4.23 PERFORMANCE INDICATORS

Time Overrun: If a project is completed with minimum time and cost over run, it is considered as a well-managed project. This appears to be partially true. It is not known whether time and cost targets fixed earlier were realistic or unrealistic. Even well-managed projects may have time and cost overruns. There is large variation in completion of similar projects due to the following factors:

(1) Zero dates are not same;
(2) Meaning of completion differs from project to project;
(3) Schedules are unrealistic;
(4) Scope changes take place.

In view of the above it can be inferred that time overruns cannot be used as true indicator for project management performance.

Cost overrun: Cost is a fact and cannot be misquoted like time. Anything done to the project including time overrun is reflected in cost. It is inferred that a well managed project will have lower costs. However, cost estimates have to be revised at various stages to improve their accuracy. Cost can be used as an indicator for project management performance. If, however, cost overrun is taken as difference between final completion cost and original approved cost, then it will not be a true indicator for project management performance.

Productivity: It can be used as performance indicator, as it indicates how resources were utilised.

Value: It can also be used as a performance indicator. Value improves when performance is achieved at no extra cost or when cost can be reduced for the desired level of performance. Value engineering review uses cost as the basis of review and ensures that value is included in the design. When non-functional cost is removed from an item, its value goes up.

❑❑❑

Chapter **5**

NETWORK ANALYSIS

5.01 INTRODUCTION

Once a project is selected, the focus of project manager shifts to its implementation. This involves completion of numerous activities by deployment of various resources. The activities of a project have inter-relationships arising from physical, technical and other considerations. Some of these activities are performed in series and some of them in parallel. Network techniques are quite useful for proper planning scheduling and controlling of the activities. They provide a rational approach to planning and controlling of construction works. Since bar charts, except for their simplicity, have several limitations, they are not effective for controlling project works. Network techniques are in essence, a modification of bar charts for controlling various activities of a project. Both networks and bar charts are graphical techniques. Their basic requirement is to analyse various work components of the project. For this it is necessary to list out various activities from beginning to end of the project. There are two basic planning and control techniques that utilise the network to complete a planned project. They are Programme Evaluation Review Technique **(PERT)** and the Critical Path Method **(CPM)**.

Strengths and Limitations of PERT

Strengths

(i) It forces managers to plan all down the line,
(ii) Focus on critical events and activities,

(iii) Facilitates forward looking control,
(iv) Provides action points at right spot and level of organisation at right time.

Limitations

(i) Not useful if time estimates cannot be made for programmes,
(ii) Not practicable for mass production,
(iii) Lays emphasis on time and not on cost,
(iv) Linear mode and in series operations only.

■ 5.02 DIFFERENCES BETWEEN PERT AND CPM

Parameter	PERT	CPM
1. Acronym	Programme evaluation	Critical path method and Review Technique.
2. Origin	US Navy for planning and scheduling of Polaris weapon system	DuPont company to solve scheduling problems in construction of chemical plants
3. Approach	Event oriented	Activity oriented
4. Suitability	For projects involving (i) New technology (ii) Rapidly changing technology (iii) R&D projects	For stable technology such as construction projects.
5. Time estimates	Probabilistic (three time estimates – optimistic, pessimistic and most likely time)	Deterministic (single time estimates)
6. Uncertainty	Allowance exists	No such allowance
7. Basis	Time based	Cost based

■ 5.03 BASIC CONCEPTS

(i) **Network:** Network is a graphic plan of all activities that must be completed to reach the end objective of the project showing their interdependency and inter-relationship. The components which make up the network are activities and events.

(ii) **Event:** Event, also called mode, is a specific definable accomplishment in a project plan. It is a point in time at which an activity begins or ends. It is recognisable at particular instant of time. It consumes neither time nor resources. It is a point in time and not passage of time. It is the state between the completion of a preceeding activity and the beginning of succeeding one. It is represented by a circle or any geometric shape.

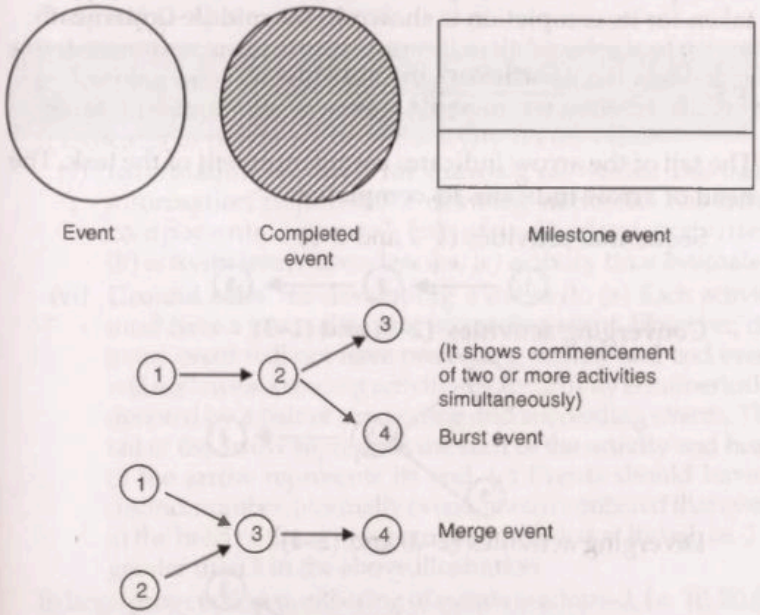
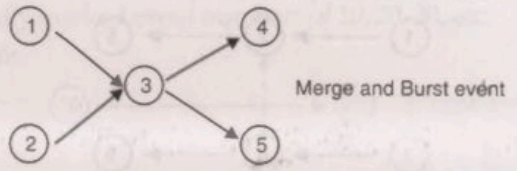


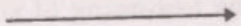
Fig. 5.1: Event/mode

Merge event (it shows completion of two or more activities simultaneously)



(Two or more activities are completed and two or more activities are commenced simultaneously.)

