

① PROJECT MANAGEMENT

Project :-

project is a temporary end of work undertaken to provide a unique product, service and result.

A project is works series of activities that consumes resources to achieve specific objectives.

Objectives of project :-

- 1) project should be completed in optimum amount of time.
- 2) project should use locally available Manpower and resources.
- 3) project should finish on time with minimum investment cost.

Project Management :-

project management is application of knowledge, skill, tools and techniques to meet requirements of the project.

Elements of project Management :-

1) planning :-

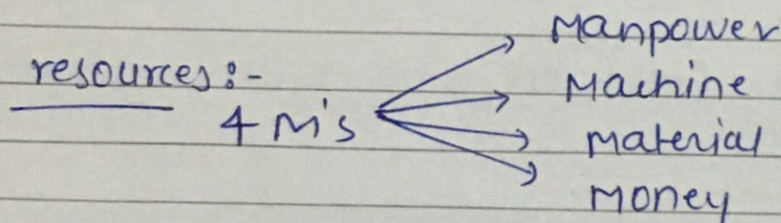
planning is one of the most imp. part of project management. planning means defining objectives of project, to identify various activities and resource requires for timely completion of project.

in planning phase a plan is made along with Work breakdown structure and organisation breakdown structure

WBS & OBS identifies group of activities that is need to be achieved for completion of project and assigning roles and responsibilities to various people in the project.

2) scheduling :-

Scheduling is the process of fixing order of all the activities and allocation of resources to these activities.



3) controlling :-

It is the process performed to observes execution of project such that potential problems can be identify in a timely manner and necessary action can be taken.

During this process project performance is regularly observed and measured to identify deviation.

NOTE :- planning & scheduling are done before the execution of project whereas controlling is generally done ~~after~~ during the execution of project.

4) Directing :-

It is function of project leader to give instruction to subordinates, supervise their work and respond to reports of subordinates.

5) Coordination :-

It is process of interaction b/w various departments of project.

6) Organising :-

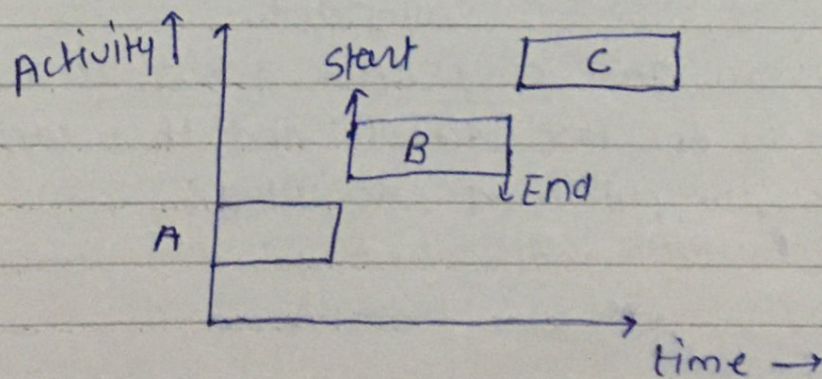
It is integration of resources.

Methods of project scheduling :-

① BAR CHART :-

It was introduced by Henry Gantt around 1900 AD.

BAR CHART is a graphical representation b/w Activity and time.



⇒ Beginning of bar
↓
Start of Activity

⇒ End of Bar
↓
Finish of Activity

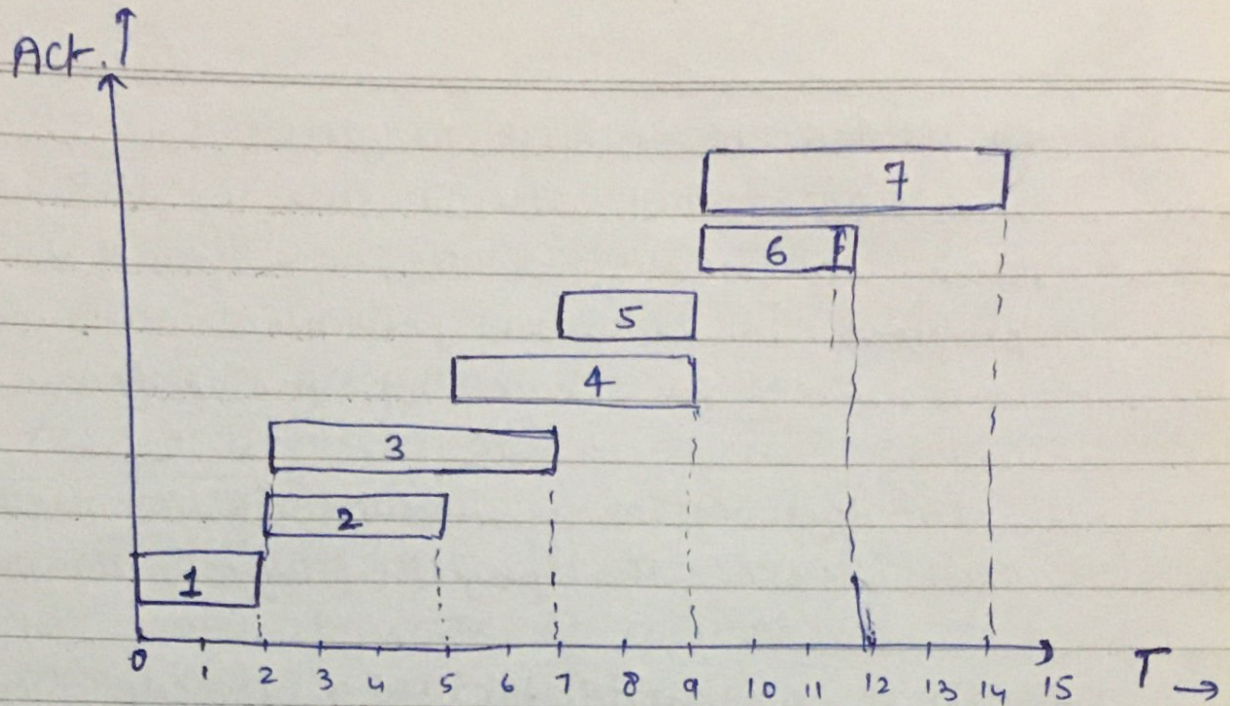
⇒ Length of BAR → Time required for the completion of Activity.

Que:- For a construction project certain activities are to be performed which are as given below:-

Activity	Duration (Weeks)	
1	2	① Activity 2 & 3 can be performed together and can start only when Activity 1 is completed.
2	3	
3	5	
4	4	② Activity 4 can start only after Activity 2 ends
5	2	
6	3	③ Activity 5 can't begin until Activities 2 & 3 are completed.
7	5	

- ④ Activity 6 can start only after 4 & 5 are completed.
⑤ Activity 7 is the last Activity and this can start only after completion of Activity 5.

Draw a BAR CHART and determine project completion time.



project completion time = 14 Weeks.

Advantages of BAR CHART:-

- 1) simple to draw and easy to understand
- 2) No skilled person is required
- 3) It can be used for determining resource required at any stage of project, Hence progressing cost of project can also be determined.
- 4) project progress can be expressed in terms of %
(with help of modified BAR CHART)

Limitations of BAR CHART:-

- 1) lack of degree of detail.

In case of Big projects only major activities can be shown otherwise, it will become overcrowded & clumsy.

Hence, BAR CHART is not preferred for big projects.

2) Review of project progress:

A BAR CHART doesn't show progress or work. Hence, it can not be used as a control device as progress made at a particular instant of time is required for control of the project.

3) It does not show interdependencies of various activities of the project (Biggest drawback)

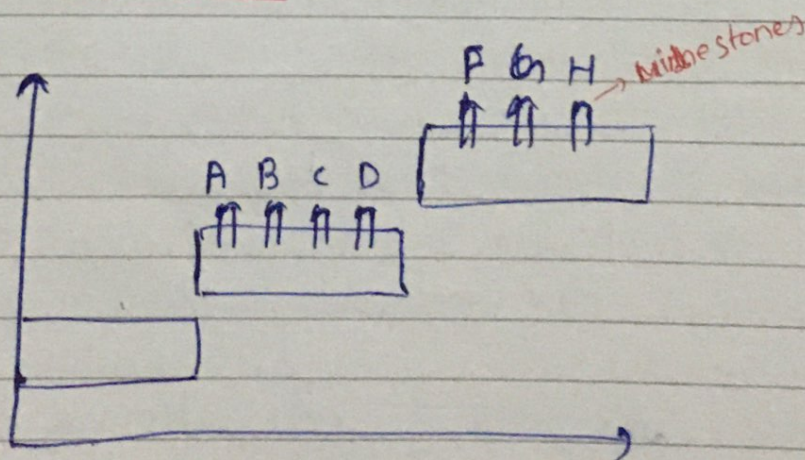
4) It is not useful for those projects where uncertainty is associated with estimation of Activity ~~at~~ time.

Ex: Research Project

5) It doesn't indicate critical path in the project

6) It doesn't allow cost optimization that is crashing.

② Milestone CHART :-



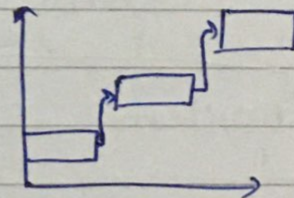
- Milestone chart is an improvement over original BAR CHART
 - In any activity there are certain key events which are to be carried out for the completion of Activity. Such key events are called as milestones.
 - Milestones can be represented by Arrow, square & circle.
 - If a particular Activity is very long then details of subActivities will be lacking which can be shown with the help of milestones.
- Hence it provides better controlling in the project.

Limitation of Milestone Chart :-

Relationship b/w subActivities and Activities is clear but interrelationship b/w various Activities is not clear.

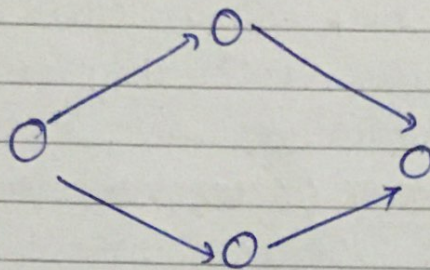
③ LINKED BAR CHART :-

- Link bar chart is an improvement over Bar chart and milestone chart.
- In link bar chart Activities are linked with Arrows and lines.

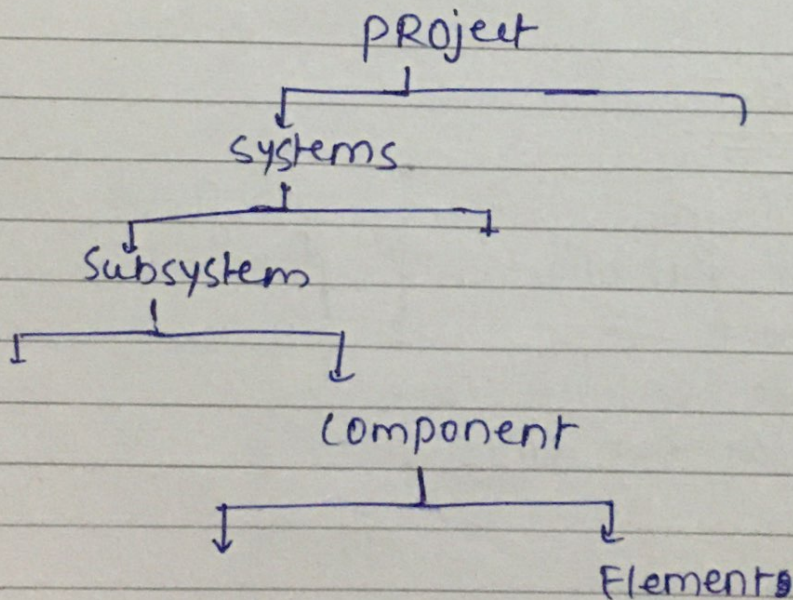


④ NETWORK DIAGRAM :-

- Network diagram is a graphical representation of Sequence of Activities.
- It is of 2 types.
 - 1) AOA → Activity over Arrow
 - 2) AON → Activity over Node



WORK BREAK DOWN STRUCTURE :- (WBS)



- WBS is a graphical representation of functional elements of entire project.
- It follows Top to Down approach
- It is a process of Breaking a complex project into system, subsystem, component and Element.
- It helps in
 - A) determining what works is need to be done
 - B) Accountability & Responsibility of project team
 - C) Ground work for estimation of time and cost.

② FUNDAMENTALS OF NETWORK

Defination of Network diagram:-

- Network diagram is a graphical representation of Arrow and nodes indicating their logical sequence.

Types of Network :-

- 1) A-O-A :- Activity over arrow / Arrow diagram
Activities are represented by Arrows and nodes represents Events.
- 2) A-O-N :- Activity over Node / "precedence diagram"
Activities are represented by Nodes and their precedence relationship (inter relationship) with the help of Arrows.

BASIC DEFINATION :-

1) Activity :-

An Activity is a task or job that consumes resource and time.

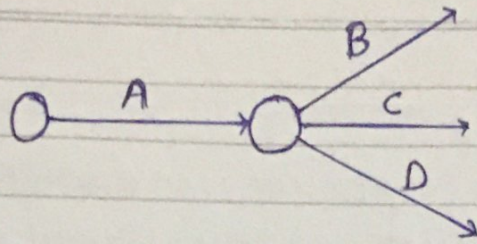
- 1) It has definite starting point and end point
- 2) It is represented by Description
time

✱ length, shape & orientation (direction) of Arrow has no significance

Types of Activities :-

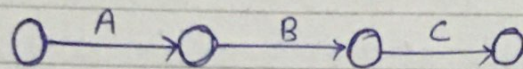
A) parallel Activities / Concurrent Activities :-

These can be performed simultaneously and are independent of each other.



② Serial Activities :-

These can be performed one after another.



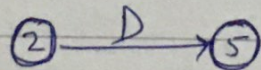
② EVENT :-

It is an instant of time at which something specific is achieved in project that is start of Activities or completion of Activities

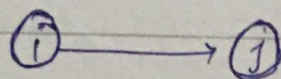
- Events Don't consume Resource and time.
- Events are represented by Nodes, shape of Node can be any regular geometrical figure such as circle, rectangle, square or oval

NOTE Events are numbered for their identification
Activity are also named by terminal Nodes

Ex Activity D is 25

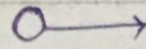


A General and most usual Convention shown for Any Activity is ij as shown below



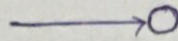
Types of Event :-

A) Tail Event :-



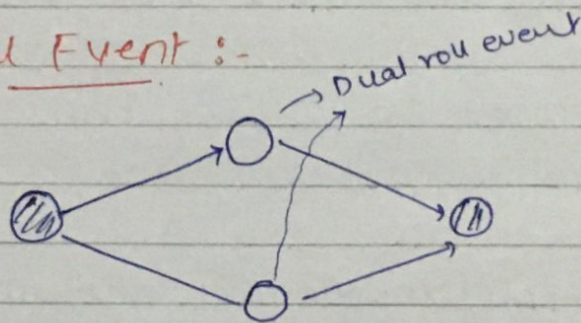
- It signifies start of an activity
- If a particular tail event represents start of the project then it is called as 'initial event'.

B) Head Event :-



- It signifies End of an activity.
- If a particular head event represents completion of a project then it is called as 'final or End Event'.

