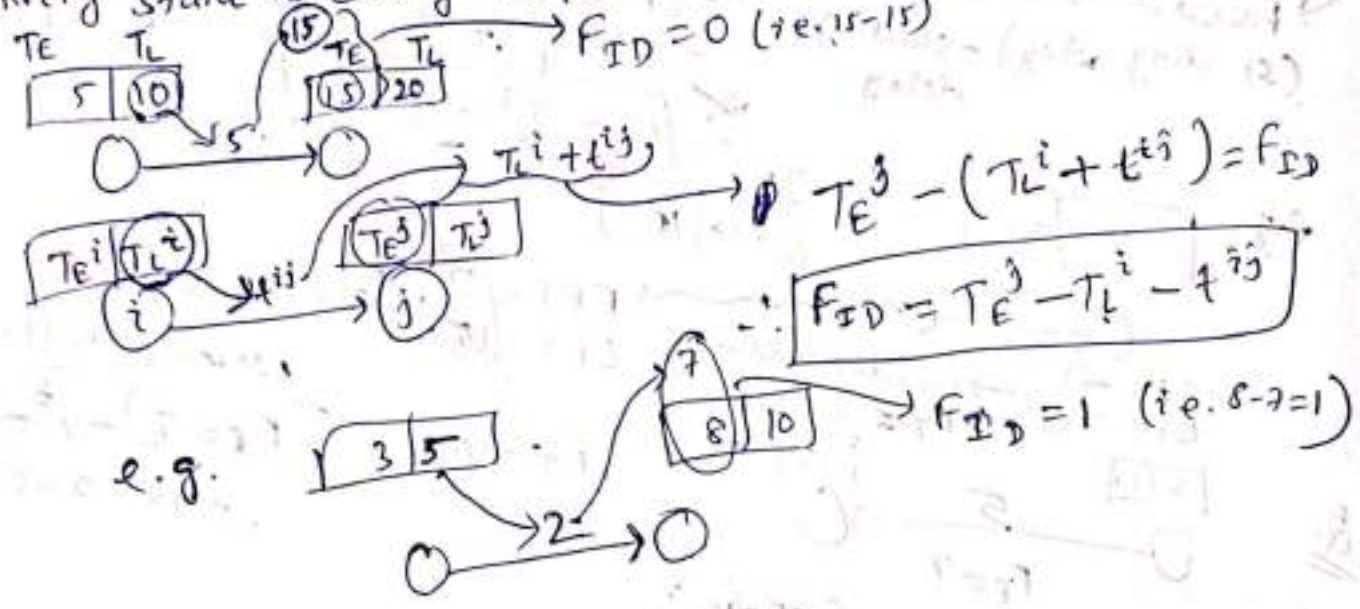


$F_{F_1} = T_E^j - T_E^i - t^{ij}$

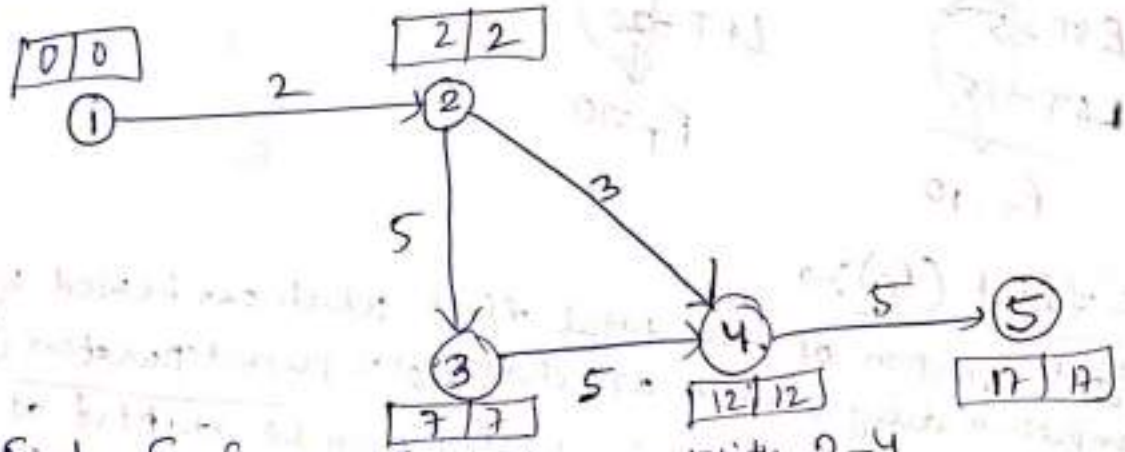
free floats affects preceding activity only, where as total float affects succeeding as well as preceding activity both.

(3) Independent float (F_{ID}):→

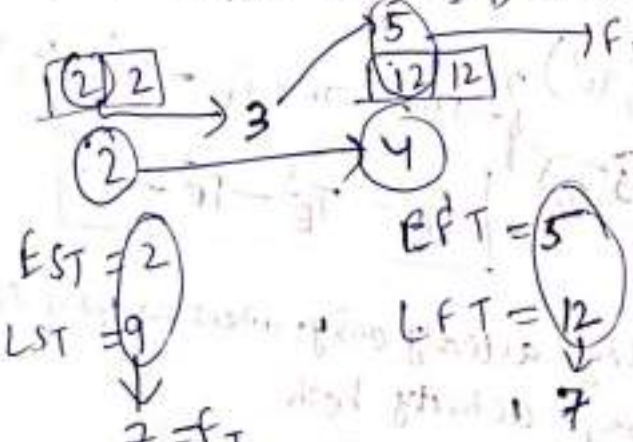
It gives the idea about excess time over activity duration when preceeding activity completing as late as possible & succeeding activity start as early as possibility.



Q.



Find F_T, F_F and F_{ID} for activity 2-4

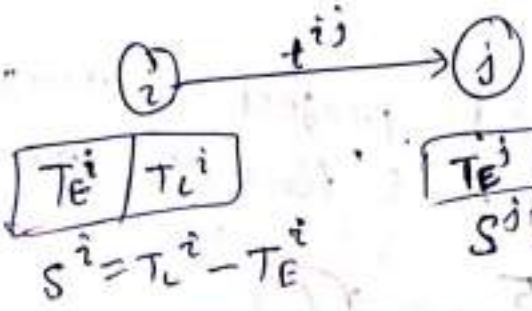


$F_T = 7$
$F_F = 7$
$F_{ID} = 7$

Ans

$$F_{SN} = F_T - F_F = T_L^j - T_E^i - t^{ij} - \left(T_E^j - T_E^i - t^{ij}\right) = T_L^j - T_E^j = S^j$$

F_{IN} = Head event slack.



formula trick

$F_T = T_L^j - T_E^i - t^{ij}$ (L, E)

$FF = T_E^j - T_E^i - t^{ij}$ (E, E)

$F_{ID} = T_E^j - T_L^i - t^{ij}$ (E, L)

just remember.