(iii) **Activity:** It is the smallest unit of productive effort in a project. It is the performance of task between any two events. It is a task performed over a period of time. It is a homogeneous element of continuous work consuming time and resources in a network plan. It is represented by an arrow

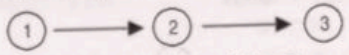


Description of the activity is written above the arrow and time taken for its completion is shown in the middle underneath.

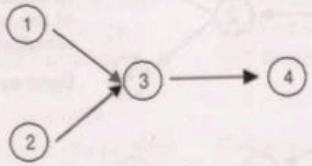
e.g. Earthwork in excavation / 10 days

The tail of the arrow indicates commencement of the task. The head of arrow indicates its completion.

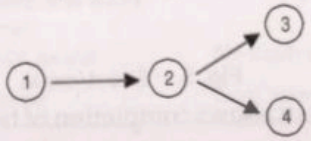
Sequential activities (1–2 and 2–3)



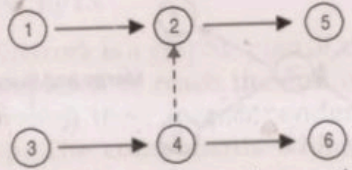
Converging activities (2–3) and (1–3)



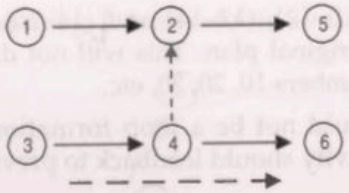
Diverging activities (2–3) and (2–4)



Parallel activities (1–2) and (3–4).



(iv) **Dummy activity:** It is a zero time activity. It is shown thus (dotted arrows).



For example (2–4) is a dummy activity. It indicates that activity (2–5) cannot start unless activity (1–2) and activity (3–4) are completed. The event (2) is accomplished when activities (1–2) and (3–4) are completed.

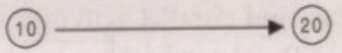
It does not consume any resource. It maintains logic of network by keeping inter-dependencies in perfect order. It also helps to maintain numbering system unique in the network diagram. It indicates dependency of one activity on the other.

(v) **Information required for drawing networks:** The basic information required for drawing networks has three components, viz., (a) list of individual activities, (b) activity interdependencies, (c) activity time estimates.

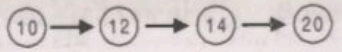
(vi) **Ground rules for developing a network:** (a) Each activity must have a preceeding and succeeding event. However, the initial event will not have preceeding activity and end event will not have succeeding activity, (b) An activity is numerically denoted by a pair of preceeding and succeeding events, The tail of the arrow represents the start of the activity and head of the arrow represents its end, (c) Events should have a distinct number. Normally events are so numbered that event at the head of the arrow is greater than that at its tail, i.e. 2 is greater than 1 in the above illustration.

In large projects skip numbering of events is adopted, i.e. 10, 20, 30 instead of 1, 2, 3 etc. This gives flexibility to introduce new activities in between those planned earlier. Between two events (10), (20), if it is necessary to introduce new activities due to variation in scope of work etc., it can be introduced as 12, 14, etc. This will not disturb originally marked event numbers of 10, 20, 30, etc.

Example:



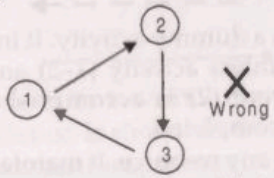
(Original plan)



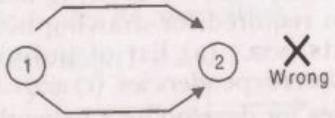
(Revised plan)

Activities (10–12), (12–14) and (14–20) are introduced subsequent to original plan. This will not disturb originally marked even numbers 10, 20, 30, etc.

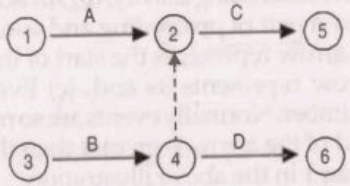
- There should not be a loop formation in a network, i.e. No activity should leadback to previous activity.



- Not more than one activity should have the same preceeding and succeeding events, i.e. only one activity may connect any two events.



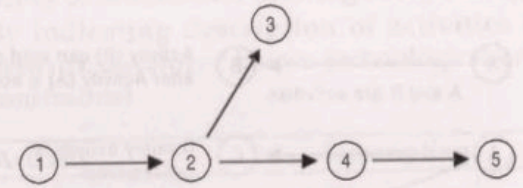
- To ensure that each activity is uniquely numbered, it may be necessary to introduce dummy activity.



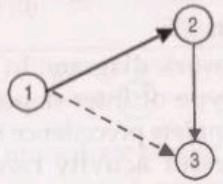
Activities A and B must be completed before activity C can start and event (2) is completed only when activity A and B are completed:

- Arrows representing activities flow from left to right. Length of arrow has no significance at the initial planning stage. (Time scaled network is an exception),
- Sequential activities and parallel activities should be decided before developing a network,
- No activity should be disconnected before completion of all activities in a network, e.g. activity (2-3) is disconnected.

It is called dangling. It is an error in a network.



- Unnecessary insertion of a dummy activity results in redundancy.