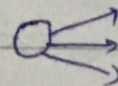
C) Dual Roll Event :-



- These events are tail events for some activities and head event for other activities
- All the events other than initial & final events are Dual roll events.

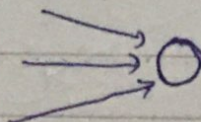
Burst event :-

NOTE :- When more than one activity is coming out from a node

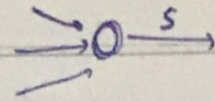


Merge event :-

When more than one activity entering to one node.



Doubt

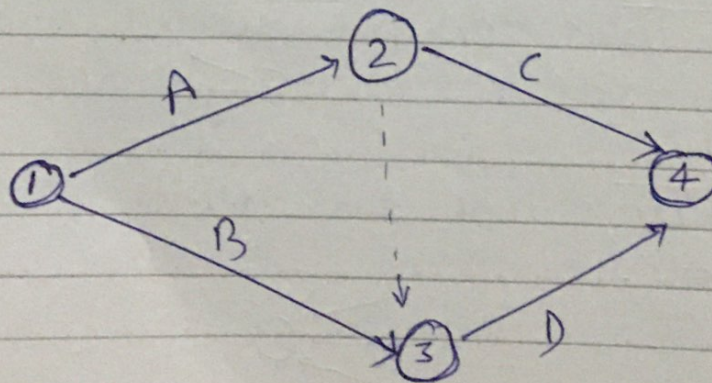


Interface Event :-

An interface event is a common event which shows linkage b/w Activities performed by ~~one or~~ more than one agencies. It may also denote linkage b/w two or more Subprojects.

③ Dummy Activity :- or Zero Time Activity :-

- Dummy is an artificial activity which neither consumes any resource nor time.
- Dummy is used to show interrelationship of Activities.
- Since Dummy is not an activity it is not represented by arrow. Rather it is represented by dotted arrow.
- Dummy is identified by terminal nodes.



Here Dummy 23 represents that Activity D depends on Activities A and B

Dummy are used to keep logical sequence and interrelationship of Activities correct.

USE OF DUMMY:-

1) Grammatical purpose:-

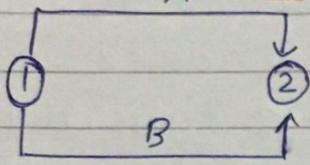


Figure A.

Wrong representation

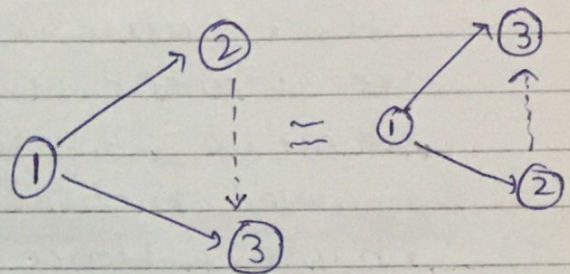


Figure B.

Correct representation

⇒ in figure A we can observe that two Activities A & B are having same starting point and same end point which is causing conflict of identity. Because these activities are also identified by terminal nodes. Hence, name of activities A and B will be 12 only. This conflict of identity can be removed by use of Dummies in figure B.

- Dummy are used to prevent two or more Activities having same starting Node and same End Node.

- Any two events can be directly connected by not more than one Activity.
- Dummies are also used to keep numbering system unique

NOTE:- If events are added or removed then there will be no change in resource requirement or time requirement whereas if Activities are added or removed then resource and time both will change. Hence events can be added or removed But Activities can not.

② Logical purpose :-

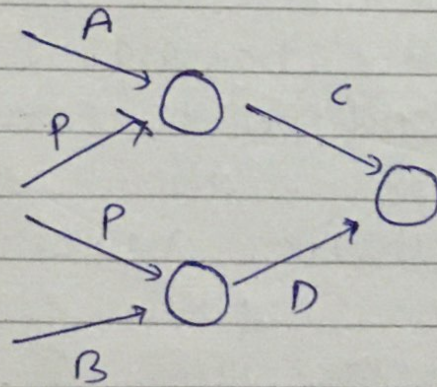


Figure A

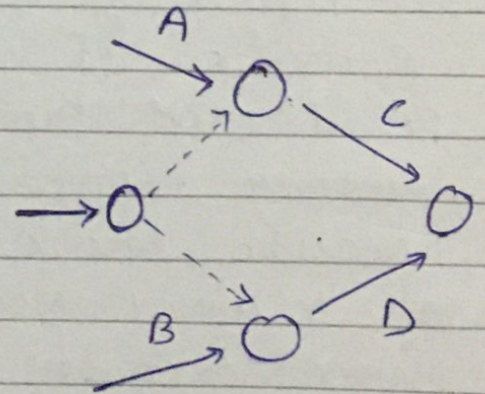


Figure B

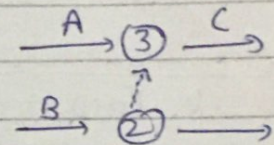
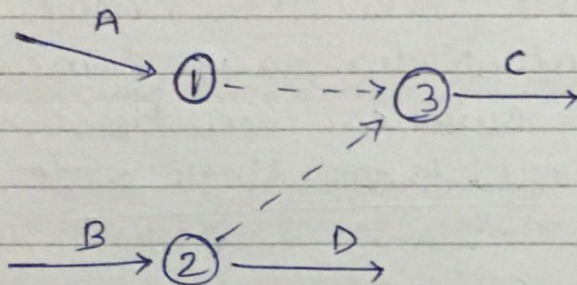
Figure A shows wrong representation because Activity p cannot have dual identity rather it should have unique identity which can be maintain by use of Dummies in, figure B

Hence two or more Arrows can not have same name because it Causes Conflict of identity.

Therefore Number of Activities should be equal to Number of Arrows.

Rules for Elimination of Dummies:-

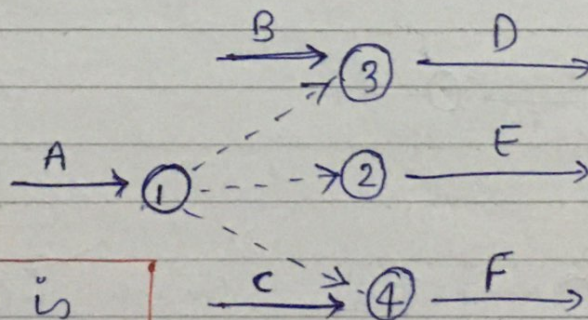
RULE 1 ~~Draw A Network~~



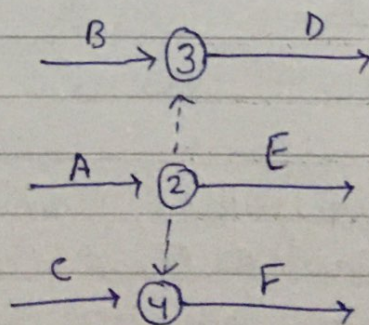
eliminate 13

* If Dummy is the only Activity Coming Out from a Node it can be Eliminated

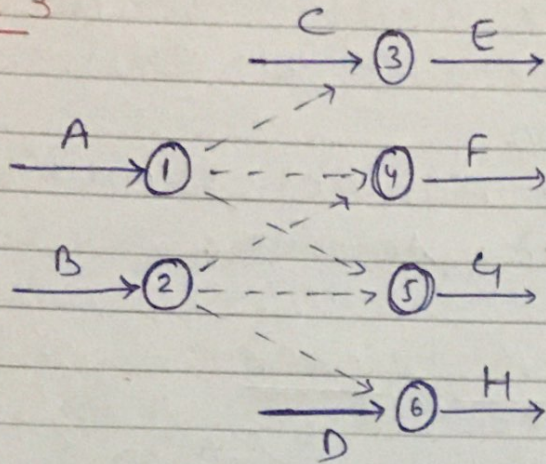
RULE 2



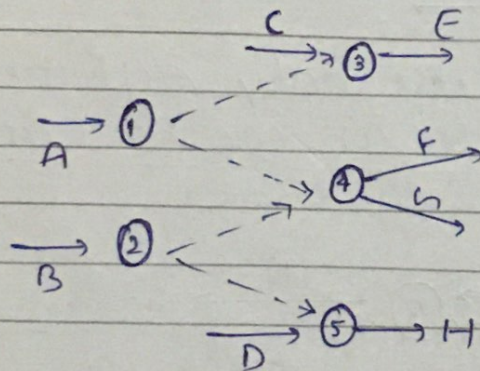
if Dummy is the only Activity entering into a Node it can be Eliminated



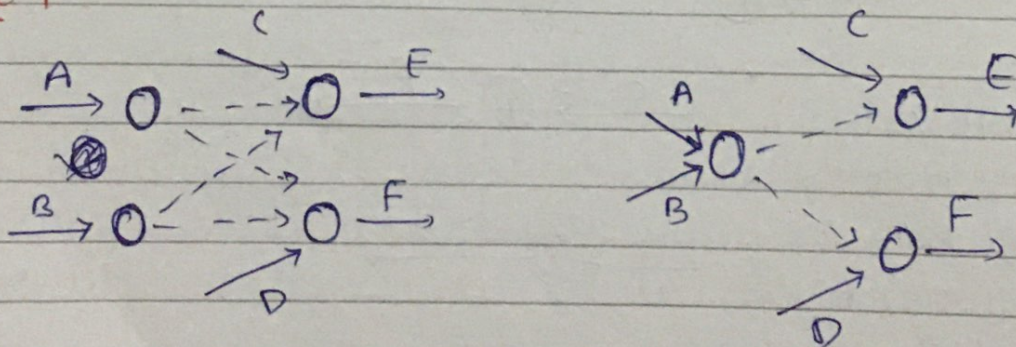
Rule 3



if two or more Activities coming out from different Nodes have same set of preceding Activities then these Activities should come out from single Node

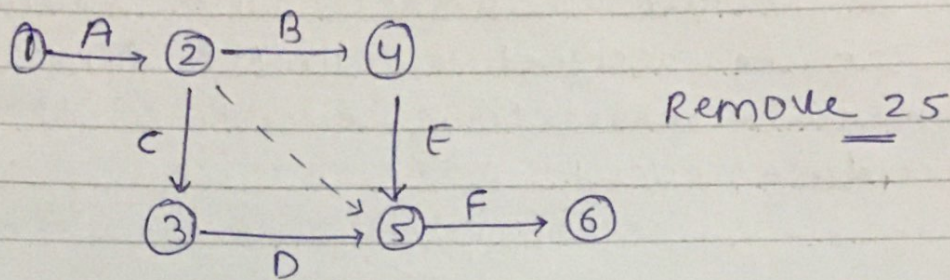


Rule 4



if two or more Activities terminating into different Nodes, Having same set of succeeding Activities, then these Activities should terminate at same Node.

RULE-5

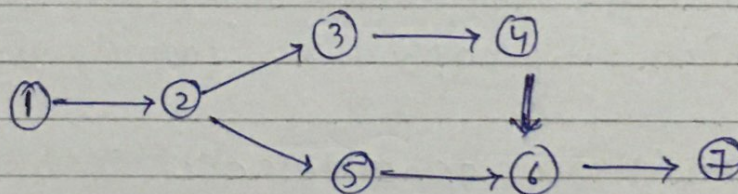


Dummy 25 is an redundant Dummy which can be Eliminated.

Numberings of Events :->

Fulkerson's Rule :-

- Event number must not be duplicated
- Number of succeeding event should be greater than preceding event



Skip Numbering :-

Network diagram represents a static picture whereas constructions are dynamic in nature. Due to which certain events are to be added in the future, hence it causes renumbering of events.

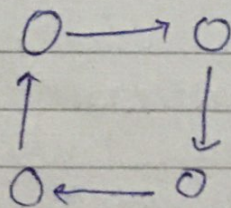
To avoid renumbering events are numbered in the multiple of 10. That is 10, 20, 30, ... which is called as skip numbering.

if an event is added later then it can be assigned a number b/w immediate preceding event and succeeding event.

NETWORK RULES:-

- Network Diagram should have one initial Node and one final Node.
- An event can occur if and only if all the preceding activities are completed. Similarly NO Activity can start until the preceding event has occurred
- An event can not occur twice. That is Arrow can not loop back to previously occurred event. Which is called as 'looping Error'

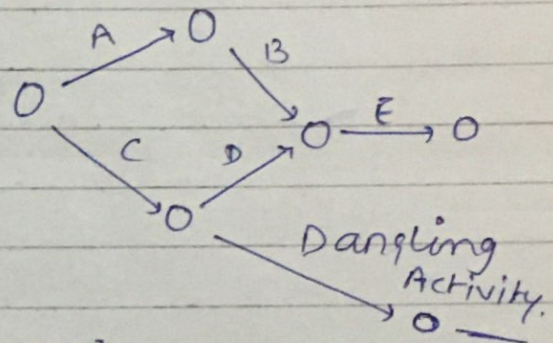
NOTE :- In looping error occurrence of an event depends on succeeding event.



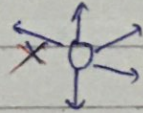
- All constraints / Restraints and interdependencies should be shown by appropriate Number of Dummies.

→ Number of Activities should be equal to Number of Arrows. That is two or more arrows can not be used for single Activity and also None of the Arrow should be unnamed.

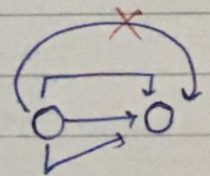
→ There 'must not' be any dead end left out except final Node, which is called as Dangling error.



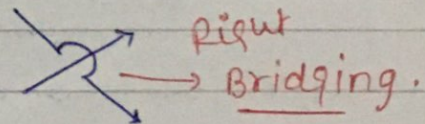
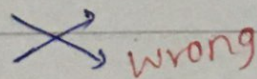
→ Time Flow is from left to Right which signifies direction of Arrow that is Arrow has to be from left to Right But at most it can be vertically upward or Downward.



→ Curved arrows are not allowed.



→ Crossing of Arrows is not allowed.



But if it is un-avoidable then bridging should be done.

③ PERT

Programme Evaluation Review Technique

- PERT is used in Manufacturing industry specially in Research and development types of project for planning, scheduling and monitoring.
- PERT was developed by US NAVY along with Lock Heed Martin for development of polaris missile. (Around 1950)

Time Estimates :-

An Important characteristic of any project is its project completion time which is function of Activity time.

Time Required for an Activity can be estimated in Two ways.

- i) deterministic Approach
- ii) probabilistic Approach

i) Deterministic Approach :-

planner provides an accurate time estimate that is single time estimate from past experience

ii) probabilistic Approach :-

planner provides a range of time within which Activity is expected to be completed. As he does not have much idea about the Activity.

PERT follows probabilistic approach and it incorporates uncertainties involved in estimation of time required for an Activity.

Hence, PERT is used for Non-repetitive type of projects like Research and development projects
Ex: space and Defence projects

As there is not much information about Activities Hence PERT Analysis is event oriented.

Three time estimates are made for each Activity to incorporate uncertainties involved in estimation of Activity time.

1) Optimistic time t_o :-

It is the min. time required for an activity if everything goes as per ideal condition that is better than normal condition.

2) Pessimistic time t_p :-

It is Max. time required for an activity if conditions are at worst.