Note

Independent float neither affect preceeding activity nor affect succeeding activity. It only affect concern activity.

Critical path

The path which connects activity means zero total float is called critical path. ($F_T = 0$)

Resources for such activity are just proper, hence any delay in any activity will resulting delay of the project.

It is time wise longest path.

Super Critical path

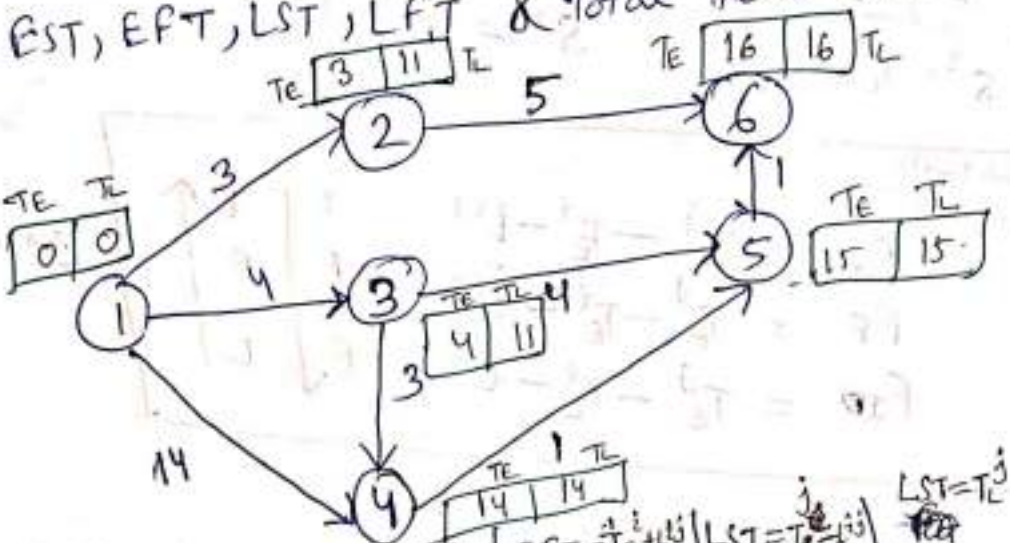
Path connecting activities which T.F.(F_T) < 0 is called supercritical path.

Resources in these path are insufficient.

Subcritical path

Path connecting activities with $F_T > 0$ is called subcritical path. Resources in these path are sufficient & enough.

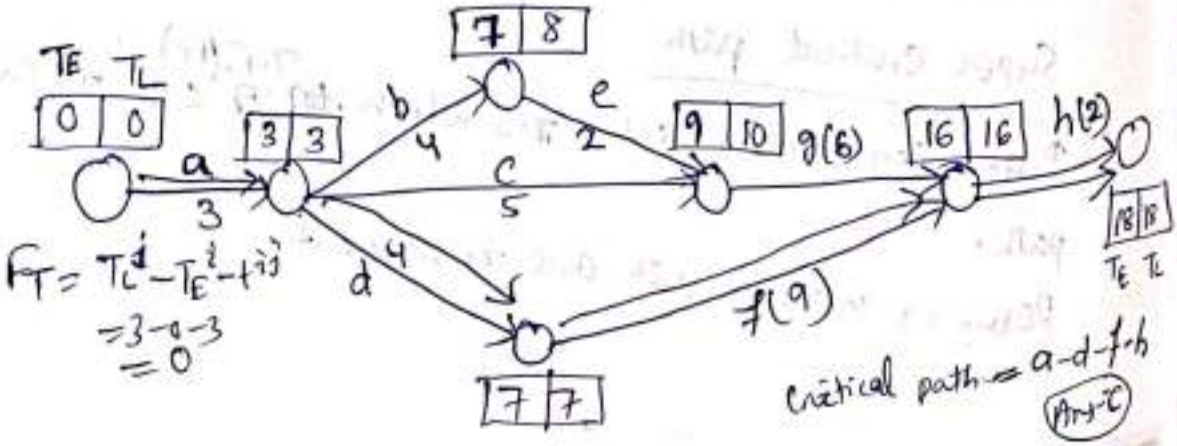
Q. For the network show in fig. Cal. project duration, critical path, EST, EFT, LST, LFT & total float for each activity.



Activity	t_0^{ij}	EST = T_E^i	EFT = $T_E^i + t_0^{ij}$	LST = $T_L^j - t_0^{ij}$	LFT = T_L^j	F_T = LFT − EFT = LST − EST	Remarks
(1)–(2)	3	0	3	8	11	8	
(1)–(3)	4	0	4	7	11	7	
(1)–(4)	14	0	14	0	14	0	Critical
(2)–(6)	5	3	8	11	16	8	
(3)–(4)	3	4	7	11	14	7	
(3)–(5)	4	4	8	11	15	7	
(4)–(6)	1	14	15	14	15	0	Critical
(5)–(6)	1	15	16	15	16	0	Critical