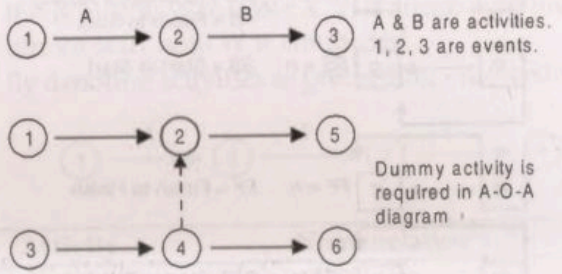


(vii) Errors in network

(i) Loop formation,
(ii) More than one activity connecting two events,
(iii) Dangling,
(iv) Redundancy.

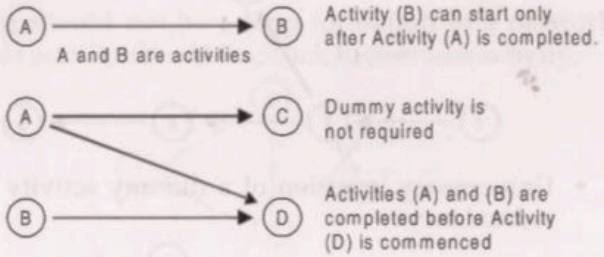
(viii) Network diagrams

(a) **A - O - A** (Activity on Arrow) network is the most commonly used diagram. In this arrows represent activities and circles represent events or nodes.



(b) In **A-O-N** (Activity on Node) diagram circles represent activities. The arrows do not represent any

entity but only show the precedence relationships between the nodes (events).



(ix) **Precedence network diagram:** In both AOA and AON diagrams one type of inter dependency between two activities, i.e. complete precedence is represented. In these diagrams successor activity can start only after the predecessor activity is completed.

However, in practice, successor activity [S] can start or finish immediately or after a time lag after start or finish of precedence activity [P]. Such situation is represented by precedence network diagram (PND). In this diagram activities are represented by squares. Arrows represent precedence relationship. The left side of square represents "start" and the right side "finish" of an activity. "n" represents lead-lag factor in time units. Flow of time is assumed to be from left to right (Fig. 5.2).

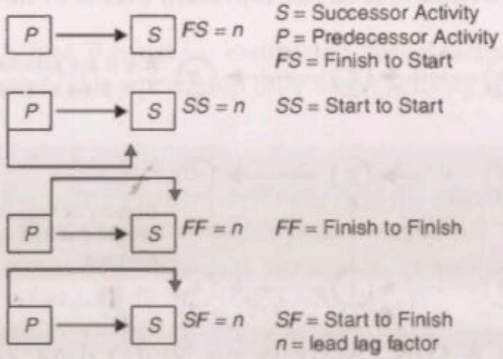
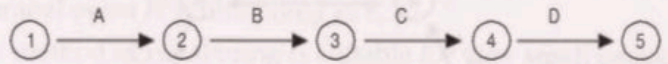


Fig. 5.2: Precedence network diagram

- Methods of denoting interrelationship and interdependency of activities for drawing network diagram.
- By indicating description of activities (assuming network developer knows technological and practical constraints).

Activity	Description
A	Site clearance
B	Marking layout on site
C	Earthwork in foundation
D	Placing PCC

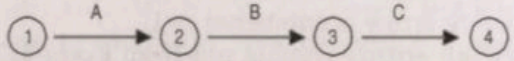


- By indicating immediate predecessor

Activity	Immediate Predecessor
A	Nil
B	A
C	B
D	C

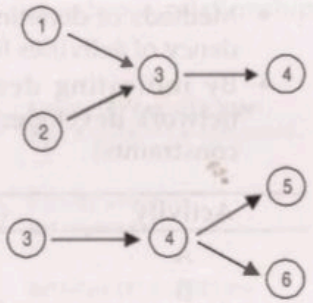
Activities B, C, D can start only on completion of activities A, B, C respectively.

- By notation A<B, B<C, C<D. It indicates that B, C, D cannot start until A, B, C are completed respectively. If it is indicated that W< X, Y, it means activities X and Y cannot start until W is completed.
- By denoting activities as preceeding - succeeding events.



Activity	Nomenclature
A	(1-2)
B	(2-3)
C	(3-4)

Activity	Immediate Predecessor
(3–4)	(1–3)
	(2–3)
(4–5)	(3–4)
(4–6)	



Fulkerson's rule for numbering the events

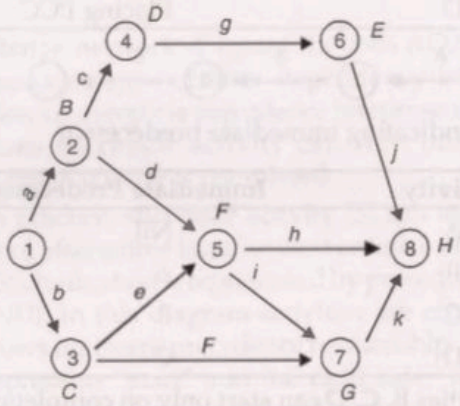


Fig. 5.3: Numbering of events

A, B, C, D, E, F, G and *H* are 8 events.

A is the starting event and *H* is the end event.

a, b, c, d, e, f, g, h, i, j and *k* are *n* activities

Events are to be numbered as 1, 2, 3, 4, 5, 6, 7 and 8

(1) The initial event which has all outgoing arrows with no incoming arrow is numbered as 1,

(2) Delete all arrows coming out from event 1. This will convert one or more events into initial events. Number these events as 2, 3,

(3) Delete all the arrows going out from these numbered events to create more initial events. Assign next numbers to these events,

(4) Continue this procedure until the final event which has all arrows coming in with no arrow going out is numbered.