Delay due to flood, Fire, earthquake, labor strike are not considered.

3) Most likely time t_m :-

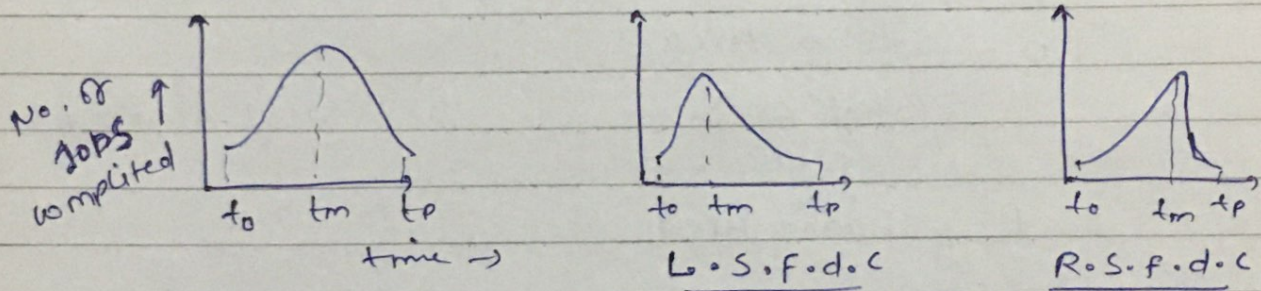
It is the time required for an Activity when conditions are normal. It lies b/w t_o & t_p .

NOTE :- • These Time estimates may look normal or simple but they provide useful information regarding Uncertainty involved with An Activity.

- lesser the distance b/w t_o & t_p , uncertainty involved is also less

Frequency Distribution :-

If a curve is plotted b/w time of completion and No. of jobs completed in that time. then a frequency distribution curve can be obtain as given.



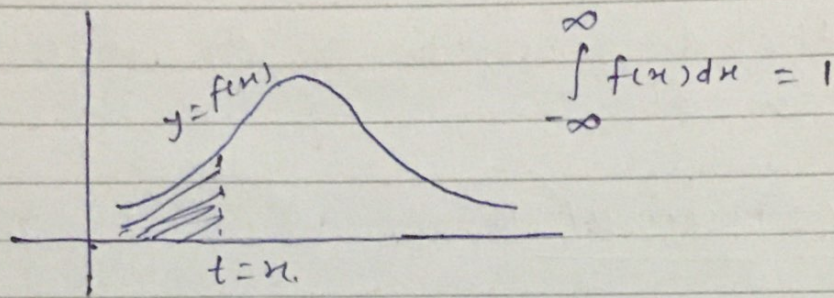
The curve can be symmetrical $\rightarrow$ Normal frequency Distribution curve
unsymmetrical $\rightarrow$ skewed curve

PROBABILITY Distribution curve :-

As there is uncertainty associated with time estimates of PERT activities, hence probabilistic Distribution can be used for Analysis.

In frequency distribution we study Group behaviour whereas in probabilistic distribution we study point behaviour. Hence prob. Distribution is preferred over Frequency Distribution

In probabilistic Distribution curve, the height of curve is standardized such that the area under this curve is unity.



In probabilistic Distribution curve, the probability value at any point $t=x$ is given by -

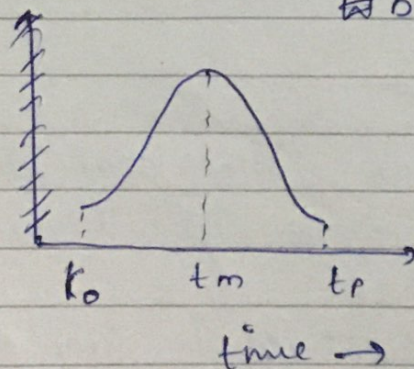
$$p = \frac{\text{shaded Area}}{\text{Total Area}}$$

$$\because \text{as Total Area} = 1$$

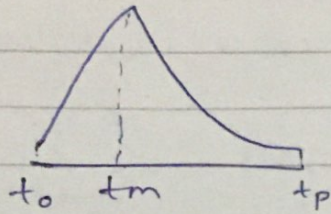
$$P = \text{shaded Area}$$

Probability Distribution curve can be

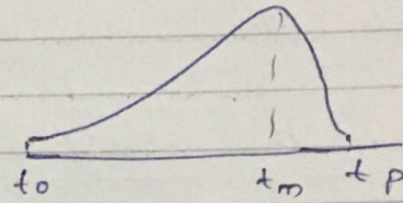
- 1) Symmetrical $\rightarrow$ Normal probability Distri. curve / Gaussian Distribution curve / bell shaped curve



2) Un-symmetrical curve $\rightarrow$ β -Distribution curve

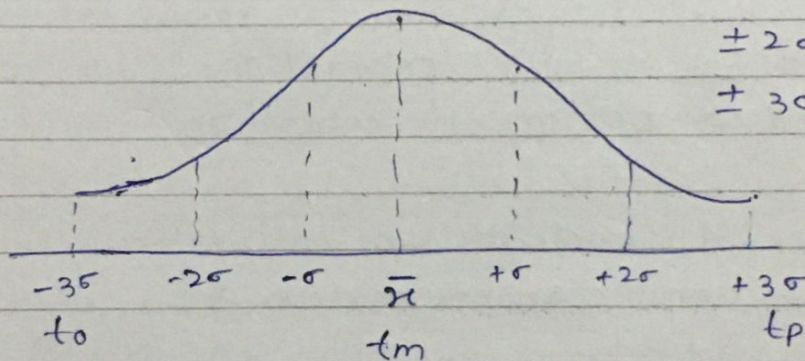


left skewed β distri. curve.



Right skewed

NORMAL DISTRIBUTION CURVE:-



$$\pm \sigma = 68\%$$

$$\pm 2\sigma = 95\%$$

$$\pm 3\sigma = 99.7\%$$

We can assume t_0 and t_p such that the chances of Activity getting completed within them is 100%.

$$\text{Hence } t_0 = \bar{x} - 3\sigma$$

$$t_p = \bar{x} + 3\sigma$$

$$t_p - t_0 = 6\sigma$$

$$\sigma = \frac{t_p - t_0}{6}$$

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

- σ or σ^2 is independent of t_m
- σ or σ^2 is dependent on relative distance b/w t_o & t_p .
- larger the value of σ or σ^2 more is uncertainty.

β -PROBABILITY Distribution curve :-

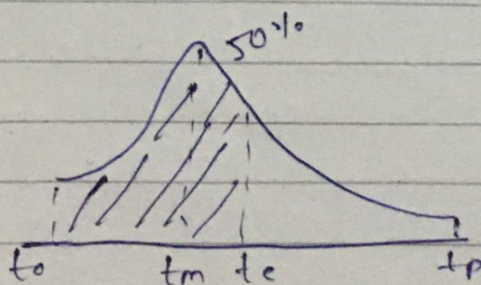
In PERT Analysis most of the Activities follow β -Distribution curve because 3 time estimates may not be uniformly spaced which is more realistic situation.

- left skewed $\rightarrow$ optimistic estimation
- Right Skewed $\rightarrow$ pessimistic estimation

For the sake of simplicity in calculation in β -Distri. σ can be approximated as

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

Expected time :- t_e :-



expected time t_e represents a particular value on the distribution curve that has 50% chances to being met or 50% chances being exceeded

- Vertical ordinate through t_e will divide β -Distribution curve into 2 equal parts

- t_e can be approximated as: -

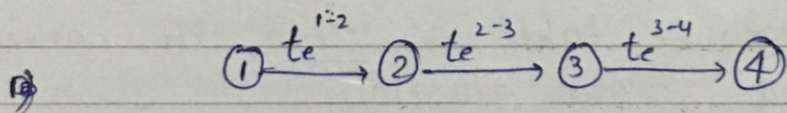
$$t_e = \frac{t_o + 4t_m + t_p}{6}$$

- t_m represents Model time, whereas t_e represents average time.

- if $t_p - t_m = t_m - t_o$
then curve is symmetrical
Hence, $\boxed{t_m = t_e}$

CENTRAL LIMIT THEOREM:

If there are n Number of Activities in series each having its own β -Distribution such that t_o , t_m and t_p are known then



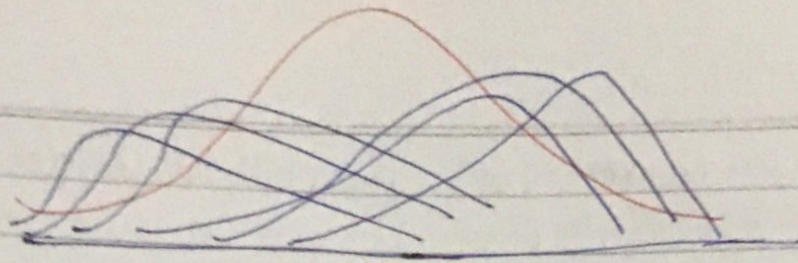
1) expected completion time for the path will be

$$= t_e^{1-2} + t_e^{2-3} + t_e^{3-4} = \frac{\sum t_o + 4 \sum t_m + \sum t_p}{6}$$

2) standard deviation for the path will be

$$\sigma_{\text{path}} = [\sigma_{1-2}^2 + \sigma_{2-3}^2 + \sigma_{3-4}^2]^{1/2}$$

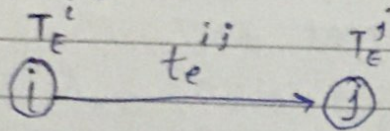
3) if N is a fairly large Number then time required for the path as a whole can be approximated as Normal distribution.



Event Time :-

1) Earliest expected event occurrence time :- T_E :-

- It is the earliest time by which an event is expected to occur, it may be noted that an event can occur if and only if all the preceding activities are completed.

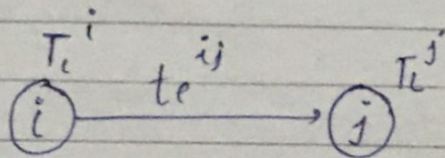


$$T_E^j = \text{Max.} (T_E^i + t_e^{ij})$$

- It is determined by forward path method

NOTE :- T_E for the initial event in the Network Diagram may be taken as zero if nothing is mentioned in the question.

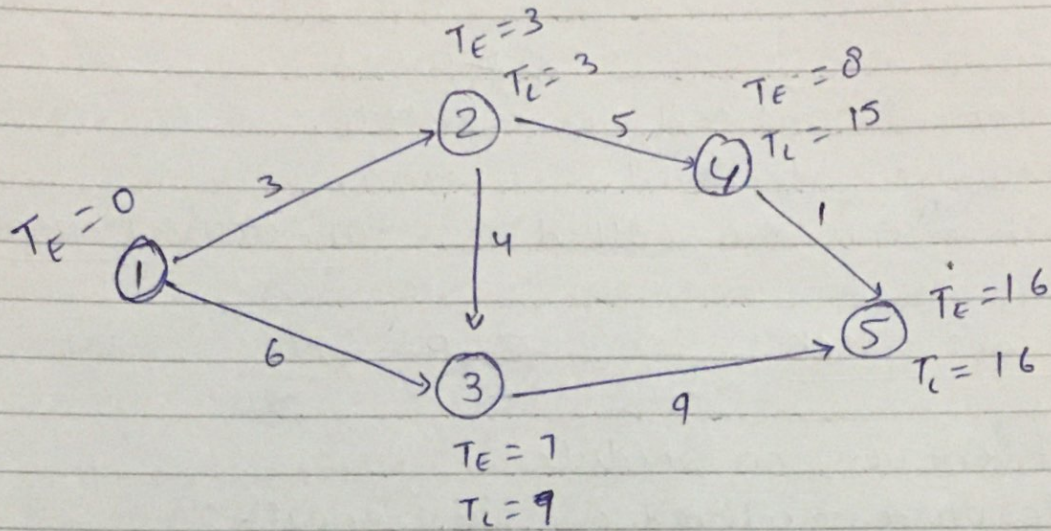
2) LATEST Allowable event occurrence Time :-



$$T_L^i = \text{Min.} (T_L^j - t_e^{ij})$$

- It is the latest time by which an event is allowed to occur without affecting project completion time

- It is determined by backward path Method.



NOTE:-

- We know that almost all the projects are time bound by a contractual obligation time or schedule completion time which is denoted by T_s . Therefore for last event $T_L = T_s$.
- If nothing is mentioned in the question then for last event we can assume that $T_s = T_L = T_E$.

SLACK :-

- Slack is associated with event
- Slack is extra available time by which occurrence of an event can be delayed without affecting project completion time.

Types of slack :-

1) positive slack :- $S > 0$

- Event is ahead of schedule
- Resources deployed are extra.
- Such events are called as sub-critical events

2) zero slack :- $S = 0$

- Event is on schedule
- Resources deployed are just enough
- Such events are called as critical events

3) Negative slack :- $S < 0$

- Event is behind schedule
- Resources deployed are less.
- Such events are called super-critical events

CRITICAL PATH :-

- Critical path is the longest path time wise in the network diagram.
- Critical path is also shortest path time wise before which project can not be completed.
- On critical path longest duration is needed and shortest duration is permissible.

- In pert Analysis slack of the events on critical path has to be Zero or Minimum. It is a Necessary condition but not sufficient or Mandatory condition.
- if there are multiple critical paths in the network diagram then path having 'larger standard deviation' will become most critical.

NOTE: $\rightarrow$ Range of project duration $\rightarrow T_E \pm 3\sigma$
 $\ast \rightarrow$ proportional variation $= \frac{\sigma}{\text{project duration}}$

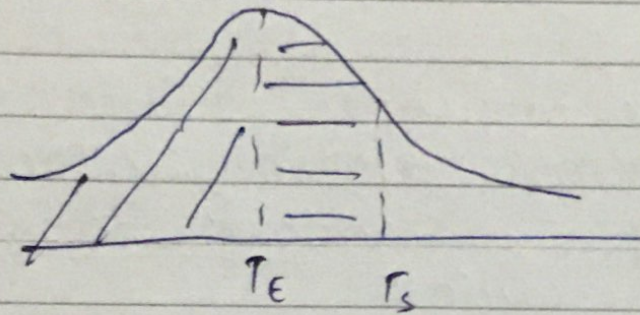
probability of completion of project:-

The probability of completion of time of any project can be determined with the help of theory of probability.

- probability of expected time t_e for each activity is 50 %.
- We know that earliest expected time for the last event T_E is sum of t_e along critical path. Therefore probability of completing the project in time $T_E = 50\%$

According to central limit Theorem project completion time follows normal Dist. curve

- if T_s is scheduled completion time for the project then probability of completing the project within T_s will be :-



$$\pm \sigma = 68\%$$

$$T_s \Rightarrow +\sigma \Rightarrow A = 50 + \frac{68}{2} = 84\%$$

$$T_s \Rightarrow -\sigma \Rightarrow A = 50 - \frac{68}{2} = 16\%$$

$$T_s \Rightarrow +2\sigma \Rightarrow A = 50 + \frac{95}{2} = 97.5\%$$

$$T_s \Rightarrow -2\sigma \Rightarrow A = 50\% - \frac{95}{2} = 2.5\%$$

$$\left\{ \begin{array}{l} p = \frac{\text{shaded Area}}{\text{Total Area}} \end{array} \right.$$

shaded Area depends on location of T_s along time axis.