WB Ch-4

12-13



$F_T = T_L^j - T_E^i - t_{ij}$

$= 3 - 0 - 3$

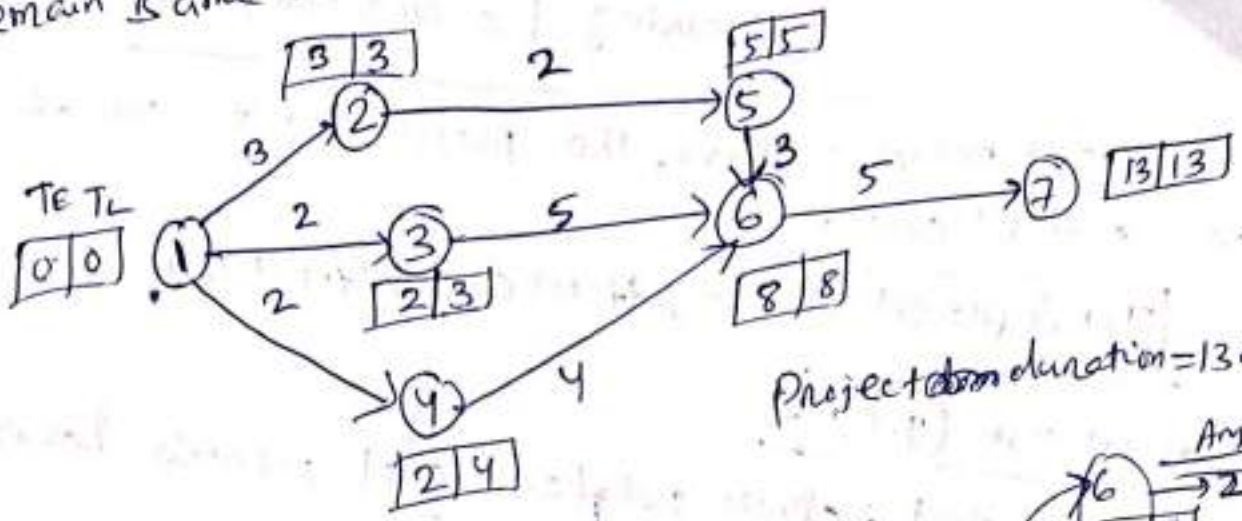
$= 0$

Critical path = a-d-f-h

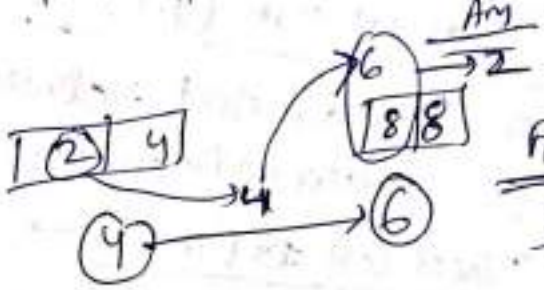
Ans-C

Q.13 Project duration will change to 19 days but critical path remain same

Q.17

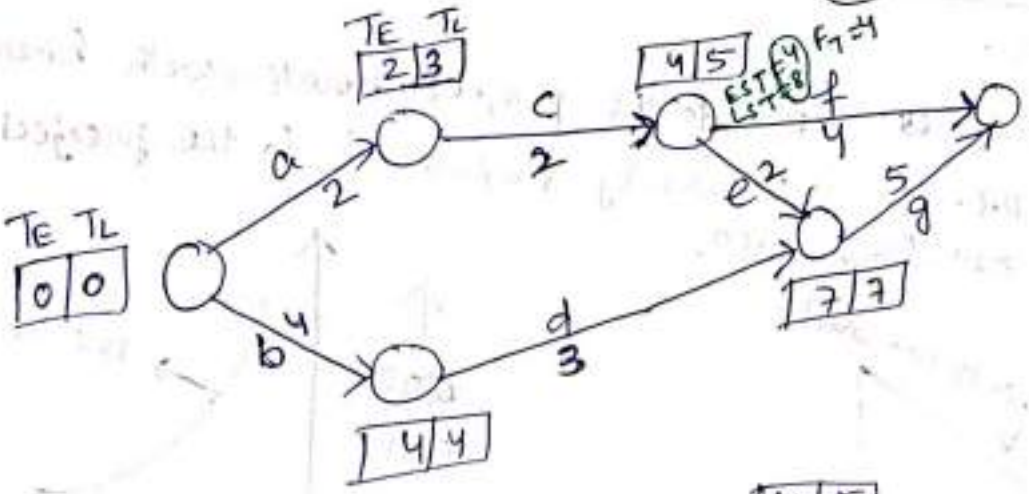


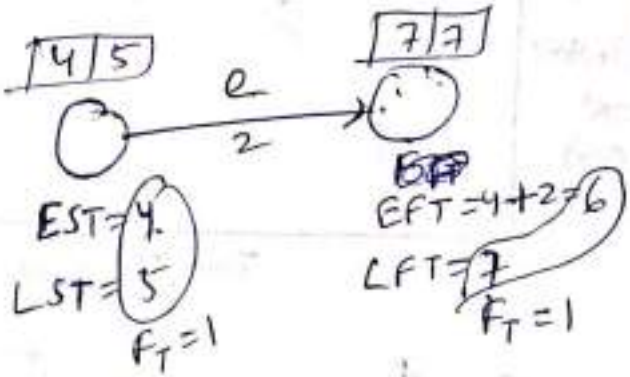
Project duration = 13 days Any



$F_F = 2$ Any

Q.18





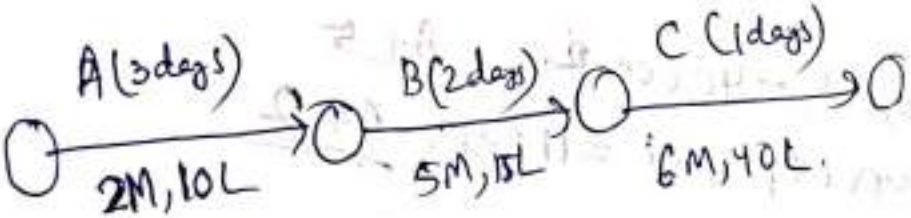
1 and 4 Any

Resource allocation and Resource levelling

Resource is a critical variable which is required for completing the diff. activities of a project. This may be material resources, Man power resources, Money, time, etc.

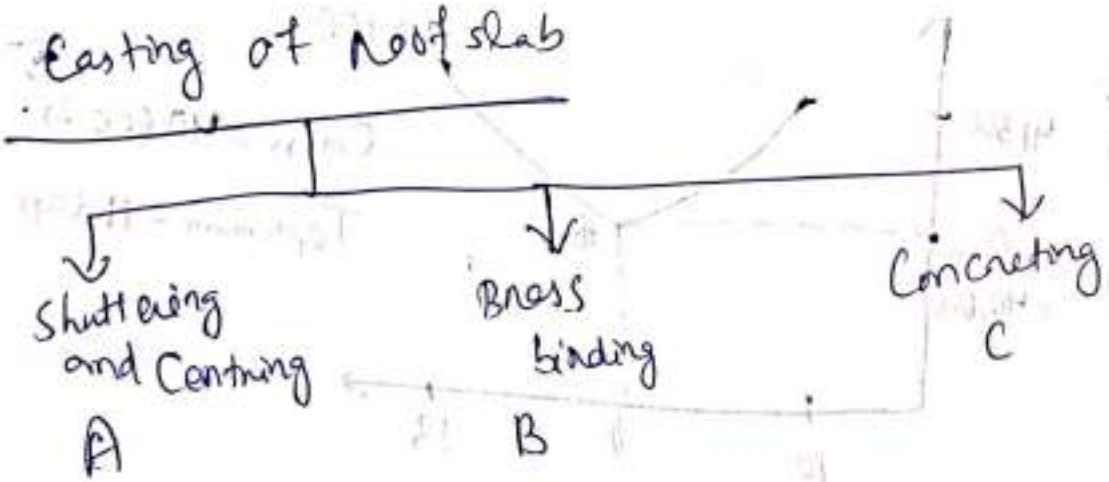
Resource allocation mean finding out which resources are to be alloted to which activity & in what quantity.