In the Fig. 5.3 A is the initial event. Number it as 1. Delete arrows a and b. This will create two more initial events *B* and *C*. Number them as 2 and 3.

Delete all arrows *c, d, e, f* emanating from events *B* and *C*. This will convert *D* and *F* into initial events. Number them as 4 and 5.

Delete arrows *g, h, i,* and *f* emanating from events *D, C* and *F*. This will convert *E* and *G* as initial events. Number them as 6 and 7.

Terminal event *H* is numbered as 8.

This method of numbering is suitable for very small projects, where the network may not undergo any modification later.

But in the case of large networks for big projects, modification may become necessary. Hence, "**skip numbering**" is resorted to by marking events as 10, 20, 30 .... in lieu of 1, 2, 3...

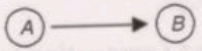
5.04 PROCEDURE TO DRAW A NETWORK

Observing the ground rules stated in para 5.3 (vi), the following procedure is followed to draw a network.

- The project is broken into well defined activities.
- Considering physical, technical and other considerations decide which activities are to be performed in series, and which are to be performed in parallel. Determine their interdependencies.
- Determine time estimates for each activity. In construction projects, for almost all activities single time estimates are feasible from experience, and information relating to quantum of work and productivity of equipment and workmen. Knowing the quantum of work, crew size employed, productivity constants and productivity of construction equipment deployed, it is possible to estimate the time required for each activity. In case of substructure and in the absence of proper soil

investigation report, it may become inevitable to go in for three time estimates for some of the foundation items.

- The network is drawn commencing from the starting event at the extreme left and ending with end event at the extreme right. In between various events linking the first and the last event are shown with their time estimates.
- PERT/CPM technique basically use the finish to-Start (FS) relationship.



Activity *B* starts when *A* is completed (*FS*) Finish to Start

5.05 TIME ESTIMATES

- **Optimistic time (t_o):** It is the time required if no hindrance or complication arises when activities are performed under *ideal* conditions and everything goes exceptionally well. It is the shortest possible time for completion of an activity. There may not be more than one chance in hundred to realise this optimistic time t_o. It is impossible to finish an activity in less than its optimistic time.
- **Most Likely time (t_m):** It is the time in which the activity is most likely to be completed. This estimate takes into account normal circumstances making allowance for some unforeseen delays. It has the highest degree of probability of occurrence among all possible values of the activity duration.
- **Pessimistic time (t_p):** It is the time required under adverse conditions, i.e. if unusual complications and/or unforeseen difficulties arise (except force majeure conditions such as earthquake, fire, etc.). There may not be more than one chance in hundred to realise this time. It is impossible for an activity to take longer than its pessimistic time for completion.
- **Average time (t_e):** It is the time taken most frequently by the activity. It is the weighted arithmetic average time.

$$t_e = \frac{t_0 + 4t_m + t_p}{6}$$

- **Probability distribution:** The probability distribution function of activity time can be approximated by β distribution (Fig. 5.4).

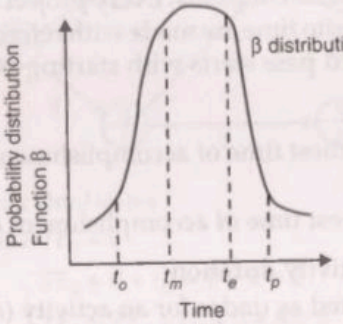


Fig. 5.4: Probability distribution

- **Phases of network:** Network techniques are useful in the basic managerial functions of planning, scheduling and controlling of projects (Fig. 5.5).

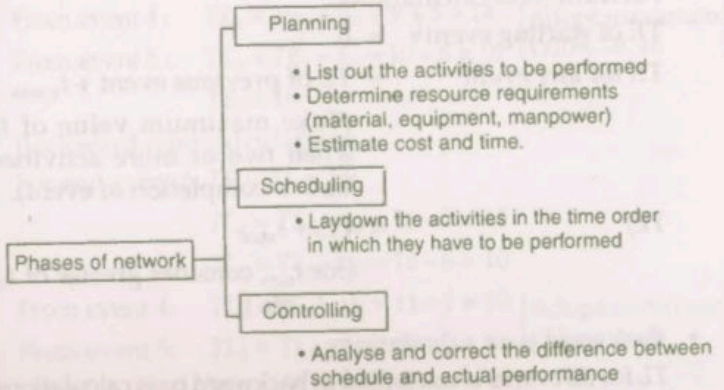


Fig. 5.5: Phases of network

5.06 TIME ANALYSIS OF NETWORKS

When once project network and activity durations are known, time analysis is a relatively easy exercise. Time analysis involves two steps.

- Forward pass calculations
- Backward pass calculations

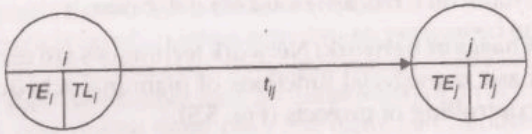
- **Forward pass calculations:** Every project has a zero date. All references to time are made with reference to this zero date. Forward pass starts with starting event marked as zero.

Let $\boxed{TE}$ = Earliest time of accomplishment of an event.

$\boxed{TL}$ = Latest time of accomplishment of an event

t = Activity duration

They are denoted as under for an activity $(i\text{-}j)$



- **Forward pass calculations**

TE of starting event i = 0

TE for any event = TE of previous event + $t_{ij\ max}$

(Take maximum value of t_{ij} when two or more activities lead to completion of event).