As T_E bisect the curve, hence it can be taken as Reference point

If T_s is at distance of $+\sigma$ then $A = 84\%$
 similarly for $-\sigma$, $A = 16\%$

procedure :-

i) Determine σ along critical path

ii) Determine $Z = \frac{T_s - T_e}{\sigma}$

Where Z is Normal Deviate or probability factor

iii) Determine probability from the table given

The value of Z can be ; $+ve \rightarrow p > 50\%$

$0 \rightarrow p = 50\%$

$-ve \rightarrow p < 50\%$

Que. A Father notes that his teenage daughter uses the telephone. She takes no less than 5 min. for a call and sometimes as much as an hour. 15 min calls are more frequent than calls of any other duration.

If daughter's call were an Activity in PERT project then determine -

a) expected duration for a phone call

b) Variance

c) in scheduling the project how much time would you allocate for a phone call.

$$a) \quad t_e = \frac{5 + (4 \times 15) + 60}{6} = 20.833 \text{ min}$$

$$b) \quad \text{Variance} = \left(\frac{60 - 5}{6} \right)^2 = 84.03 \text{ min}^2$$

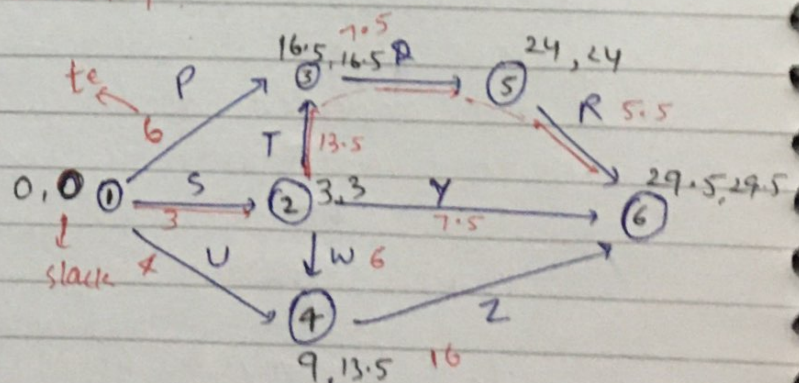
c) in scheduling this activity we would allocate $t_e = 20.833 \text{ min.}$

Que. A construction work consists of following Activities.

Act	I. P.	t_o	t_m	t_p	t_e
P	-	3	6	9	6
Q	P, T	4	8	9	7.5
R	Q	4	5	9	5.5
S	-	3	3	3	3
T	S	8	14	17	13.5
U	-	1	4	7	4
W	S	2	5	14	6
Y	S	4	7	13	7.5
Z	U, W	6	15	30	16

- Determine
- project completion time
 - critical path
 - probability of completing the job in 32 days
 - time required to complete the project with 50% probability

Z	P
-1.5	0.07
-1.3	0.10
-1.0	0.16



- A. project completion time is 29.5 days
 B. critical path is 1, 2, 3, 5, 6 or S T Q R
 D. time required for 50% probability is 29.5 days
 C. calculation for probability of completing the job in

32 days, $\sigma = \sqrt{0^2 + (1.5)^2 + (0.833)^2 + (0.833)^2} = 1.904 \text{ days}$

$$Z = \frac{T_s - T_e}{\sigma} = \frac{32 - 29.5}{1.904} = 1.313$$

Z	P
1.5	0.93
1.3	0.9
1.0	0.84

assuming straight line
interpolation

$$P = 0.9 + \frac{0.93 - 0.9}{1.5 - 1.3} \times (1.313 - 1.3)$$

$$P = 0.902$$

so @ $Z = 1.313$ probability will be 0.902

④ CPM

Critical path method was developed in US around 1950 for the construction of chemical plants.

Difference b/w PERT & CPM

PERT

- 1) Network diagram is event oriented
- 2) Used for Non-repetative type of projects like Research & development project
- 3) probabilistic Approach
- 4) 3 time estimates for each Activity
- 5) Activities follow β -Distri.
- 6) Time is a controlling factor and we assume total project cost is directly proportional to time
- 7) Slack is associated with event

CPM

- Activity oriented
- Used for Repetative type of projects like - construction projects
- Deterministic Approach
- Single time estimate for each Activity
- Normal Distribution
- Time & cost both are controlling factor, but their relationship is not linear
To determine min. total project cost we establish a cost model
- Float is associated with Activity

TIME ESTIMATES:-

In pert Analysis Activities follow β -distribution and they have probabilistic approach, Hence we gave 3 time estimates for each Activity. But Range of variation is large.

In CPM analysis we have deterministic Approach and we give single time estimate for each activity. Then also activities follow normal distribution

Since Variation is very small in this case Hence normal Distribution can be approximated as single time estimate.

NOTE:- In PERT Analysis Activity time is denoted by t_e^{ij} , whereas in CPM it is denoted by t^{ij} .

EVENT TIME:-

1) Earliest Event Occurrence Time:-

$$T_E^j = \text{Max.} (T_E^i + t^{ij})$$

Here word expected is missing because there is no uncertainty.

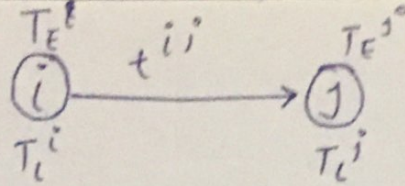
2) LATEST Allowable Event Occurrence Time:-

$$T_L^i = \text{Min} (T_L^j - t^{ij})$$

ACTIVITY TIMES:-

1) Earliest start time EST:-

This is earliest time by which an Activity



can be started

$$EST = T_E^i$$

Earliest Finish Time EFT

it is earliest time by which an activity can be finished

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

Latest start time LST :-

it is latest time by which an activity can be started without affecting project completion time.

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

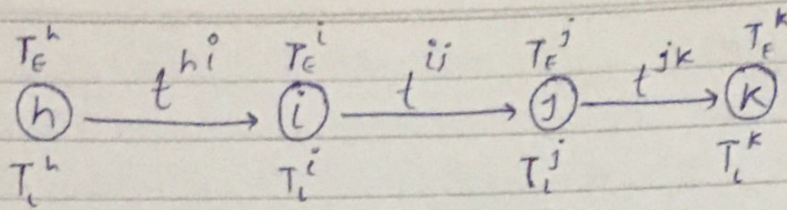
Latest Finish time LFT :-

it is latest time by which an activity can be finished without affecting project completion time.

$$LFT = T_L^j$$

FLOAT :-

- Float is associated with Activity
- Float is extra available time by which start or finish of any activity can be delayed without affecting project completion time.



① Total Float :- (Max.)

represented by F_T

It is maximum available time by which an activity can be delayed without affecting project completion time.

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

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

$$F_T = LFT - EFT$$

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

$$F_T = LST - EST$$

② Free Float :- (extra)

represented by F_F

It is extra available time by which an activity can be delayed without affecting earliest start time (EST) of succeeding activity

$$F_F = (T_E^j - T_E^i) - t^{ij}$$

$$F_F = T_E^j - (T_E^i + t^{ij})$$

$$F_F = T_E^j - (T_L^i - F_T)$$

$$F_F = F_T - (T_L^i - T_E^j)$$

$$F_F = F_T - S_j$$

F_{ID}

③ Independent float :- (min.)

It is minimum available time by which an Activity can be delayed.

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

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

$$F_{ID} = (F_i + T_E^i) - T_L^i$$

$$F_{ID} = F_i - (T_L^i - T_E^i)$$

$$F_{ID} = F_i - S_i$$

④ Interfering float :- F_{IN} :-

$$F_{IN} = S_j = F_T - F_F$$

NOTE :- → Total Float of an Activity affects Float of preceding & succeeding Activity

→ Free float of an Activity affects Float of preceding Activity but it does not affect Float of succeeding Activity.

→ Independent Float neither affects succeeding Activity nor preceding Activity. It only affects the concerned Activity.

→ Interfering Float is shared by succeeding Activity.

→ Free Float & Independent Float can never be negative. If a Negative value is obtained then it should be taken as 0

Types of Total Float :-

Out of all the four floats the most important is Total Float because it is involved with maximum Duration it can be of three types :-

- 1) Negative Total Float :- Super critical Activity
- 2) Zero Total Float :- Critical Activity
- 3) positive Total float :- Sub-critical Activity

CRITICAL PATH :-

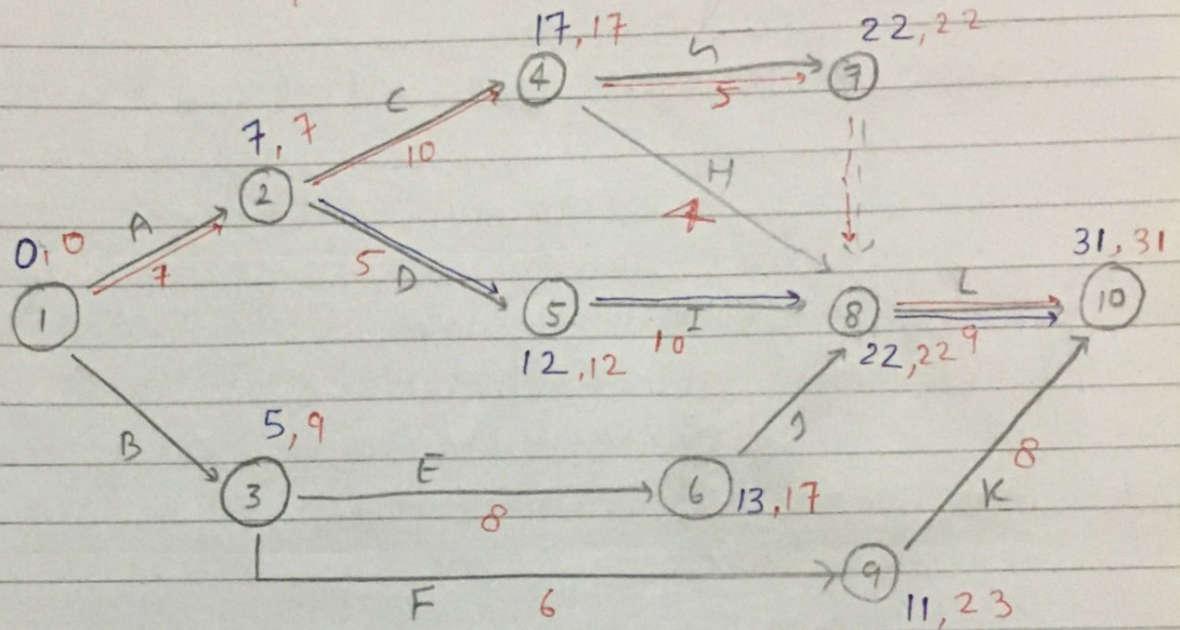
critical path is longest path time wise in the Network diagram

In CPM analysis it is necessary and Medatory that on critical path Total float has to be zero or minimum.

Que A building project consists of 12 Activities their duration and relationship is as given below:-

Act.	I.P	t	Act.	I.P	t
A	-	7	G	C	5
B	-	5	H	C	4
C	A	10	I	D	10
D	A	5	J	E	5
E	B	8	K	F	8
F	B	6	L	G, H, I	9

Determine project completion time, critical path, Activity times and all the Floats.



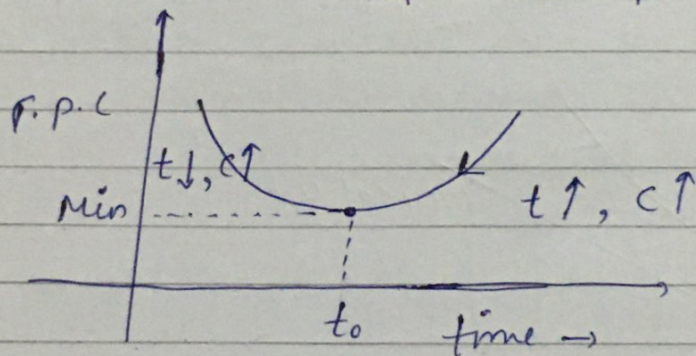
- project completion time is 31 days
- critical paths are 'ACHL & ADIL'

ACT	t_{ij}	EST	EFT	LST	LFT	FT	FF	FLD	FEN
✓ A	7	0	7	0	7	0	0	0	0
B	5	0	5	4	9	4	0	0	4
✓ C	10	7	17	7	17	0	0	0	0
✓ D	5	7	12	7	12	0	0	0	0
E	8	5	13	9	17	4	0	0	4
F	6	5	11	17	23	12	0	0	12
✓ G	5	17	22	17	22	0	0	0	0
H	4	17	21	18	22	1	1	1	0
✓ I	10	12	22	12	22	0	0	0	0
J	5	13	18	17	22	4	4	0	0
K	8	11	19	23	31	12	12	0	0
✓ L	9	22	31	22	31	0	0	0	0

⑤ CRASHING

In any project two important aspects are to be considered 1) project completion time
2) total project cost

- project completion is determined along critical path
- Total project cost is related time but this relationship is not linear
- To establish this relationship a cost model or time cost relationship or project cost function has to be developed.
- project time corresponding to Min. project cost is called as optimum project duration.



Total project cost

Direct cost

Indirect cost

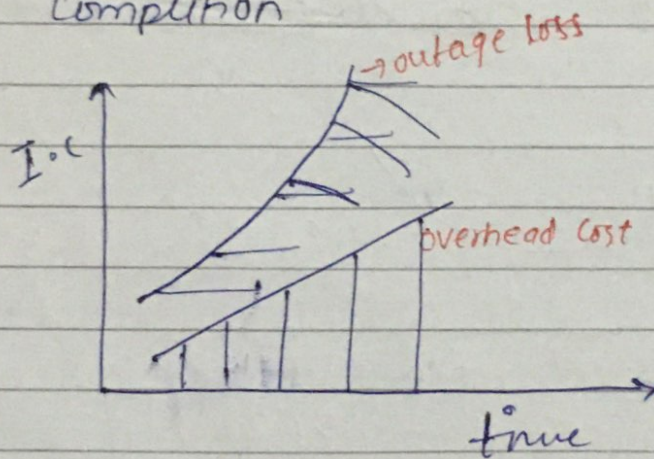
over head cost

outage loss

Indirect cost :-

Indirect costs are those expenses which can not be associated or assigned to any individual Activity or the project

- Indirect cost is either associated with group of activities or with the whole project.
- Indirect Cost = Overhead cost + Outage loss
- Overhead cost $\Rightarrow$ establishment charges, expenditure for maintenance of services during operations and insurance charges
- Outage loss $\Rightarrow$ it is loss in profit or liquidity damages that is penalty for delay in project completion



- Indirect cost increases with time
- Overhead cost increases linearly with time but outage loss increases non-linearly with time, Hence indirect cost increases non-linearly with time

NOTE:- for simplicity in calculation we assume that indirect cost increases linearly with time.

Direct cost :-

These are those expenses which can be directly associated with an Activity of the project.

It has been observed that direct cost decreases with the increase in time whereas indirect cost increases with time.