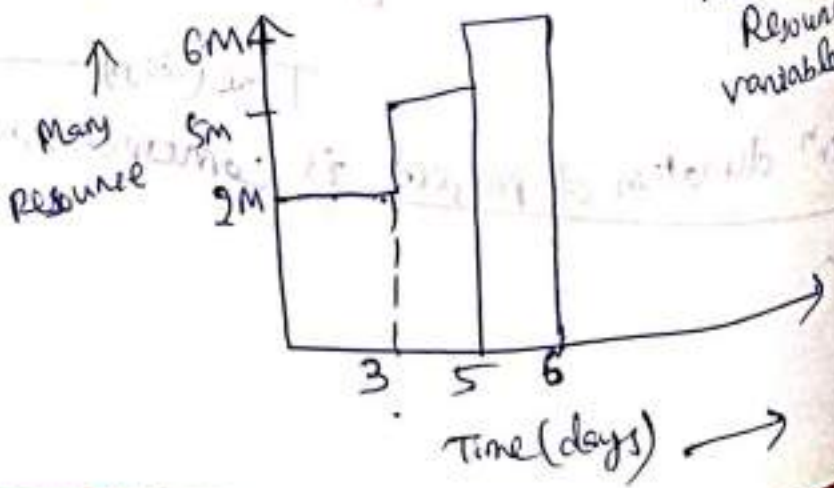
The dig. which show the variation in the requirement of resources with time is called resource histogram.



M → Masons.

L → Labour.





Resources histogram
Resources are variable

Resource allocation can be done by 2 techniques:

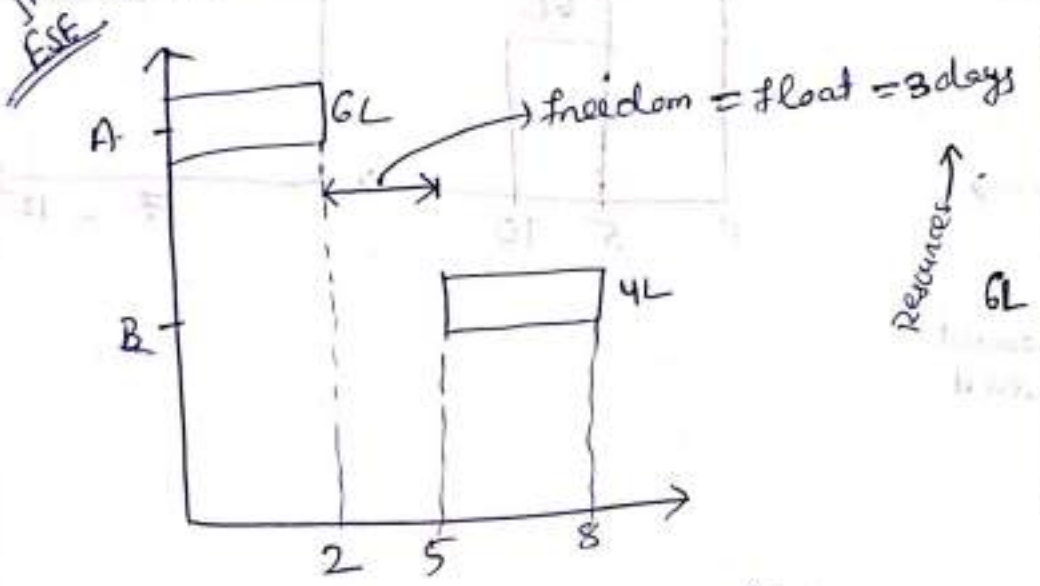
1. Resources smoothening
2. Resource Levelling

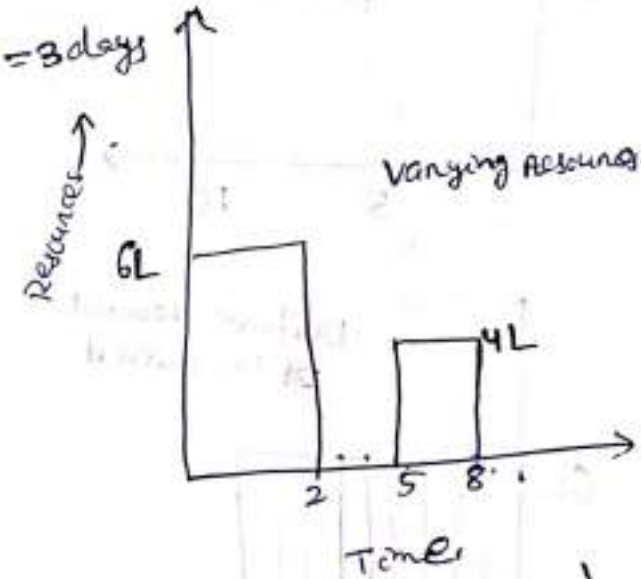
(1) Resources Smoothening

In this process of resource allocation the activities are delayed by their available total float in such a way that uniform demand of resources is achieved.

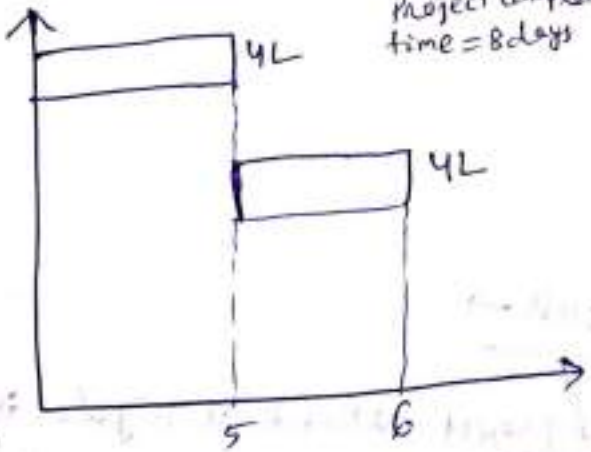
It is to be noted that resources in this case are considered as unlimited & critical activities remain unchanged.