TEj = $TE_i + t_{max}$

(for t_{max} consider greater of t_1, t_2, t_3, etc.)

- **Backward pass calculations**

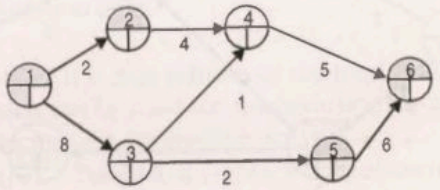
TL for all events is computed in backward pass calculations

For the end event take TL = TE of end event.

TL of any event = TL of previous event - t_{min}

(Take minimum of t when two or more activities are there, i.e. take minimum of t_1, t_2, t_3, etc.)

Example: Compute TE, TL for the network given below:



- **Forward pass calculation**

Starting Event 1: $TE_1 = 0$

$TE_2 = 0 + t_{12} = 0 + 2 = 2$

$TE_3 = TE_1 + t_{13} = 0 + 8 = 8$

From event 2: $TE_4 = TE_2 + t_{24} = 2 + 4 = 6$ {Adopt maximum value, i.e. 9.

From event 3: $TE_4 = TE_3 + t_{34} = 8 + 1 = 9$

$TE_4 = 9$

$TE_5 = TE_3 + t_{35} = 8 + 2 = 10$

From event 4 : $TE_6 = TE_4 + t_{46} = 9 + 5 = 14$ {Adopt maximum value, i.e. 16

From event 5 : $TE_6 = TE_5 + t_{56} = 10 + 6 = 16$

$TE_6 = 16$

- **Backward pass calculations**

For end event 6: $TE = TL = 16$

$TL_4 = TL_6 - t_{46} = 16 - 5 = 11$

$TL_5 = TL_6 - t_{56} = 16 - 6 = 10$

From event 4: $TL_3 = TL_4 - t_{43} = 11 - 1 = 10$ {Adopt minimum value, i.e. 8

From event 5: $TL_3 = TL_5 - t_{35} = 10 - 2 = 8$

Hence $TL_3 = 8$

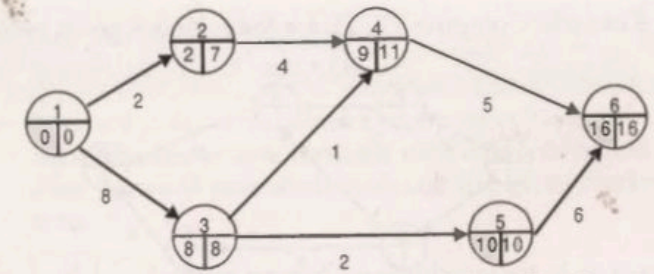
$TL_2 = TL_4 - t_{24} = 11 - 4 = 7$

From event 2: $TL_1 = 7 - 2 = 5$ {Adopt minimum value = 0

From event 3: $TL_1 = TL_3 - t_{31} = 8 - 8 = 0$

$TL_1 = 0$

The above values are shown in the following Fig.



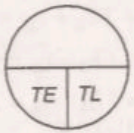
For events 1, 3, 5 and 6: $TE = TL$ and $TE - TL = 0$

Hence, Critical Path (*CP*) is 1-3-5-6.

■ 5.07 EVENT SLACKS AND ACTIVITY FLOATS

Slack for an event and Float for an activity is the **time to spare**. For critical events and activities, slack values and Float values are zero.

For critical events



$TE = TL$ and

Event slack $TL - TE = 0$

or $TL = TE$

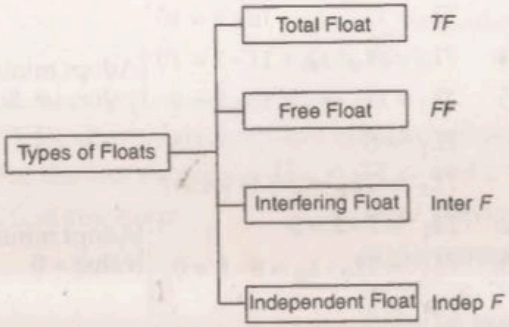


Fig. 20: Types of floats

(a) **Total Float (TF):** It is the time by which an activity can be delayed or allowed to expand without affecting the project completion date.

$$TF = LS - ES = TL_j - t_{ij} - TE_i$$

(b) **Free Float (FF):** It is that portion of the total Float of an activity which can be used for rescheduling the activity without affecting the succeeding activity.

Free Float (*FF*) = Total Float (–) Slack time of succeeding event

$$= TL_j - t_{ij} - TE_i - (TL_j - TE_j)$$
$$= TL_j - t_{ij} - TE_i - TL_j + TE_j$$
$$= TE_j - TE_i - t_{ij}$$

(c) **Interfering Float (Inter F):** This is the difference between Total Float and Free Float. If this interfering float is absorbed, the floats of previous and subsequent activities are affected.