Normal time :- t_n :-

It is standard time that a estimator will assign for an activity.

crash time t_c :-

It is minimum time in which an activity can be completed.

- Time can not be reduced beyond t_c even by deploying infinite number of resources

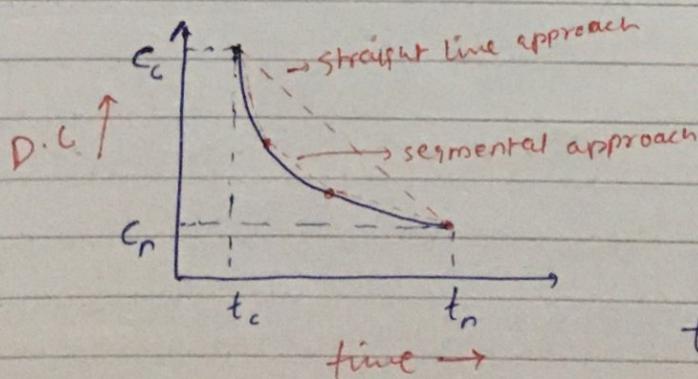
Normal cost C_n :-

It is direct cost associated with normal time t_n .

crash cost C_c :-

It is direct cost associated with crash time t_c

Cost slope / slope of direct cost curve :-



$$C/s = \frac{C_c - C_n}{t_n - t_c}$$

$t_n - t_c \Rightarrow$ crashing potential

significance of cost slope:- increase in direct cost of an activity per unit time.

- for accurate calculation segmented approach of cost slope is adopted but for ease in calculation straight line approximation is used.

CRASHING:-

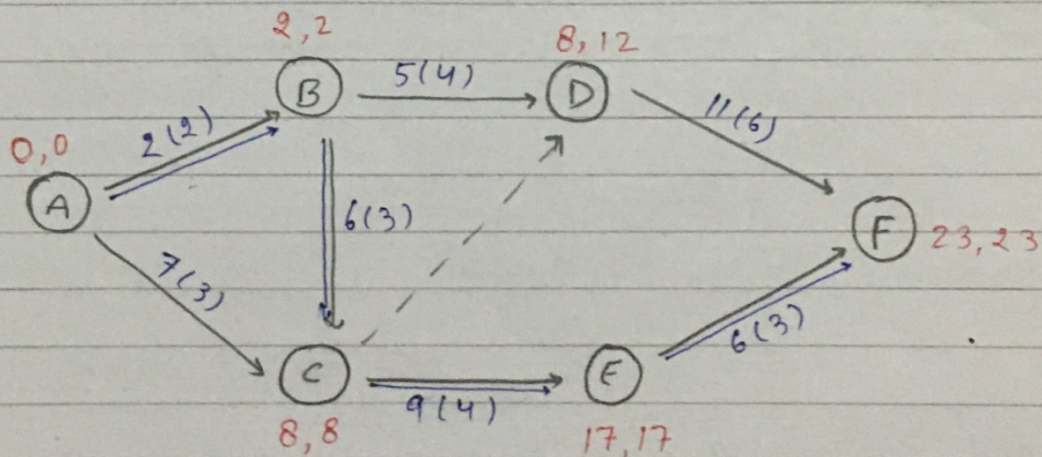
crashing is the process of reducing duration of project along critical path.

steps of crashing:-

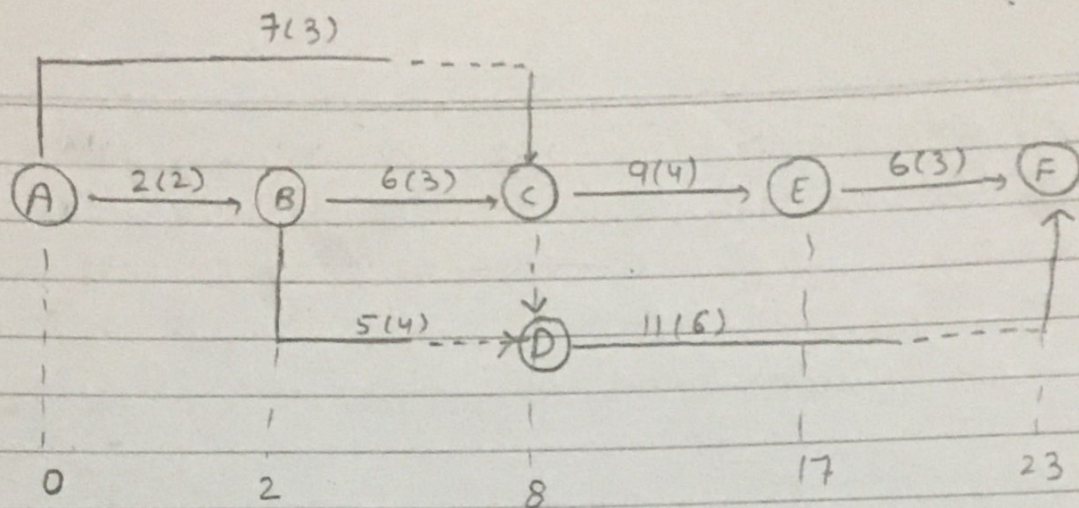
- ① Draw the network diagram
- ② Determine critical path
- ③ indicate critical path along Network diagram or time scale diagram
- ④ determine cost slope of each activity
- ⑤ start crashing the Activities along the critical path having minimum cost slope
- ⑥ Activity having minimum cost slope is crashed until its crashing potential is exhausted or new critical path are formed
- ⑦ if new critical path are formed then we've to crash combination of critical Activities (parallel Activities) having min. cost slope and continue till there is no further scope of crashing.
- ⑧ for each crashing determine cost implication and draw total project cost vs time curve

Que: Determine minimum cost and optimum duration for a project network. The duration and cost of each activity is given in following table. If indirect cost is 800 £/day

Act.	t_n	C_n	t_c	C_c	$CIS = \frac{C_c - C_n}{t_n - t_c}$
A-B	2	10,000	2	10,000	0
A-C	7	5,000	3	9,000	1000
B-C	6	3,000	3	4,200	400
B-D	5	2,000	4	2,500	500
C-D	0	0	0	0	0
C-E	9	6,000	4	9,000	600
D-F	11	6,000	6	10,000	800
E-F	6	7,000	3	9,100	700



- 1) project completion time = 23 days
- 2) critical path → A B C E F
- 3) Total project cost = direct cost + indirect cost
 indirect cost = $23 \times 800 = 18400$ £
 Direct cost = 39000 £
 Total cost = 57400 £



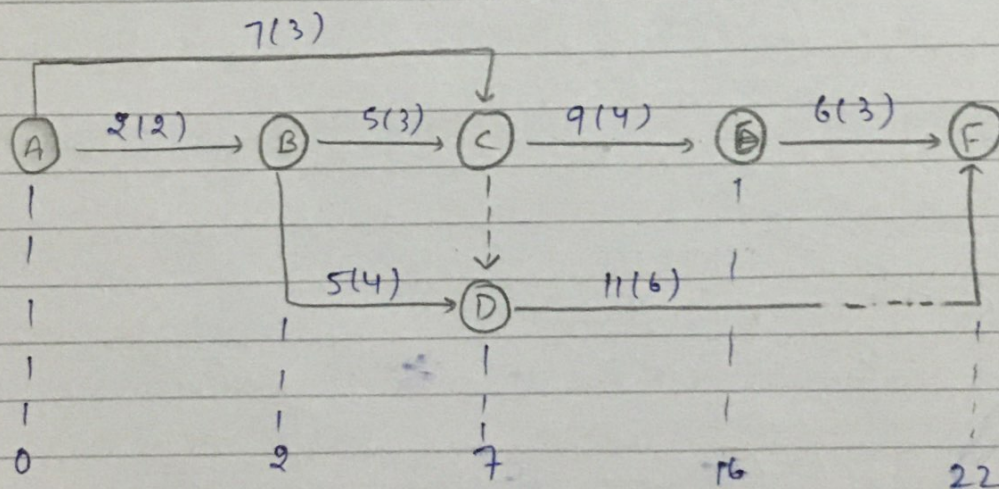
First stage crashing:-

We will crash activity Bc

by 1 one.

New project duration is 22 days

$$\text{Total project cost} = 57400 - 1 \times 800 + 1 \times 400 \\ = 57000 \text{ £}$$



Second stage crashing:-

crashing alternatives:- A) AC + BC $\rightarrow 1000 + 400 = 1400$

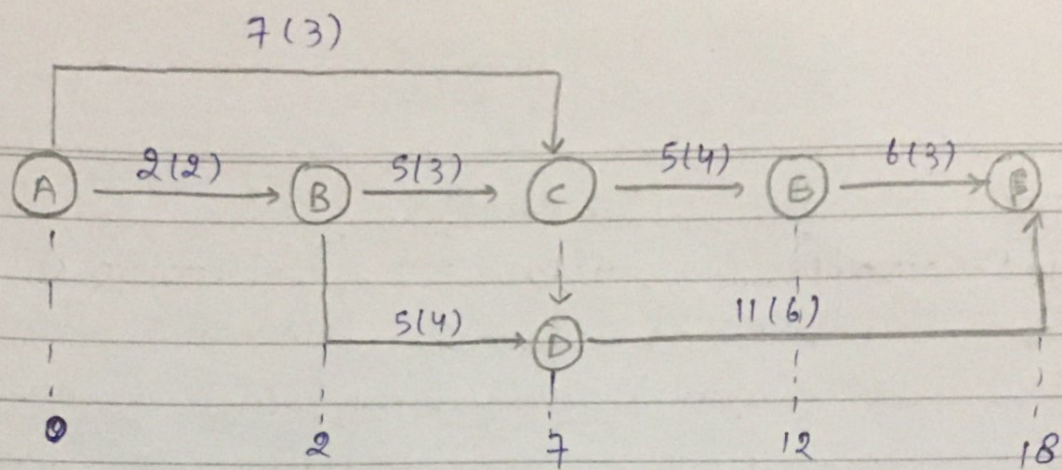
B) CF $\rightarrow 600$ ✓ (min.)

C) EF $\rightarrow 700$

We'll crash Activity by 4 days

New project duration = ~~22~~ 18 days

$$\text{Total project cost} = 57000 - 4 \times 800 + 4 \times 600 \\ = 56200 \text{ £}$$



Third stage crashing :-

- There are 5 critical paths
- A-B-C-E-F
 - A-C-E-F
 - A-C-D-F
 - A-B-C-D-F
 - A-B-D-F

Crashing Alternatives are :-

$$AC + BC + BD = 1900$$

$$CE + DF = 1400$$

$$EF + DF = 1500$$

We can observe that the least cost slope is greater than indirect cost per day, Hence there is no benefit of further crashing it hence, minimum project cost = 56200 ₹
optimum project duration = 18 days

⑥ UPDATING

updating is a process which involves flow of information or execution of work at regular interval

Hence it requires upward flow of information

- if all the activities are promising as per schedule then updating is not required but this rarely occurs.

DATA Required for updating :-

- ① original network diagram
- ② Network calculation chart
- ③ stage at which updating is done
- ④ Actual project execution information
- ⑤ New information or knowledge that will affect duration of future activities

Act.	if completed or not		if in progress then	if did not start
	Y/N	if N then time required for completion	time req. for completion	then time req. for completion.

When to update :-

- it is done whenever there is major change in duration of any activity.
- for small duration project frequency of project is high from initial stages only

because any kind of slippage (Delay) will result in Delay of the project

- For large duration project frequency of updating is less in the initial stages because few delay can be absorbed later on. but when project approaches towards end frequency of updating increases.

• Important points :-

① During the process of updating any Activity is neither added nor deleted

② updating of critical activities is mandatory.

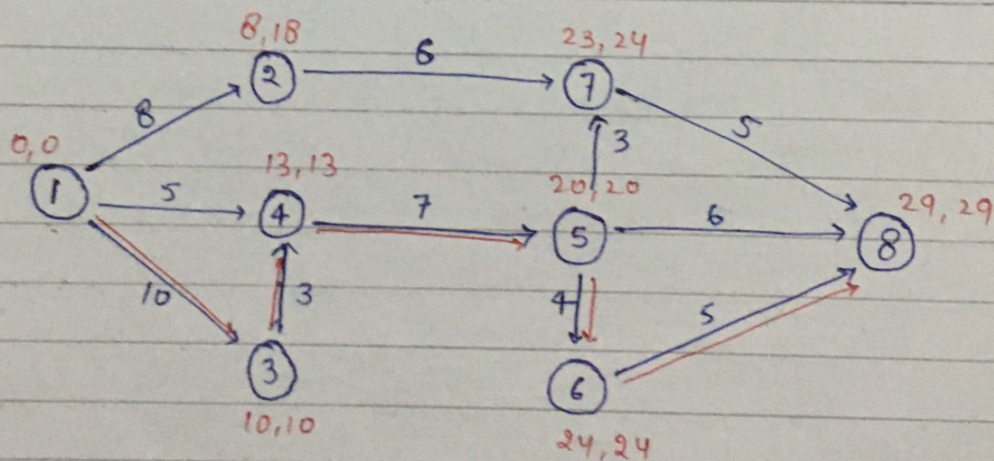
③ Critical path may change during updating.

Que. Figure below shows the Network of a project which is to be updated at the end of 12 days. The following conditions exists at the time of updating

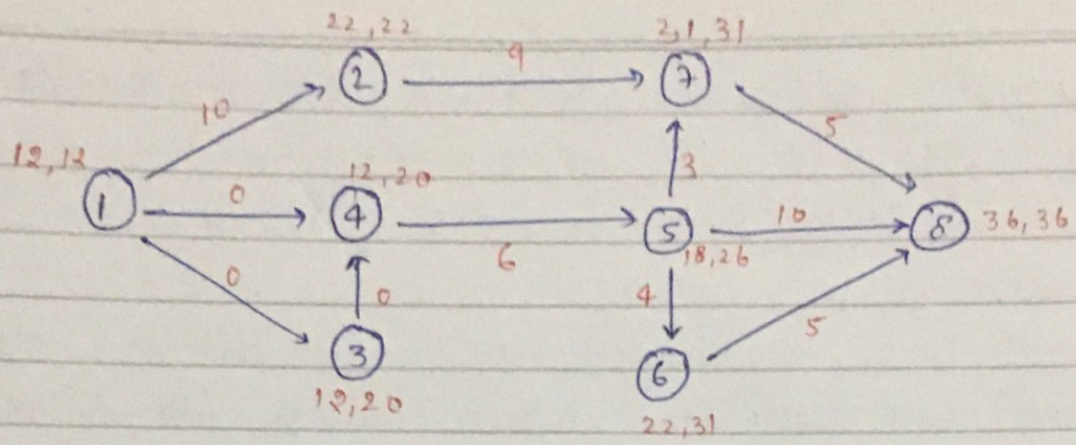
- Activity 14 was completed as originally planned
- Activity 13 was executed more rapidly than originally scheduled and it required 8 days for its completion.
- Activity 34 started following the completion of Activity 13 and was finished at the end of 11th day.