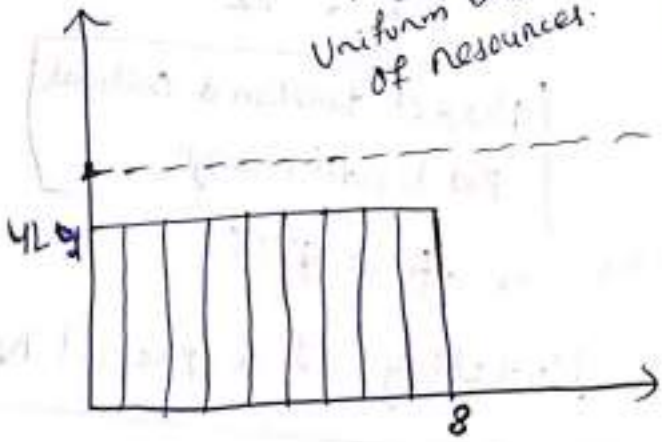
The project completion time & critical path also remain unchanged.





Project completion time = 8 days.





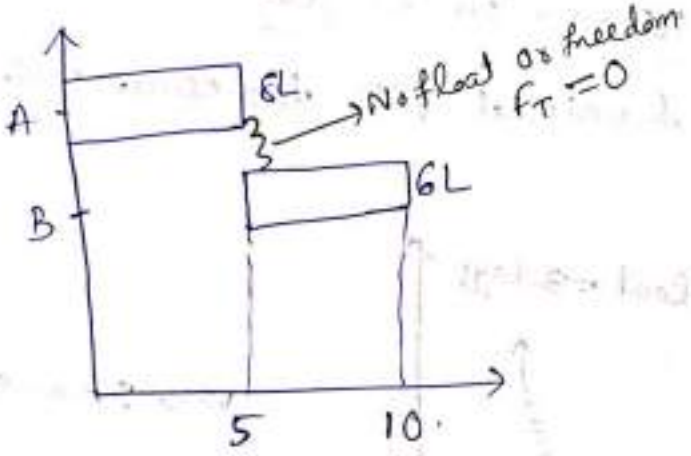
Project duration and critical path remain unchanged.

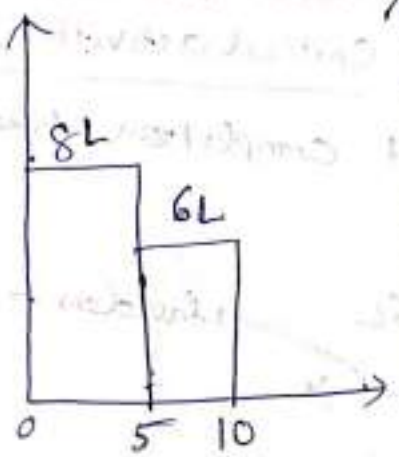
****

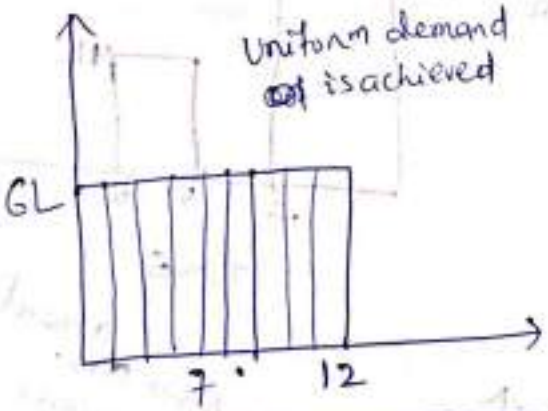
(2) Resource Levelling :→

In this process of resource elongation the activities are rescheduled in such a way that the peak requirement at any point of time is less than the max. resources available.

In this process the resources are considered to be limited & Critical path as well as project completion time remain changed.







Project duration & Critical path will change

* * * *

Updating of a Project Network →

Updating is the process of renew of a project network at regular interval in order to account for last moment change in program or any deviations in

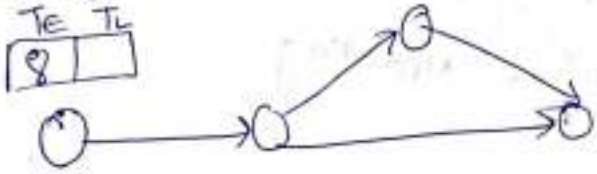
(8) During updating network dig. is redraw, dates and times are revised hence total project duration as well as critical path will change.

Procedure of updating

Step

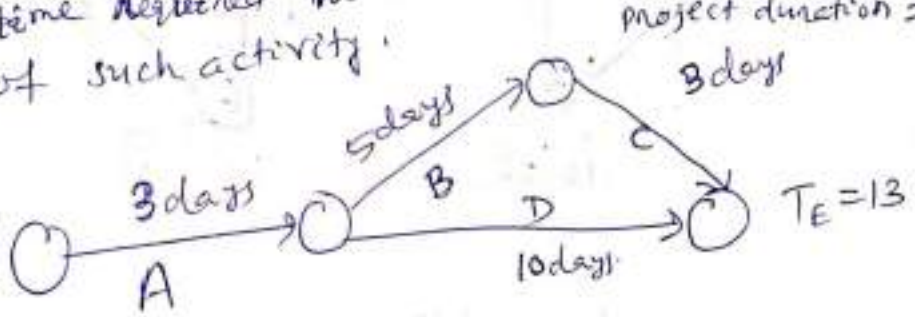
1. At the time of updating redraw the network dig. The start time of critical event = no: of days after which updating is done.

Review after 8 days.



2. On the date of updating determine how much time will further require for completion of each activity including activities in progress or activities to a start and enter time required above the required activity.

3. If some activities are completed at the time of updating then further time required for that activity is 0 (zero) & enter time in front of such activity.

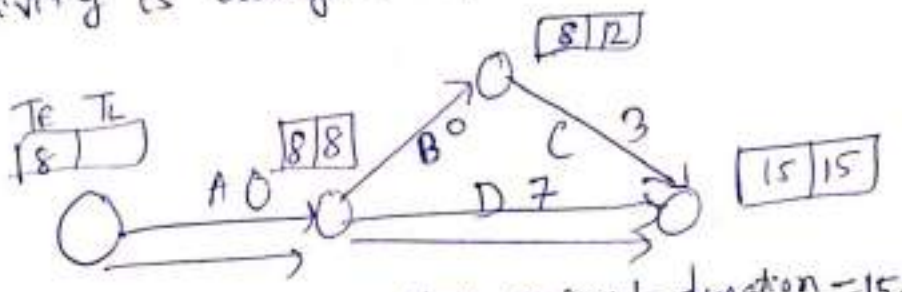


Review after 8 days.