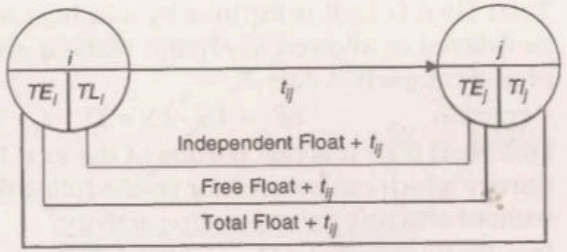
$$\text{Inter } F = TF - FF = TL_j - TE_i - t_{ij} - (TE_j - TE_i - t_{ij})$$
$$= TL_j - TE_i - t_{ij} - TE_j + TE_i + t_{ij}$$
$$= TL_j - TE_j$$
$$= \text{Slack of succeeding event}$$

Total Float = Free Float + Interfering Float

(d) **Independent Float (Indep F):** It is the time by which an activity can expand without affecting any other activity either previous or subsequent.

$$\text{Indep } F = \text{Free Float - Slack of preceeding event}$$
$$= TE_j - TE_i - t_{ij} - (TLi - TE_i)$$
$$= TE_j - TE_i - t_{ij} - TL_i + TE_i$$
$$= TE_j - TL_i - t_{ij}$$

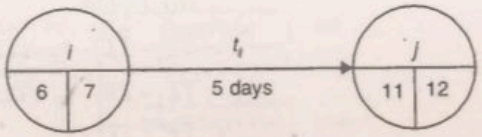
It represents float under most adverse conditions. It can be negative. When an activity has positive independent float, it has a cushion equal to independent float irrespective of what happens elsewhere.



Total Float	$= LS - ES$	Free Float	$= TE_j - TE_i - t_{ij}$
Inter Float	$= TL_j - TE_j$	Indep Float	$= TE_j - TL_i - t_{ij}$
Total Float	$= FF + \text{Inter } F$		

- **Conclusions drawn from Total Float Values**
  - Total Float is negative
    - Resources are not adequate
    - Activity may not finish in time
    - Induct extra resources
  - Total Float is zero
    - Resources are just sufficient to complete the activity. Activity cannot be delayed. It is a critical activity.
  - Total Float is positive
    - Resources are extra
    - One has the freedom to reallocate resources
    - Activity can be delayed by so much period.

Example: Compute all floats for an activity (i -j) with TE and TL values as given below.



$$ES = TE_i = 6$$
$$EF = ES + t_{ij} = 6 + 5 = 11$$
$$LF = TL_j = 12$$
$$LS = LF - t_{ij} = 12 - 5 = 7$$

(a) Total Float $= LS - ES = 7 - 6 = 1$
$= TLj - tij - TEi = 12 - 5 - 6 = 1$

(b) Free Float $= TEj - TEi - tij = 11 - 6 - 5 = 0$
$=$ Total Float (-) Slack of succeeding event
$= 1 - (12\text{-}11) = 1 - 1 = 0$

(c) Interfering Float $= TL_j - TE_j =$ Slack of succeeding event
$= 12 - 11 = 1$

(d) Independent Float $= TE_j - TL_i - t_{ij}$
$= 11 - 7 - 5 = -1$
$=$ Free Float – Slack of preceeding event
$= 0 - (7 - 6) = 0 - 1 = -1$

Check: Total Float = Free Float + Interfering Float
$1 = 0 + 1 = 1$

5.08 CRITICAL PATH

- It is the longest path in a project network,
- It determines project completion time,
- There will be one set of events from start event to end event for which slack values are zero. Critical path passes through these events and these event are called critical events,
- The activities on this path are called critical activities. The total and free floats for the critical activities will have zero value. The sequence of critical activities in a network is called critical path,
- It is also the shortest possible time to complete the project,
- There may be more than one critical path in a project network,
- Critical path may change its path when network is reviewed later during execution of project works if there is variation in actual and estimated activity durations,

- If any of the critical activity is delayed, it will affect the project completion time. Hence, project manager should focus his attention on completion of critical activities,
- If project completion time obtained from network analysis is not acceptable to project authorities, the critical activities will have to be crashed involving additional direct costs,
- Resources are diverted from non critical activities to critical activities lagging behind to avoid delay in project completion,
- In time scale network critical path is drawn on a horizontal line to a time scale and non critical activities are plotted to time scale above/below horizontal critical path line.

Standard deviation (σ) and variance (υ)

Standard deviation for an activity (σ) $= \frac{t_p - t_o}{6}$

variance for an activity $= \sigma^2 =$ (standard deviation)$^2 = \left(\frac{t_p - t_o}{6}\right)^2$

σ network $= \sqrt{\sum \upsilon}$ along critical path $= \sqrt{\sum \sigma_{ij}^2}$

variance is measure of uncertainty. Greater the value of variance, greater will be the uncertainty.

Example: Three time estimates are given for critical activities. Starting event number is 1 and end event number is 8. Calculate standard deviation for the critical path 1-2-3-4-6-7-8.

Critical activity	Time estimates		
	t_o	t_m	t_p
1-2	2	5	8
2-3	8	11	20
3-4	0	0	0
4-6	7	10	13
6-7	2	3	10
7-8	2	4	6

Standard Deviation Chart

Critical activity	t_p	t_o	$\frac{t_p - t_o}{6}\ \sigma = \left(\frac{t_p - t_o}{6}\right)^2$	= variable (v)
1-2	8	2	$\frac{8-2}{6} = 1$	$1^2 = 1$
2-3	20	8	$\frac{20-8}{6} = 2$	$2^2 = 4$
3-4	0	0	0	0
4-6	13	7	$\frac{13-7}{6} = 1$	$1^2 = 1$
6-7	10	2	$\frac{10-2}{6} = \frac{4}{3}$	$\frac{16}{9} = 1.78$
7-8	6	2	$\frac{6-2}{6} = \frac{2}{3}$	$\frac{4}{9} = 0.44$

$\sigma cp = \sqrt{\sum v} = \sqrt{1+4+0+1+1.78+0.44} = \sqrt{8.22}$

= standard deviation for critical path (SCP) $= \sqrt{8.22} = 2.87$

5.09 CRASHING PROJECT COMPLETION TIME

Normal time for each activity refers to time taken for its completion when resources are deployed at normal level. The project network is analysed by adopting normal activity durations for all activities and project completion time is computed. Due to some constraints, it may be necessary to compress the project completion time. This is done by deploying additional resources at extra cost to crash the activity durations. Thus, for each activity, it is possible to arrive at:

Normal time	*NT*,	Crash time	*CT*
Normal direct cost	*NC*,	Crash direct cost	*CC*
Project total cost	(*TC*)	= Sum of direct costs and indirect costs of all activities.	