- Activity 45 started following the completion of Activity 34 (that is at the end of 11th day), And still requires 6 more days for its completion
- Completion of Activity 12 was delayed drastically and still requires 10 more days for its completion
- Activity 27 will start following the completion of Activity 12 and will require 9 days for its completion instead of 6 days as per original plan
- The time required to perform Activity 58 has been revised based on experience from the project, it now required 10 days, instead of 6 days
- NO other activities have been started, and original time estimates for these Activities still appear to be accurate.

Update the Network and determine critical path.

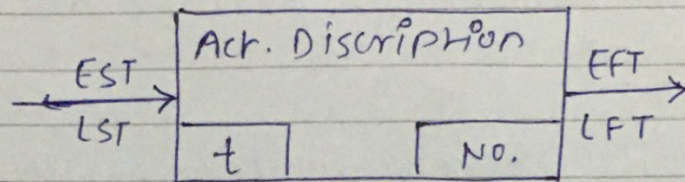


Solⁿ

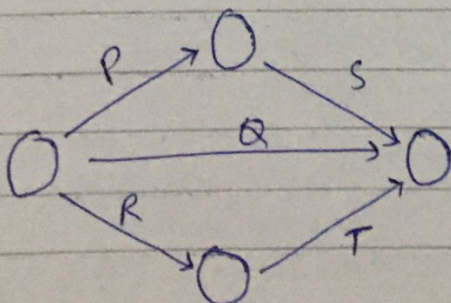
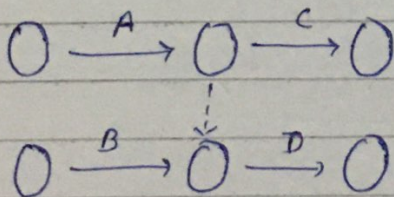
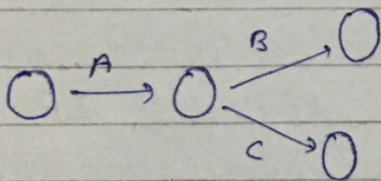
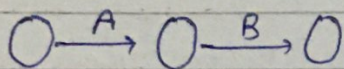


⑦ A-O-N Diagram

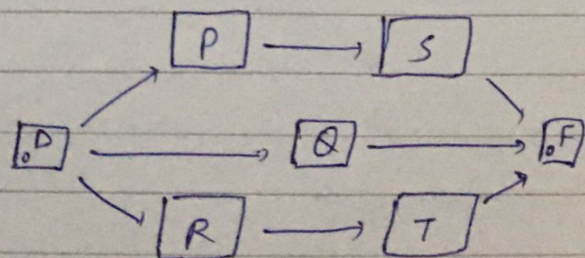
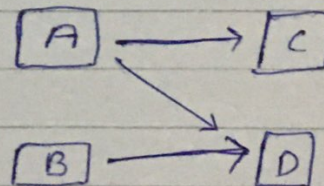
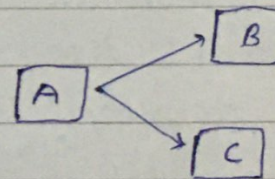
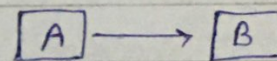
- Activity over Node Network system is also called as 'precedence network diagram' in which Node represents activities and Arrow represents their interrelationship
- ~~Arrows~~ ^{Nodes} are represented by rectangle or square



A-O-A



A-O-N



NOTE:-

When there are more than one initial activity then an artificial activity of 0 duration called Debut activity is provided as first Activity.

Similarly When there are more than one final Activity then an artificial Activity of 0 duration called Finish Activity is provided as last Activity.

Important points:-

- ① Events Don't have any place. Hence, this Network diagram is not suitable for PERT analysis.
- ② This system Eliminates use of dummies.
- ③ This system is self sufficient as it contains all activity times that is EST, EFT, LST, LFT, which helps in rescheduling or modification of Activities.

⑧ Resource ALLOCATION

Resource Smoothing:-

- In this project duration is not changed but Activities having float are rescheduled such that a uniform demand for resources is achieved.

IMP. points:-

- project duration is not changed
- resources are unlimited
- Critical path is not changed

Resource levelling:-

In resource levelling activities are rescheduled such that Max. demand of resource does not exceed availability of resources.

Imp. points:-

- Resources are limited.
- Critical path may change.
- project duration may change.

ENGINEERING ECONOMY

Time Value of Money:-

Time value of money means that two equal amounts at different period of time do not have same value if interest rate > 0

- Time value of money is important when person is either investing or borrowing.
- Interest rate is used to determine difference b/w invested amount and received amount.

Rate of Interest:-

It is the amount charge of a percentage of the principle amount for the use of that asset over a period of time

Time period for which rate of interest is expressed is called as interest period.

- Interest period can be one year, one month, one week.
- Similarly rate of interest will be expressed as per year, per month, per week etc.

Simple Interest:-

$$SI = P \times i \times n$$

Where $P \rightarrow$ principle amount

$n \rightarrow$ number of interest period

$i \rightarrow$ rate of interest per interest period

Compound interest :-

$$C.A = P(1+i)^n$$

$$C.I = C.A - P$$

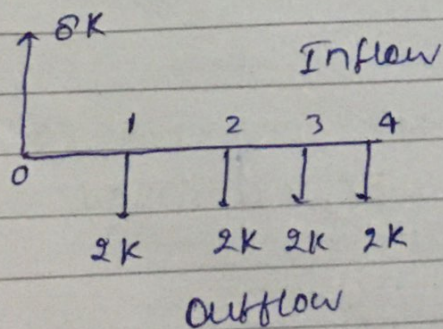
NOTE:- • Simple interest considers time value of money on principle amount only

• Compound interest considers time value of money on principle amount as well as accumulated interest.

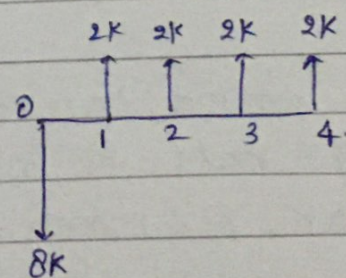
CASH FLOW DIAGRAM:-

• it is a graphical representation of monetary transaction that is inflow & outflow of money on time scale

• Cash flow diagram depends on point of view also



Borrower's perspective



Loaner's

NOTATIONS :-

- i → Rate of interest per interest period
- n → number of interest periods
- P → ~~prin~~ present worth of money or worth of money @ 0 point of time

F → Future worth of money or future worth equal to compound amount after n number of interest period.

A → Equated series of payment or uniform series of payment at the end of each interest period and continuing over a specified number of interest period.

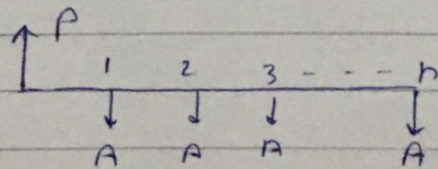
NOTE → A is also called as Annuity if interest period is one year.

Interest Formula :-

① $SPCAF = \frac{F}{P} = (1+i)^n$
single payment compound amount factor

② $SPPWF = \frac{P}{F} = \frac{1}{(1+i)^n}$
single payment present worth factor

③ $USPWF = \frac{P}{A} = \frac{(1+i)^n - 1}{(1+i)^n \times i}$
uniform series present worth factor



$$P = \frac{A}{(1+i)} + \frac{A}{(1+i)^2} + \frac{A}{(1+i)^3} + \dots + \frac{A}{(1+i)^n}$$

$$P = A \frac{(1+i)^n - 1}{(1+i)^n \cdot i}$$

Capital recovery factor

$$(4) CRF = \frac{A}{P} = \frac{i \times (1+i)^n}{(1+i)^n - 1}$$

$$(5) USCAF = \frac{F}{A} = \frac{P}{A} \times \frac{F}{P} = \frac{(1+i)^n - 1}{i}$$

Uniform series compound amount factor

$$(6) SFF = \frac{A}{F} = \frac{i}{(1+i)^n - 1}$$

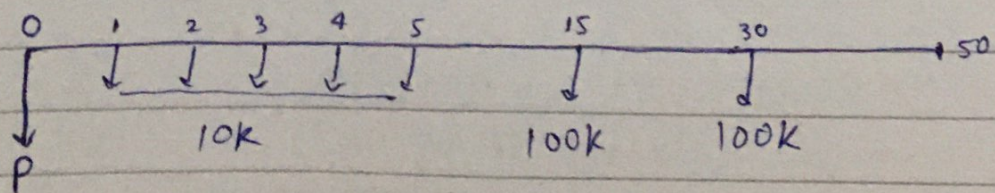
sinking fund factor

NOTE:- $SFF = CRF - i$

$$\Rightarrow \frac{i}{(1+i)^n - 1} + i$$

$$\Rightarrow \frac{i + i((1+i)^n - 1)}{(1+i)^n - 1} = \frac{i(1+i)^n}{(1+i)^n - 1}$$

Que. Maintenance cost of a New bridge with an expected 50 year life was estimated to be ₹ 10000 each year for first 5 year followed by ₹ 100000 expenditure and in 15th year & 30th year. If rate of interest is 10% year, what is uniform Annual cost over the entire 50 year period?



$$P = 10000 \times \frac{1.1^5 - 1}{1.1^5 \times 0.1} + \frac{100000}{(1.1)^{15}} + \frac{100000}{(1.1)^{50}}$$

$$P = 67577 \text{ ₹}$$

$$A = \frac{P(1+i)^n \times i}{1.1^{50} - 1} = \frac{67577 \times 0.1 \times 1.1^{50}}{1.1^{50} - 1} = 6815 \text{ ₹}$$

Nominal & Effective Interest rate:-

If interest is compounded twice thrice or more than once in a year then effective interest rate is greater than nominal interest rate

$$\text{Effective Annual interest rate} = \left[\left(1 + \frac{i}{c} \right)^c - 1 \right]$$

$i \rightarrow \text{N.I.R / year}$
 $c \rightarrow \text{no. of times compounding in a year}$

Que. If I have taken a loan of 100000 ₹ from sir which is to be paid as a monthly installment. its rate of interest is 12% / year. Amount is to be paid for 5 year. What is amount of each installment?

$$P = 100000, \quad i = \frac{12\%}{12} = 1\%, \quad n = 60$$

$$A = \frac{100000 \times 1.01^{60} \times 0.01}{1.01^{60} - 1} = \underline{2224}$$

- ⑥ if rate of interest is 12% per month and installment is to be paid after ~~6 months~~ ^{1 year}.

$$\text{effective interest rate} = \left[\left(1 + \frac{12\%}{12} \right)^{12} - 1 \right] = 12.68\%$$

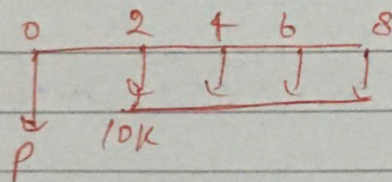
$$A = \frac{100000 \times (1.1268)^5 \times 0.1268}{(1.1268)^5 - 1}$$

$$A = \underline{28210.2} \text{ /year}$$

NOTE if rate of interest is 12%/year compounded monthly and installment is to be paid after 1 year

Same calculation!

Que.



$$i = 10\% / \text{year}$$

$$P = ?$$

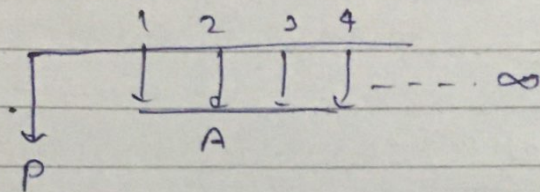
$$\text{FIR} = \left[\left(1 + \frac{20}{2} \right)^2 - 1 \right] = 21\%$$

$$P = \frac{10,000 \times 1.21^4 - 1}{(1.21)^4 \times 0.21} = \underline{25404.2}$$

Capitized Cost :-

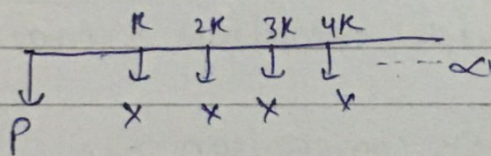
Capitized cost is the present worth of a uniform series of equal amount payment for infinite period or perpetual life.

P is often called as Capitized Value of A



$$P = \frac{A}{(1+i)} + \frac{A}{(1+i)^2} + \dots \infty$$

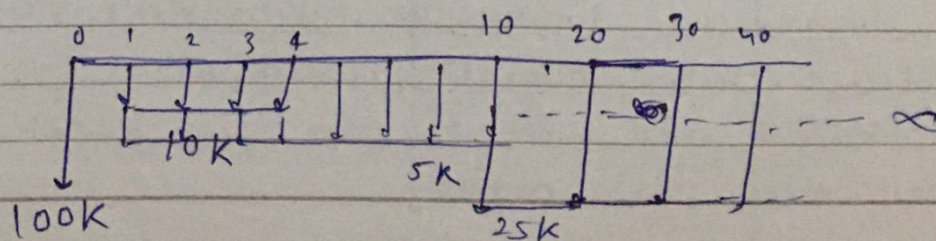
$$P = A/i$$



$$P = \frac{X}{(1+i)^k} + \frac{X}{(1+i)^{2k}} + \frac{X}{(1+i)^{3k}} + \dots \infty$$

$$P = \frac{X}{(1+i)^k - 1}$$

Que. What is total capitalized cost of Structure that will require a construction cost of 100000 ₹ immediately and 10,000 ₹ for each year for first 4 year and annual year end maintenance cost of 5000 ₹, + expenditure of 25000 ₹ at the end of every decade. Assume rate of interest as 8% per year.



$$P = 100000 + \frac{10000 \times (1.08)^4 - 1}{(1.08)^4 \times 0.08} + \frac{5000}{0.08} + \frac{25000}{1.08^{10} - 1}$$

$$P = 100000 + 33121.2684 + 62500 + 21571.715$$

$$P = 217193 \text{ ₹}$$

Comparison of Alternatives:-

Construction management often involves cost comparison b/w different engineering efficiencies

Example:- One with high initial cost and low operation and maintainance cost compared with low initial cost having high operation & maintainence cost. ~~most~~

Most common bases of comparison are

1) present Worth amount.

In this method present worth of cashflow in the form of equivalent single sum is calculated using interest rate -

Case - I Alternative with equal service life
in this case alternative with lower present worth is accepted as economical.

Case - II Alternative with unequal service life
in this case a common life period which is taken as L.C.M of given values is selected. then overall present worth of alternative is obtained and then compare for selection of economical alternative.

2) Annual equivalent amount :-

In this Method cashflow is converted into a series of equal amounts by at first calculating present worth amount and then multiplying it by capital recovery factor

$$A_p = P' \times CRF$$

3) Capitized amount :-

This method is used to

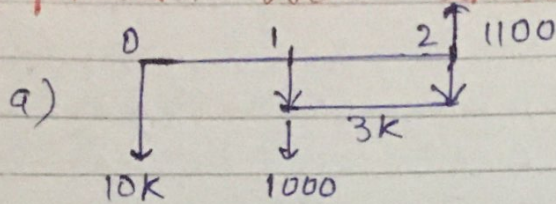
- To compare long term project
- in this method A is assumed to extend upto ∞ period and then we determine capitalized cost.

4) Rate of Return method.