(1) Activity A and activity B is completed.

(2) Activity C is on time.

(3) Activity is delayed drastically & it requires 7 more days

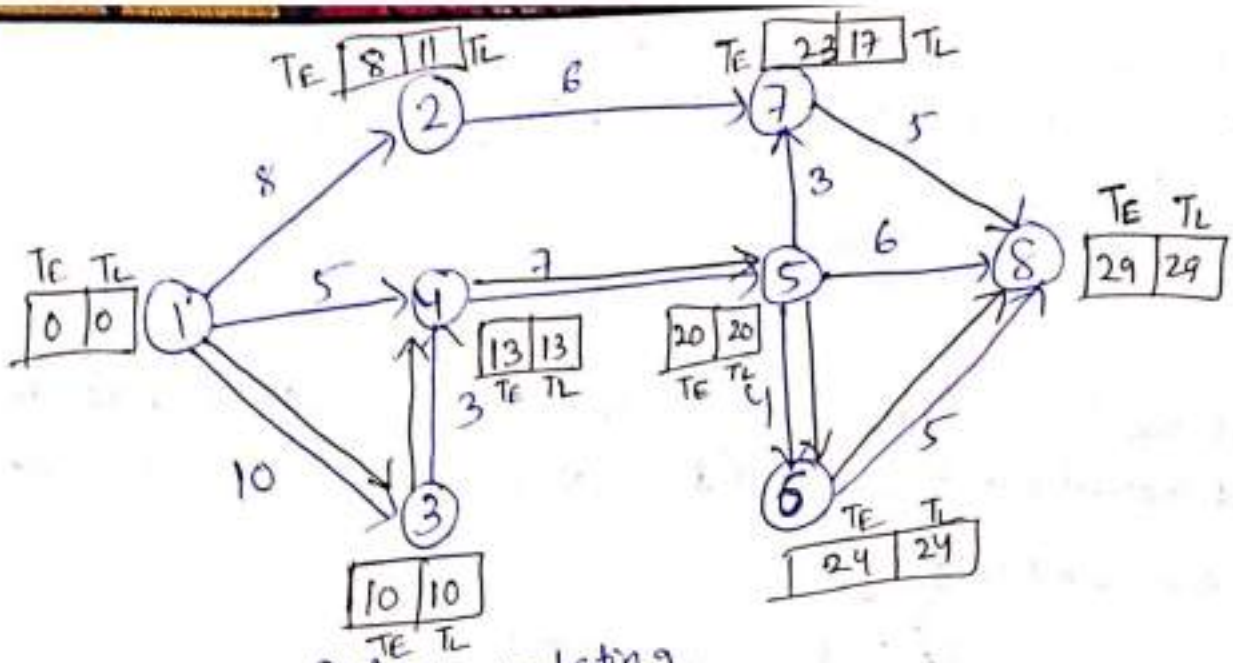


Now project duration = 15 days

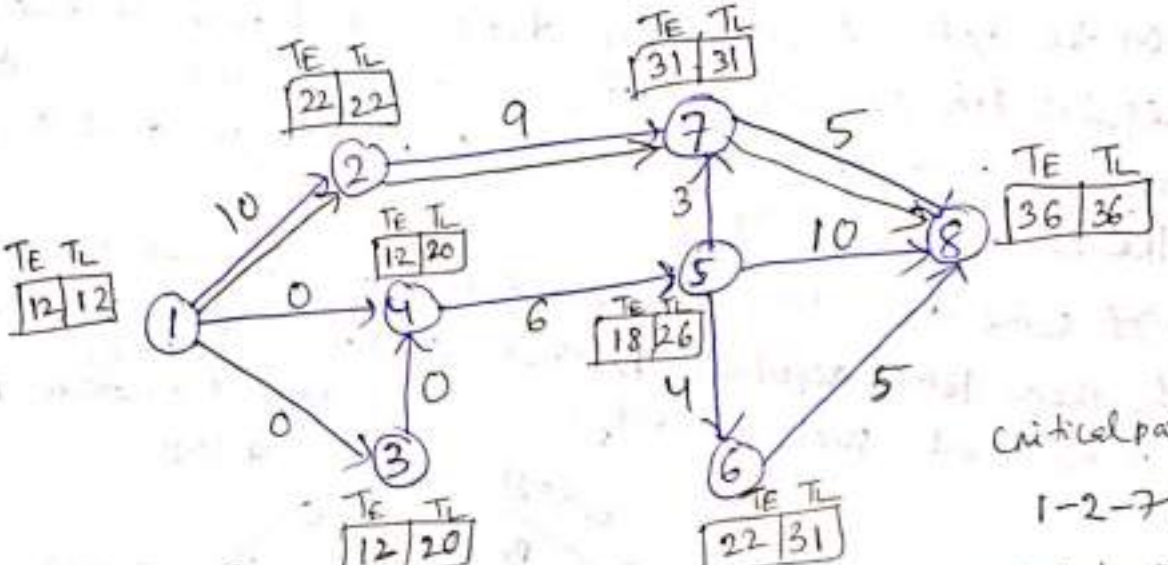
(4) Find TE and TL for each event and then find critical path and project dur^n.

WB

Q.14



Before updating



Critical path

1-2-7-8

Project duration = 36 days

After updating

(A)

A-O-N Network

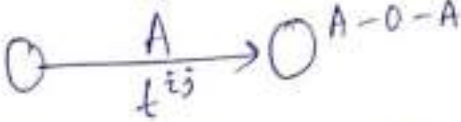
A-O-N stands for Activity On Node Network. The network diagram is self explanatory and it is activity oriented. It is suitable only for CPM based project.

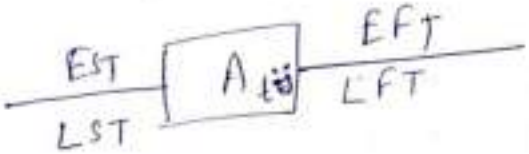
Features of A-O-N Network

→ In this network only activities are shown and events are no place.