In reality indirect costs will not vary in the same pattern as that of direct costs as shown in the Fig. 5.7.

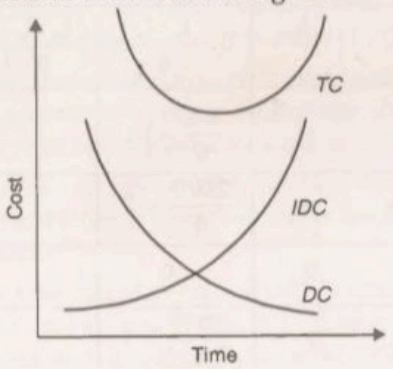


Fig. 5.7

Guidelines for compressing project completion time:

(1) Draw the network diagram with normal activity durations. Indicate on the network the following: (a) Duration of each activity, (b) earliest and latest times of each event, (c) free float for each activity, (d) critical path or paths, (e) project completion time.

(2) Calculate cost slope

$$\frac{\Delta C}{\Delta T} = \frac{CC - NC}{NT - CT} \text{ for each activity}$$

Compute total direct costs of all activities corresponding to normal activity durations.

(a) If there is only one critical path in the network, crash that critical activity which has the least cost slope. Crashing should be done within crashable limit of that critical activity and within free float limit of the project,

(b) If there is more than one critical path, crash one critical activity on each critical path which has least cost slope within the crashable limit of the critical activity and within the free float limit,

(c) If there is one critical activity common to two or more critical paths, crash that common critical activity within its crashable limit and within the free float limit,

When a critical activity or activities is/are crashed as above, adopt corresponding crash time(s) for the crashed activity or activities and normal times for all other activities. Analyse the network, mark critical path (there may be shift in critical path in some cases) and compute project completion time. Compute extra direct cost incurred and indirect cost corresponding to compressed project completion time.

(3) Repeat this process until there is at least one critical path on which none of the activities can be crashed, i.e. the critical activities have reached their respective crashable limits. Then stop further crashing.

(4) Total Project Cost = Sum of normal direct costs of all activities corresponding to normal activity durations + Extra direct cost due to crashing + Indirect cost corresponding to compressed project completion time.

(5) As the project completion time is crashed, there will be increase in direct costs and decrease in indirect costs. Sum of these representing total cost will be minimum for a particular project completion time. There are C_{min} and T_{min} (optimum project cost and project completion time).

(6) A graph shown in Fig. 5.8 is reproduced, below showing the variation of: (a) Direct Costs DC, (b) Indirect Costs (IDC), and (c) Total Cost (TC) with respect to Time.

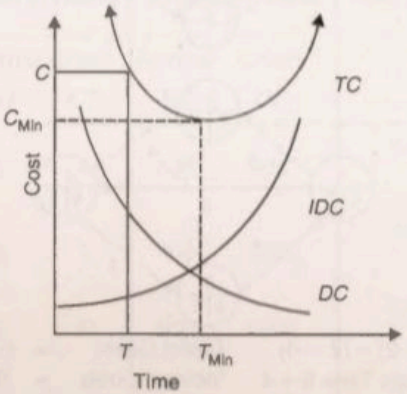


Fig. 5.8: Variation of cost *vs.* time

Due to some constraints, if any other project completion Time (T) is desired, the corresponding project completion Cost (C) may be obtained from the graph.

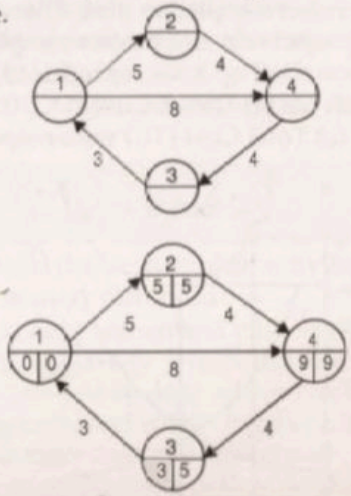
Example: A project consists of 5 activities as detailed below: Determine optimum project completion time assuming indirect costs @ Rs. 450/- per week.

Step 1: Network is drawn adopting normal activity durations as given above.

Activity	Time in Weeks		Direct Cost in Rs.	
	Normal *NT*	Crash *CT*	Normal *NC*	Crash *CC*
(1 – 2)	5	4	600	800
(1 – 3)	3	1	400	600
(1 – 4)	8	5	900	1200
(2 – 4)	4	2	600	1200
(3 – 4)	4	3	500	700

Total Direct Cost = 3000

Compute *TE* and *TL*, mark critical path and compute project completion time.



Critical path (1—2) – (2 —4)
Project completion Time 5 + 4
= 9 weeks = TE4

Direct Costs = Rs. 3000
Indirect Costs = 9 x 450
= Rs.4050
Total Costs = 7050/9 weeks
= Rs. 7050 / 9 weeks

Event No.	1	2	3	4
TL	0	5	5	9
TE	0	5	3	9
Slack	0	0	2	0

Total Float = *LS – ES*
Free Float = Total Float (–) Slack of succeeding event

Activity	*ES = TE$_i$*	*EF = ES+t$_{ij}$*	*LF = TL$_j$*	*LS=LF-t$_{ij}$*	Floats	
					TF	*FF*
(1 - 2)	0	5	5	0	0	0
(2 - 4)	5	9	9	5	0	0
(1 - 4)	0	8	9	1	1	1
(1 - 3)	0	3	5	2	2	0
(3 - 4)	3	7	9	5	2	2

Step 2: Calculate cost slope for each activity and compute sum of normal direct cost of all activities.