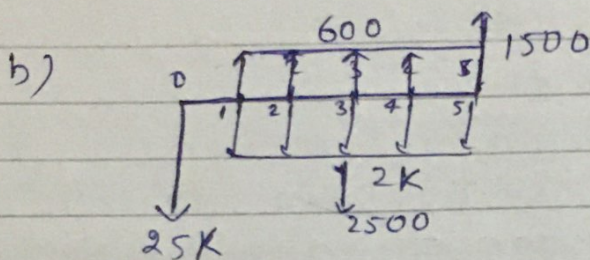
Que: Two alternatives A & B have following Cost. With Rate of interest 8% / year.

Expendature	Alternative A	Alternative B
initial cost	10,000	25,000
salwage value	1100	1500
Uniform year end expendature	3000	2000
irregular expendature at the end of 1 st year	1000	-
irregular expendature at end of 3 rd year	-	2500
benifit from quality control at the end of every year	-	600
Life	2	5

1) present worth amount



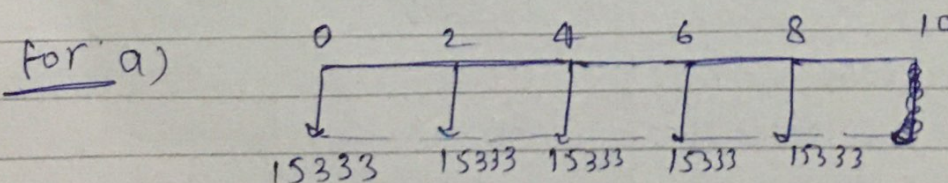
$$P_A = 10000 + \frac{4000}{1.08} + \frac{1900}{1.08^2} \Rightarrow \boxed{P_A = 15333.2}$$



$$P_B = 25000 + \frac{1400 \times ((1.08)^5 - 1)}{(1.08)^5 \times 0.08} + \frac{2500}{(1.08)^3} - \frac{1500}{(1.08)^5}$$

$$\boxed{P_B = 31553.2}$$

Since life of both the equipment is not same. Hence, we will assume a common life span which is L.C.M of both the life span that is 10 years.

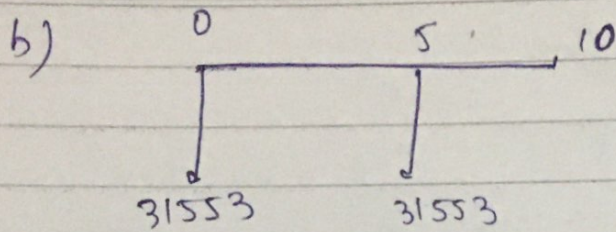


effective rate of interest for two years will be

$$i = 16.64\%$$

$$P_A = 15333 \times \frac{1.1664^5 - 1}{1.1664^5 \times 0.1664} + 15333$$

$$\boxed{P_A = 57695.2}$$



$$P_B = 31553 + \frac{31553}{(1.08)^5}$$

$$P_B = 53028$$

Alternative B is economical.

2) Annual equivalent amount:-

$$\begin{aligned} a) A_A &= P_A \times CRF = 15333 \times \frac{1.08^2 \times 0.08}{1.08^2 - 1} \\ &= 8598 \text{ ₹} \end{aligned}$$

$$\begin{aligned} b) A_B &= P_B \times CRF = 31553 \times \frac{1.08^5 \times 0.08}{1.08^5 - 1} \\ &= 7902 \end{aligned}$$

B

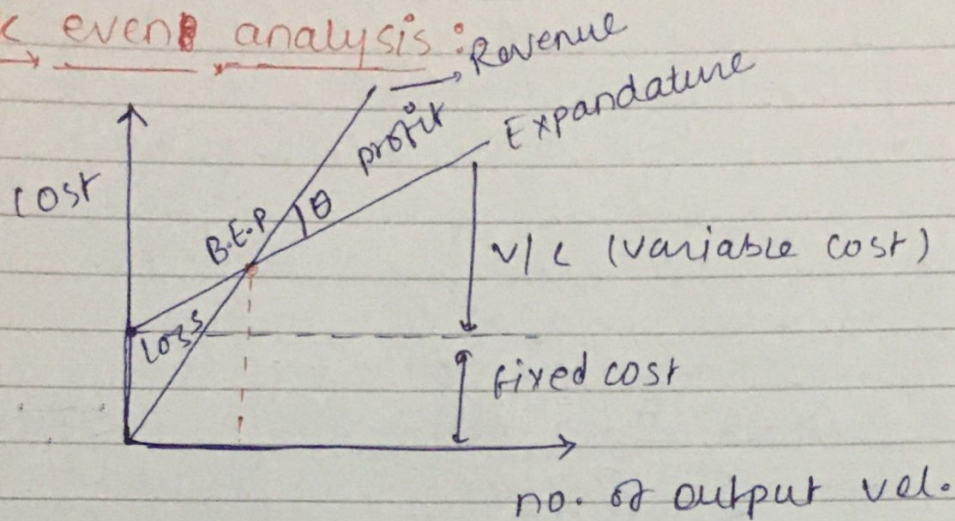
3) Capitlized amount:-

$$P_A = A_A / i = 107475$$

$$P_B = A_B / i = 98775$$

B

Break even analysis:



- it is also called as cost volume profit studies
- At break even point there is neither profit nor loss
- it is a graphical representation of relationship b/w cost and revenue for all possible volume of output

function:- • it is suitable for business firm to study cost and revenue relationship

- it is a decision making tool.
- it indicates effect of variation of fixed cost, variable cost & revenue on profitability of business.
- it indicates profit and loss for various output level.
- possibility of profit can be determined for any rate of production
- it shows whether the business is good or bad with the help of angle of incidence. Greater the angle of incidence it means more profit

Limitation:-

- it is a tool for short term analysis
- it provides a static picture whereas business processes are dynamic in nature
- Revenue line may not be a straight line
- Analysis of break even becomes difficult when company manufactures variety of product.
- Cost & revenue are only related with number of output units but they have no relation with time

Depreciation:- (Write-off)

it is reduction in the value of asset in passage of time due to wear and tear, deterioration etc.

- Not all the asset depreciate with the passage of time ex' land

Types of Depreciation:-

- 1) physical:- due to wear & tear of an asset due to constant use, impact, corrosion, abrasion etc.
- 2) functional / Obsolescence:- Due to change in fashion, design, structure, efficiency etc.
- 3) contingent:- Due to disease or circumstances

Salvage Value:-

It is value of an asset at the end of its utility period before the end of useful life.

Scrap Value:-

It is the value of an asset at the end of useful life that is its utility is considered as junk or scrap.

At the end of useful life scrap value equal to salvage value.

Book Value:-

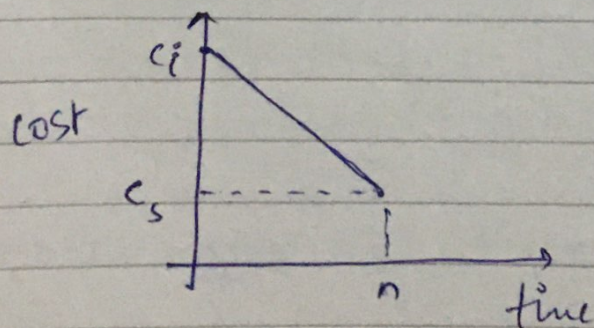
It is the value of an asset shown in account book of a company at the end of every year.

$$\text{Book Value} = \text{initial cost} - \text{depreciation}$$

METHODS OF DEPRECIATION:-

1) Straight Line Method:-

On this method asset is assumed to lose its value by a fixed amount every year.



$$D = \frac{C_i - C_s}{n}$$

Rate of depreciation
= $\frac{1}{n}$

Where D is Depreciation amount per year
and ' n ' useful life of the asset
 $C_i \rightarrow$ initial cost

NOTE initial cost = purchased cost + transportation cost + installation charges.

$C_s \rightarrow$ salvage value at the end of useful life that is scrap value.

$B_m \rightarrow$ Book value at the end of n^{th} year

$$D = \frac{C_i - C_s}{n}$$

$$D = D_1 = D_2 = D_3 = \dots = D_m = D_n$$

$$B_m = C_i - m \times D$$

$$B_n = C_i - n \times D$$

$$B_n = C_i - n \times \left(\frac{C_i - C_s}{n} \right)$$

$$B_n = C_s$$

at the end of useful life book value = Salvage value = scrap value.

2) Decline balance Method / constant % method :-

In this Method asset is assumed to lose its value by a fixed % of book value.

FDB $\rightarrow$ Fixed declined balance rate @ which depreciation occurs.

$$D_1 = C_i \times FDB$$

$$B_1 = C_i - (C_i \times FDB)$$

$$B_1 = C_i (1 - FDB) \quad \dots (i)$$

$$D_2 = B_1 \times FDB$$

$$B_2 = B_1 - (B_1 \times FDB)$$

$$B_2 = B_1 (1 - FDB)$$

$$B_2 = C_i (1 - FDB)^2 \quad \dots (ii)$$

$$B_m = C_i (1 - FDB)^m$$

$$B_n = C_i (1 - FDB)^n$$

$$\because B_n = C_s$$

$$C_s = C_i (1 - FDB)^n$$

$$FDB = 1 - \left(\frac{C_s}{C_i} \right)^{1/n}$$

Drawback:-

This Method can not be used for those assets whose Scrap value is zero or Negative

3) Double Decline balance Method :-

In this Method asset is assumed to lose its value by a fix rate of book value every year

FDDB $\rightarrow$ Fixed double decline balance rate at which depreciation occurs

$$FDDDB = \frac{2}{n}$$

FDDDB equals to twice of rate of depreciation in straight line Method.

$$B_m = (C_i(1 - FDDDB))^m$$

(iv) Sum of year Digit Method:-

Depreciation in m^{th} year

$$D_m = (C_i - C_s) \left[\frac{n-m+1}{\frac{n(n+1)}{2}} \right]$$

(v) Sinking Fund Method:-

Depreciation in m^{th} year

$$D_m = D(1+i)^{m-1}$$

$$D = (C_i - C_s) \times \frac{i}{(1+i)^n - 1}$$

Que. $C_i = 1100 \text{ ₹}$, $C_s = 100 \text{ ₹}$, $n = 5 \text{ year}$, $i = 8\% \text{ per yr}$
Determine Depreciation & Book value every year by all the five Methods.

(i)

$$D_1 = \frac{1100 - 100}{5} = 200$$

$$D_1 = D_2 = D_3 = D_4 = D_5 = 200 \text{ ₹}$$

$$B_1 = 1100 - 200 = 900, B_2 = 700, B_3 = 500$$

$$B_4 = 300, B_5 = 100$$

(ii)

$$FDB = 1 - \left(\frac{C_2}{C_1}\right)^{1/n}$$

$$FDB = 1 - \left(\frac{100}{1100}\right)^{1/5}$$

$$FDB = 0.381$$

$$D_1 = 0.381 \times 1100 = 419.1$$

$$B_1 = 1100 - 419 = 681$$

$$D_2 = 0.381 \times 681 = 259$$

$$B_2 = 681 - 259 = 422$$

$$D_3 = 422 \times 0.381 = 161$$

$$B_3 = 422 - 161 = 261$$

$$D_4 = 0.381 \times 261 = 99$$

$$B_4 = 261 - 99 = 162$$

$$D_5 = 0.381 \times 162 = 62$$

$$B_5 = \underline{\underline{100}}$$

(iii)

~~Don~~ $FDDB = 2/n = 2/5 = 0.4$

$$D_1 = 0.4 \times 1100 = 440$$

$$B_1 = 1100 - 440 = 660$$

$$D_2 = 0.4 \times 660 = 264$$

$$B_2 = 660 - 264 = 396$$

$$D_3 = 0.4 \times 396 = 158$$

$$B_3 = 396 - 158 = 238$$

$$D_4 = 0.4 \times 238 = 95$$

$$B_4 = 238 - 95 = 143$$

$$D_5 = 0.4 \times 143 = 57$$

$$B_5 = \underline{\underline{143 - 57 = 86}}$$

Since book value can not be less than
 Scrap Value Therefore $B_5 = 100 \text{ ₹}$
 Therefore $D_5 = 143 - 100 = 43 \text{ ₹}$

$$(iv) \quad D_m = (C_i - C_s) \times \left(\frac{n+m+1}{\frac{n(n+1)}{2}} \right)$$

$$D_1 = 332, D_2 = 267, D_3 = 200, D_4 = 133$$

$$D_5 = 67$$

$$B_1 = 1100 - 332 = 767$$

$$B_2 = 767 - 267 = 500$$

$$B_3 = 500 - 200 = 300$$

$$B_4 = 300 - 133 = 167$$

$$B_5 = 167 - 67 = \underline{100}$$

$$(v) \quad D = (C_i - C_s) \times \frac{i}{(1+i)^{n-1}}$$

$$= 1100 - 100 \times \frac{0.08}{(1.08)^5 - 1} = 170.45$$

$$D_1 = 170.45 \times 1.08^0 = 170$$

$$D_2 = 170 \times 1.08^1 = 184$$

$$D_3 = 170 \times 1.08^2 = 199$$

$$D_4 = 170.45 \times 1.08^3 = 215$$

$$D_5 = 170.45 \times 1.08^4 = 232$$

$$B_1 = 1100 - 170 = 930, B_2 = 930 - 184 = 746$$

$$B_3 = 746 - 199 = 547, B_4 = 547 - 215 = 332$$

$$B_5 = 332 - 232 = \underline{100}$$

- NOTE:-
- In straight line Method depreciation amount is constant every year
 - In Constant % Method, Double decline Balance rate Method and Sum of year digit Method depreciation is high in early year and it reduces in later year.
 - In Sinking fund method depreciation is less in early year and it increases in later year.

NOTE:- $P_{avg} = \frac{P(n+1)}{2n}$

$$P_{avg} = \frac{P(n+1) + S(n-1)}{2n}$$

* Cost-Benefit studies are essential to —
evaluate the viability & worth whiteness
of taking up the project.

Fundamental of Equipments

Life of an equipment

Physical $\rightarrow$ before it becomes unable to produce a good

Economic $\rightarrow$ expected to use with Normal repair/Maintenance

Investment Costs

i) No salvage value

$$P_{av} = \frac{P(n+1)}{2n}$$

ii) Salvage value

$$P_{av} = \frac{P(n+1) + S(n-1)}{2n}$$

Depreciation

Maintenance and repair cost

Downtime cost $\rightarrow$ The time when machine is under repairing.

Obsolescence cost $\rightarrow$ by installation of new machine production cost is reduced by some amount as compared to the production cost of existing machine, then existing machine is said to suffer a loss of that amount it is called obsolescence cost.

Rolling resistance analogous to dynamic coefficient μ

$$R = \frac{P}{W}$$

$R \rightarrow$ rolling resistance (kg/tonne)

$P \rightarrow$ Tractive force req. (kg)

$W \rightarrow$ Gross wt. of vehicle (tonne)

Grade resistance taken as 10 kg/tonne. i.e. 1%.

* Grade resistance is overcome with the help of drawbar pull (crawler) or Rimpull (Rubber tyred) it acts against wt. of both tractor and loading unit

Total resistance = Rolling Resistance $\pm$ Grade Resistance

Usable traction = coefficient of traction $\times$ wt.

Usable tractive force = Available tractive effort - Total resistance.