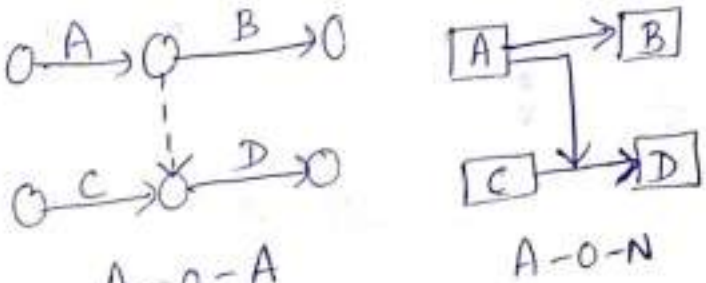
→ The network dig. is self explanatory and all activities time are shown in the network. (EST, EFT, LST, LFT)

→ There is no role of dummy however here inter relⁿ ship is maintained by arrow.

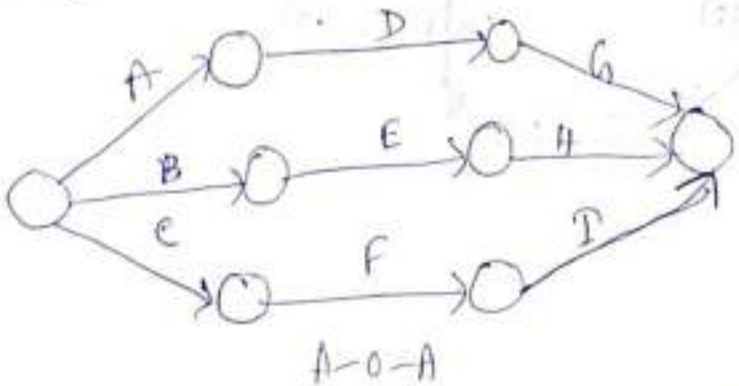


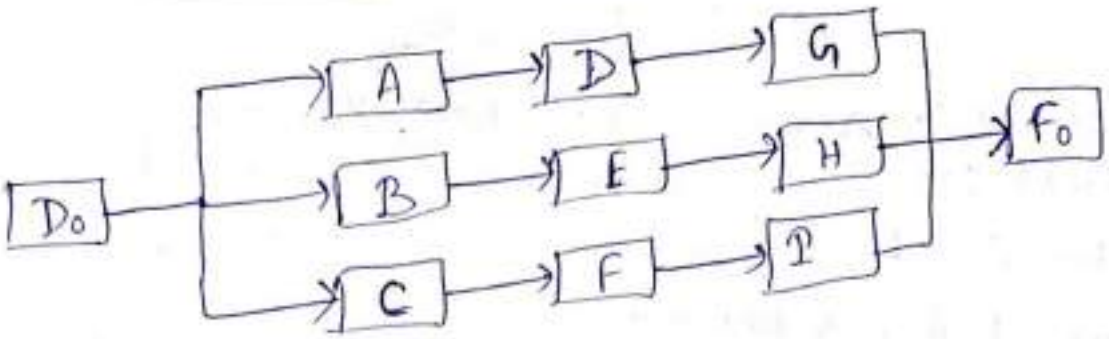


A-O-N



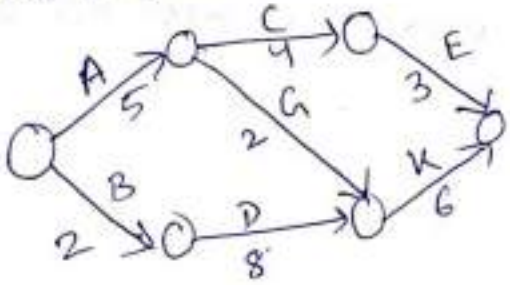
→ If there are more than one activity which will start simultaneously than a new activity DEBUT (D_o) has introduced. similarly if more than one activity will finish at the same time than a new activity finish (F_o) has been introduced. Such activity doesn't require any resources and anytime for it's occurance.

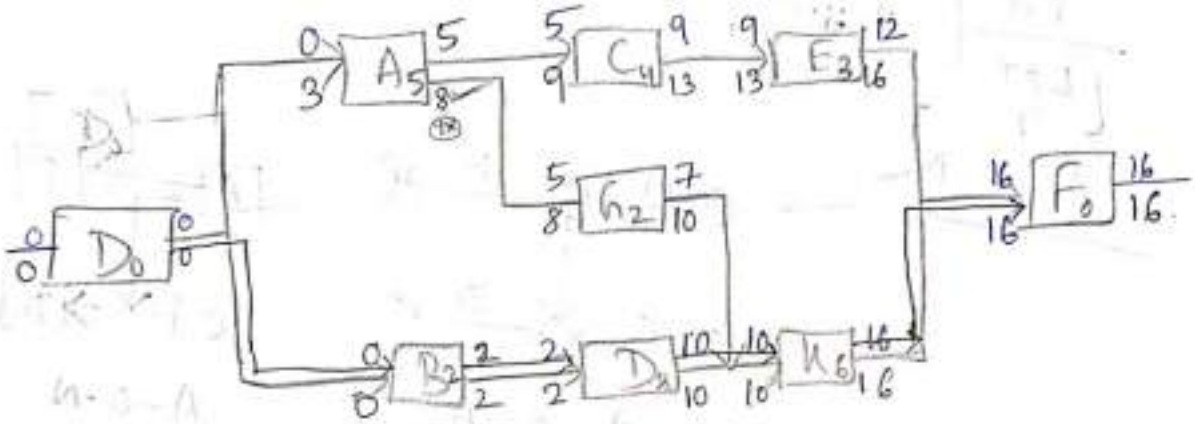




A-O-N

Q. A-O-A network is shown in fig. Convert it into A-O-N network & find project duration and critical path.

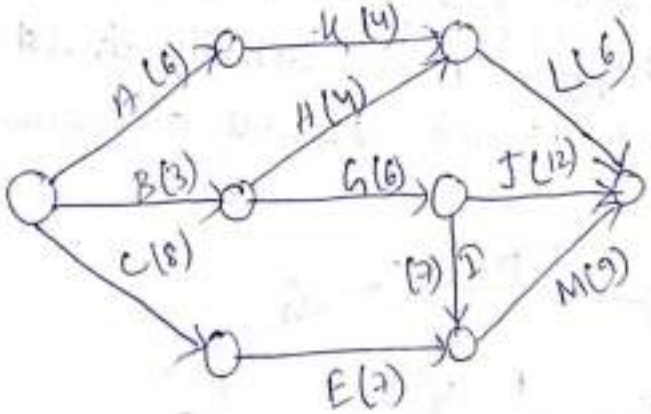


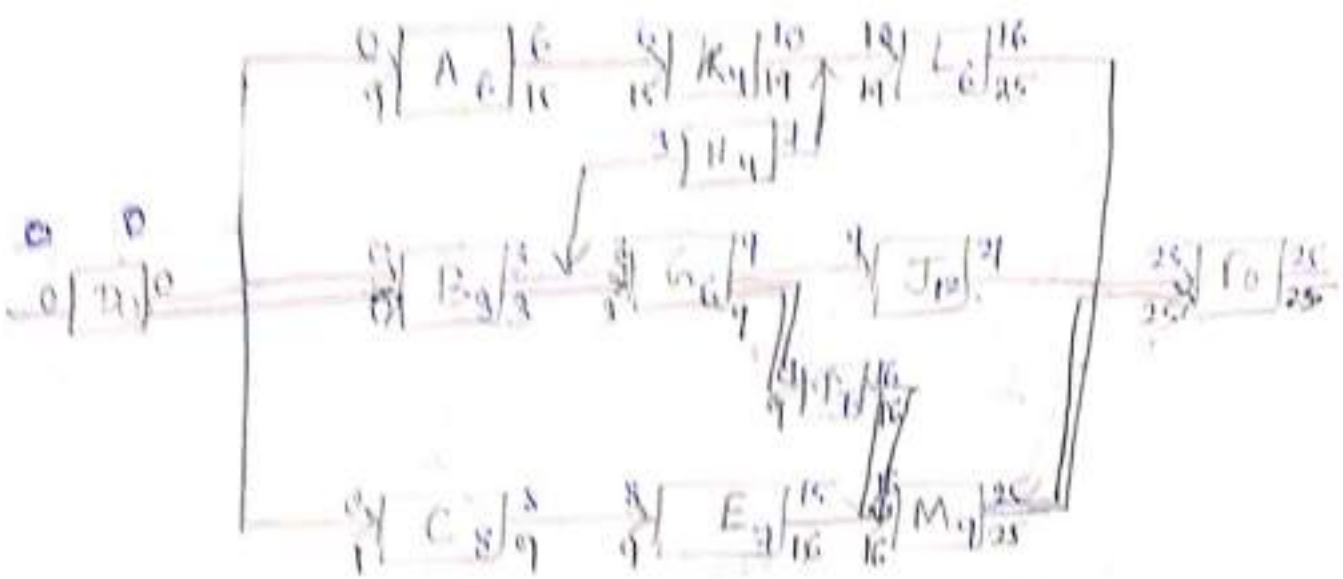


Critical path → B-D-K

Project duration = 16 days.

Q.

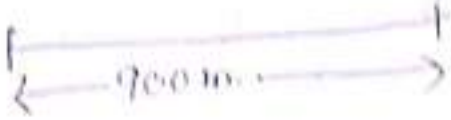




LADDER NETWORK

Ladder network is generally used when one activity is delayed due to another activity during construction. It is generally used to minimise time of completion of a project. In this method all activities are divided into equal sub activities.

Eg: Installation of underground pipeline in 900 m. length.



Activity

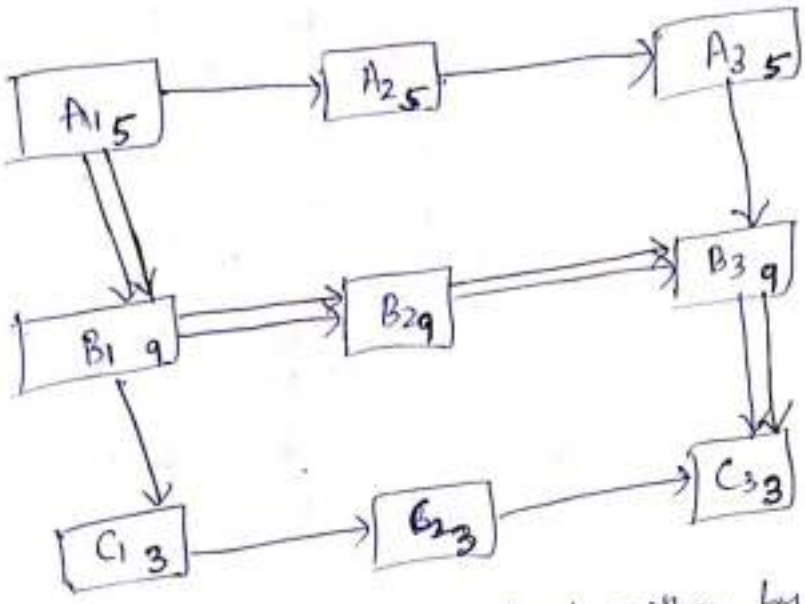
Excavation of trench → A → 15 days
Installation of pipe line → B → 27 days
Refilling → C → 9 days

51 days = project duration

A → A1 → 5 days
A → A2 → 5 "
A → A3 → 5 "

C → C1 → 3 days
C → C2 → 3 "
C → C3 → 3 "

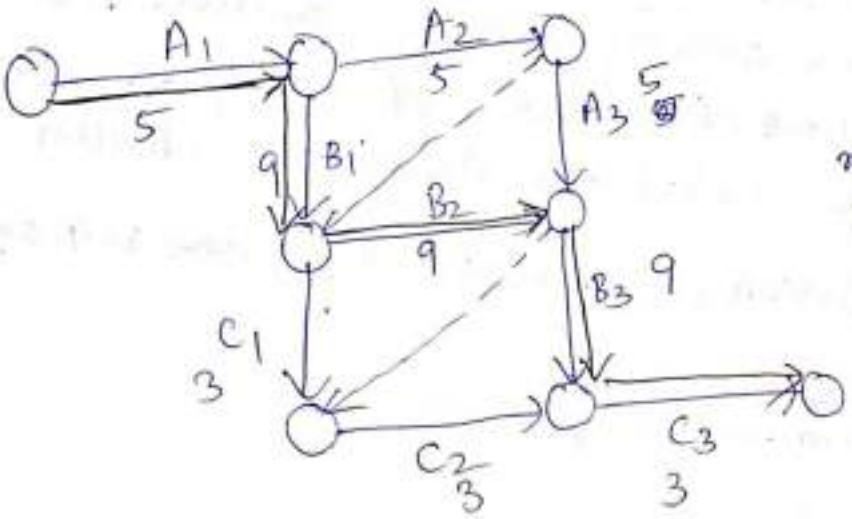
B → B1 → 9 "
B → B2 → 9 "
B → B3 → 9 "



Project duration = 35 days

Saving = 51 - 35
= 16 days.

Ladder network can be solved either by A-O-A network or by A-O-N network but preference is given to A-O-N analyser.



objectives.

no. of dummy = 2

project duration
= 35 days.