Drawbar pull

Force need by tractor to pull trailing load
vary inversely proportional to Gear.

Rimpull force by Rubber tyred tractor on surface.

a) When Slippage is eliminated

$$\text{Max. Rimpull} = \frac{375 \times \text{HP} \times \text{Efficiency}}{\text{Speed in mph.}}$$

b) Max. Slippage starts before its rated capacity $\eta = 0.80 - 0.85$

$$\text{Max. effective Rimpull} = \text{Total pressure b/w tyres and surface} \times \text{Coefficient of friction.}$$

Gradability Max. slope on which tractor can move @ Uniform speed-

Combined effect of pressure and temp. on I.C engines

$$H_c = H_o \frac{P_s}{P_o} \sqrt{\frac{T_o}{T_s}}$$

s $\rightarrow$ standard

o $\rightarrow$ observed

c $\rightarrow$ corrected

Bank Volume earth measured in site

Loose Measure Vol. after deposition in loosen state

Compacted/Fill Volume Vol. of earth it has been placed in a fill and compacted.

$$\% \text{ swell} = \left(\frac{W_u}{W_L} - 1 \right) \times 100$$

c $\rightarrow$ compacted
u $\rightarrow$ undisturbed
l $\rightarrow$ loosen state

$$\% \text{ shrinkage} = \left(1 - \frac{W_u}{W_c} \right) \times 100$$

$$\text{swell Factor} = \frac{W_L}{W_u} = \frac{100}{100 - \% \text{ of swell}}$$

$$\text{shrinkage factor} = \frac{W_c}{W_u} = \frac{100}{100 - \% \text{ of shrinkage.}}$$

Struck Capacity $\rightarrow$ Vol^m in the body @ level measure or water level capacity

Heaped capacity $\rightarrow$ Total Vol^m of material as it is heaped up over the sides with 1:1 inclusive of Struck Vol^m.

Earthwork Equipments

Tractor To pull or push the loads, or mount for other equipments

i) crawler tractor → tractor mounted on crawler where is an endless chain consisting of steel links made of steel plates connected together by pins and bushings. 

(ii) Wheel tractor → for high speed by gears. Sacrifices pulling effort

* Wheel tractors are faster, may slip over smooth surface
crawler → costly, compact, powerful, can handle heavier load
need greater skills in operation, pavement damage by
transporting crawler by putting it over trailers, operational cost ↑

Power shovels → digging, lifting, earth except solid rock without prior loosening.

For excavating hard tough soil, dipper of large shovel can exert greater downward pressure will be more suitable.

$$\text{Output of shovel} = \frac{\text{loose vol}^m \text{ of dipper}}{1 + \text{swell function}} \times \frac{\text{Actual time in sec/hr} \times \text{Efficiency}}{\text{cycle time (s)}}$$

Drag line -

it has long boom to disperse earth from one place to embankment place
can excavate below its level and under water

Hoes → long handle hand equipment having a light blade to dig, scrap, till or weed. For excavating below ground

Clamshells → Machine having characteristics of crane & dragline.

Digging is done like dragline and then works like a crane

• For vertical lifting of materials.

Bulldozers → efficient excavator for short hauling application upto 100m. A heavy steel blade mounted on front of a tractor

$$\text{Output} = \frac{\text{loose vol}^m \text{ of Dipper}}{1 + \text{swell fraction}} \times \frac{\text{Actual time in min/hr}}{\text{Time req}^m \text{ per trip (min)}}$$

$$\text{Time req}^m = \frac{\text{Haul Distance}}{(\text{forward} + \text{backward}) \text{ speed}} + \text{Gear shift time}$$

Scrapers:- self operating, dig, load, haul, discharge
 not used for Hard rock, sand which won't pile up into scraper
 also not in wet & muddy material.

output = loose Vol^m per trip X swell factor X 60 X Efficiency
 cycle time Per Minute.

Trenchers → Fast digging with control depth & width.
 • can dig any material except rock, Generally for pipelines.
 • can't use where large ground water.

In cohesive soil it req^r more power, better to use power shovel / backhoe

Motor Graders → for road construction, levelling, land reclamation,
 Finishing earthwork, mixing Gravel and trimming slopes.

Output usually expressed in unit of area covered per hour.

S/N	Item of comparison	power shovel	Back Hoe	Drag line	clam shell.
1)	in Hard soil/rock	Good	Good	Not Good	poor
2)	wet soil / muddy	poor	poor	<u>Moderately Good long.</u>	
3)	Distance b/w footing & digging	small	small	—	
4)	loading efficiency	Very Good	Good	Moderately Good	precise but slow
5)	footing required	close to work	close to pit	Fairly away	from pit
6)	Digging level	@ or above footing	below ground	(below)	at or below
7)	cycle time	Short	slightly more than power shovel	more than power shovel	more than any other equipment

Loading & conveying Equipments

- ① Trucks
- earth, aggregate and rock
 - high speed
 - high degree of flexibility

RDT on both axle.
ADT on front axle.

- ⊕ of ADT over RDT → High maneuverability
Low turning Radius
High tractive effect
Better operator comfort
Fast cycle time, lower fleet cost

Rear Dump Truck → blasted rock, earth, sand, gravel, ore, coal for flowing material.

- Max. flexibility, Max. gradability, rapid spotting area.

Bottom Dump Truck → semi-trailer

flowing material like sand, gravel, dry earth

Grade > 5% , Not suitable for large, wet, sticky material

Side Dump truck → • Dump material in long narrow stretch.
• Quick.

Favourable factors for small trucks

More flexible, High speed, less loss if fleet breaks down
Easy balancing with output of excavator

Favourable factors for large trucks

less total investment in hauling units.

Reduction in operation cost • more excavator output

$$* \text{productive capacity / Hour} = \frac{60}{\text{cycle time (min)}} \times \text{payload per cycle (tonnes)}$$

② Belt conveyors

Horizontal or inclined → conveyor

vertical → Elevator.

for earth, sand, gravel, crushed stone, concrete.

fixed installation • woven cotton belt.

can operate over any terrain

- ⊕ • Continuous, high speed, uniform.
- low maintenance
- labor required • High reliability.
- Excellent safety • Ability to cross a diverse terrain

- ⊖ • Req. skilled labour
- Very high initial cost
- Needs continuous supply of electricity.

power for belt

Sum of move + lift + turn + compensate for
driving loss + operate a ripper

Hoisting Equipments

- ① pulley → Rough surface and heavy objects.
- ② chains → upto 50 tonnes (Hand chain and load chain)
- ③ jacks → 5-100 tonnes, based on inclined plane
- ④ winch → (gear + clutches + brakes) • for railway gates.
- ⑤ cranes → 0.5 tonne → 500 tonnes. , 3D.

{	• electric	{	Light Duty
	• diesel	{	Medium
	• Diesel-electric	{	Heavy
		{	Very Heavy Duty

① Stationary / Derrick crane

a) Guy derrick → 200 tonnes 360° rotation

b) Stiff leg Derrick → 7-50 tonnes 270-290° rotation

② Mobile cranes • Mounted on crawler or rubber tyred truck
• economical when Ground is poor

③ overhead / Gantry cranes • freedom from floor obstruction.
• 3 way motion
• Used in factories / steel plant / storage yard / welding yard

④ Tower crane

- High industrial and residential frames.
- element of steel structures

⑤ Traveller crane

- laid on tyre, rail track.

crane selection → • Wt. dimensions of load

• Height

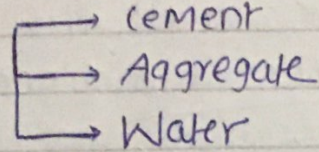
• climbing arrangement

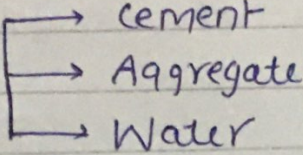
• Area reached

• Hoist speed

• length of cable

Concreting Equipments

① storing 

② Batching 

- ③ Mixing
- ④ Handling/Transporting
- ⑤ placing
- ⑥ compacting
- ⑦ Finishing
- ⑧ curing.

① storing

① ceMent

- should not come in contact of moisture.
- stored about 60 cm away from external wall and 15 cm above the floor.
- H $\times$ 10 or 12 bags.
- Shed completely dry.
- closer to reduce air circulation.
- First IN, FIRST OUT

② Aggregate

- Must be clean and free from dust, clay, mud, silt, dirt
- Hard and Dry base, Diffⁿ size $\rightarrow$ Diffⁿ compartments.
- near mixer, fine particles shouldn't concentrate @ centre

③ Water Masonary built tank clean, should not stored for longer period but stored a day in advance only.

② Batching

- By Volume
- By Weight * preferred by IS code reliable

ceMent $\rightarrow$ 50 Kg bags

Weighing hopper Beam scale | springless dial scale

Aggregate Based on one bag of cement

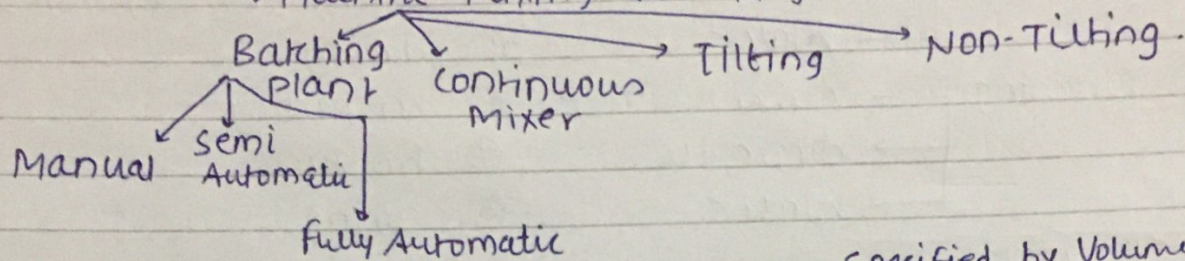
- Wt. batching by
- i) simple spring balances
 - ii) platform Weighing Machines
 - * iii) Automatic weighing Machine

both wt. and volume batching gives same results

Water $\rightarrow$ easy by Volume.

③ Mixing

- Hand Mixing for small jobs
- Machine Mixing for large works.



Concrete Mixers $\rightarrow$ (2-3 min) (18-20 rpm)

Specified by Volume Capacity.

- (i) Drum type (ii) Pan type (efficient)

Tilting $\rightarrow$ Non-Tilting

$\downarrow$

$< 75\text{mm}$

- $> 75\text{mm}$ aggregate
- for large work
- easy to clean, quick
- Min. segregation

Paving mixture $\rightarrow$ Rigid pavement, on crawler tractor.

$27E \rightarrow 27$ (volume in ft^3), $E \rightarrow$ Paving Mixer

Factors affecting output of a Mixer

Size, speed, cycle time, unloading loading transporting time.

Actual operating time factor (45-50 min/hr)

④ Transporting

- | | |
|--------------------|---|
| a) pans (प्रति) | Small jobs |
| b) Wheel barrows | Medium jobs |
| c) power Buggies | 24 km/h |
| d) Towel bucket | Guide Rails (capacity $\rightarrow$ 0.226-1.02 cum. (less space)) |
| e) crane bucket | 0.38 - 6.1 cum. |
| f) Dump truck | without agitation |
| g) chutes | below Ground |
| h) concrete pump | 300 m Distance 40m Upward - |
| i) transit Mixer | Truck (0.76 - 5.7 cum) 2-6 rpm |
| j) Agitating Truck | prevent segregation |
| k) Belt-conveyor | continuous Supply. |

Must be economical
 • prevent segregation
 • before initial setting time.

⑤ COMPACTING · 1% voids reduce 5% strength.

① Manual → Tamping

- Rod or hand tool
- 15cm in RCC
- 30cm in mass concrete.

② Mechanical → vibrator

gets higher density of concrete so, less seepage.

- a) Needle / ~~Internal~~ → Mass concrete work.
- b) Form / External → Heavily R/C column / thin tunnel lining.
- c) Table / platform → Cube specimen / precast concrete member.
- d) Surface vibrator / screed → Pavement / thin slab / floor

③ Special methods

- a) vibro pressing → external pressure (paving, road kerbs)
- b) shock / jolting → precast concrete products.
- c) centrifugation → Water tight structures.
- d) Air jets → Air is driven out.

⑥ FINISHING

- a) screeding → Strik off the excess concrete
- b) Floating → remove irregularities
- c) Trowelling → after the excess water has evaporated. smooth finish.

⑦ CURING · To increase durability and impermeability

- To gain strength · Reduce shrinkage
- Improves water / weather resisting qualities.

Temp → $5^{\circ} - 28^{\circ}C$

Lower temp. → rate of setting ↓

High temp. → reduces strength.

Compacting Equipment

- Kneading Action → Manipulation or rearranging
- static weight → pressure application
- Impact → sharp blow
- Vibration → shaking

Types of Rollers :-

(Mixture of sand & clay) (Clay)

- ① Sheep's Foot Roller :-
- Suitable for fine grained material
 - Not suitable for sand and gravel

• Depth of soil compacted = length of feet

• Feet shape → Taper foot
→ Club foot

- Small Contact Area of foot so require more (large) No. of passes to cover area of soil
- Slow and very high rolling resistance so cost/unit vol. ↑

② Smooth Wheel Rollers :-

- Effective in compacting granular soils, sand, gravel, stone pieces
- Effective in smoothing surface of soil
- While compacting cohesive soil form a crust over surface will prevent adequate compaction.
- Contact Area is narrow strip, so stresses fall off rapidly as depth of layer ↑
- To increase wt. rolls are ballasted with sand or water
- 7.3 - 12.8 t Min. wt = 7.3 t, Max wt = 12.8 t

③ Pneumatic-tired Rollers :-

- Kneading Action (provides shear)
- Used for rolling subgrades, airfield and bases of earthfill dams
- 13.6 - 180 tonnes wt.

④ Impact Rollers :- Recent development

- Concrete block square shape with steel covering having rounded corners
- Can be applicable to wide range of soil types.
- Can compact upto a considerable depth.

VIBRATING COMPACTORS :- enhance the performance of static wt. rollers by providing dynamic forces. Excellent densification of sand gravel, stones

1) Manually operated Vibratory plate compactors :-

- have flat plate in contact with soil
- Smaller size, so lower output
- used for cohesionless soil in confined areas or spaces

2) Manually operated vibratory tamping compactors :-

- engine-driven mechanism, acts on spring system
- vertically oscillations ~~10-80~~ (10-80 mm)
- suitable for most types of soil
- low output, so used in confined areas
- portability & maneuverability are advantages

3) Manually operated Rammer compactors :-

- each blow moves them ahead slightly to contact new soil
- Performance kg/blow, area covered/hour, depth in cm.
- impact from 40-120/sec, 850/min.

Output of compactor =

$$Q = \frac{S \times N \times P \times T}{N}$$

$$\text{Overlap} = \frac{\text{width of overlap}}{\text{No. of Drums} \times \text{width of each drums}}$$

For a 2 Drum roller, 120 cm width if overlap is $\frac{1}{4}$ of one drum

$$\text{overlap} = \frac{1}{4} \times \frac{120}{2 \times 120} = 0.125$$

then use a factor $1 - 0.125 = 0.875$ in above formula.