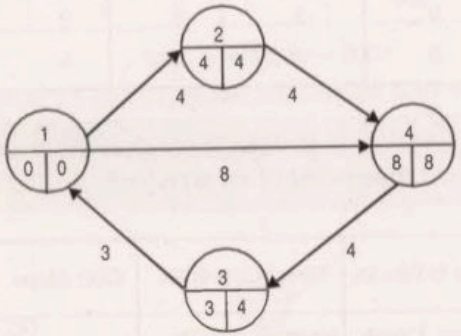
Activity	Time in Weeks		Direct Cost in Rs.		Cost Slope $\frac{\Delta T}{\Delta C}$ Rs./week
	Normal *NT*	Crash *CT*	Normal *NC*	Crash *CC*	$= \frac{CC - NC}{NT - CT}$
(1 - 2)	5	4	600	800	$\frac{800-600}{5-4} = 200$
(1 - 3)	3	1	400	600	$\frac{600-400}{3-1} = 100$
(1 - 4)	8	5	900	1200	$\frac{1200-900}{8-5} = 100$
(2 - 4)	4	2	600	1200	$\frac{1200-600}{4-2} = 300$
(3 - 4)	4	3	500	700	$\frac{700-500}{4-3} = 200$
		Total	3000		

Step 3: There is only one critical path (1-2), (2-4).

The cost slopes are Rs. 200/week for activity (1-2) and Rs. 300/week for activity (2-4).

The least cost slope is for critical activity (1-2) @ Rs. 200/ week crash critical activity (1-2) by one week, i.e. from 5 weeks to 4 weeks. By this activity (1-2) has reached its crashable limit.

Analyse the network by adopting crash time for critical activity (1-2) and normal times for other activities as given below:



Extra cost of crashing critical activity (1 - 2)	=	Rs. 200
Sum of direct costs of all activities with normal duration	=	Rs. 3000
Sum of direct costs	=	Rs. 3200
For 8 weeks indirect costs = 8 × 450	=	Rs. 3600
Total cost	=	Rs. 6800 / 8 weeks

There are two critical paths after crashing activity (1 - 2).

(1) Critical path (1 - 2) - (2 - 4)
(2) Critical path (1 - 4)

Crash one critical activity on each path.

In CP_1, activity (1-2) has reached its crashable limit

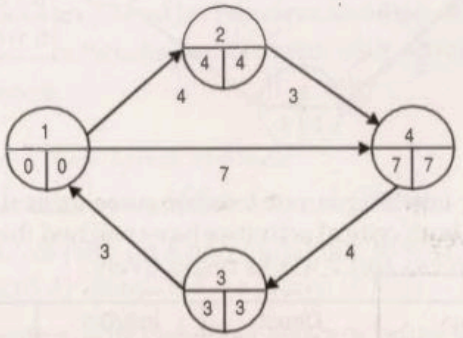
Cost slope for activity (2-4) = Rs. 300.

In CP_2, cost slope for critical activity (1 - 4) = Rs. 100

Crash (2-4) and (1-4) by one week

Extra direct cost = Rs. 300 + Rs.100	=	Rs. 400
Total direct cost = Rs. 3200 + 300 + 100	=	Rs. 3600*
Indirect cost = 7 × 450	=	Rs. 3150
Total cost	=	Rs. 6750 / 7 weeks

Network is shown below:



There are three critical paths after crashing (1 - 4) and (2 - 4)

CP1 = (1 - 2) - (2 - 4)

CP2 = (1 - 4)

CP3 = (1 - 3) (3 - 4)

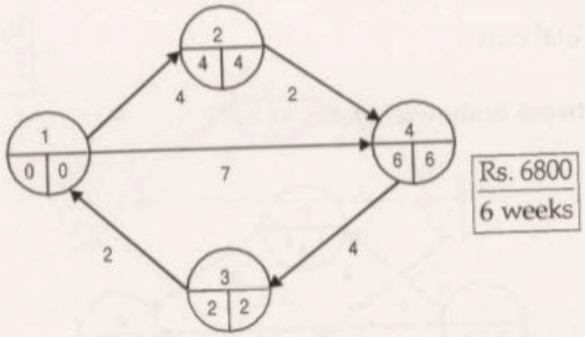
Crash (2 - 4), (1 - 4) and (1 - 3) by one week.

Project completion time = 6 week

Indirect cost = 6 × 450 = Rs. 2700

Direct costs

Extra cost due to crashing by one week (2 - 4)		300
(1 - 4)		100
(1 - 3)		100
Add as above		3600
Total direct cost	=	4100
Total cost = 4100 + 2700	=	6800



Further, crashing is not feasible since critical path (1–2), (2–4), (2–4) both critical activities have reached their crashable limits of 4 weeks and 2 weeks respectively.

Project Completion Time	Direct Costs Rs.	Indirect Costs Rs.	Total Costs Rs.
9 Weeks	3000	4050	7050
8 Weeks	3200	3600	6800
7 Weeks	3600	3150	6750
6 Weeks	4100	2700	6800

Hence, optimum time and cost are 7 weeks and Rs. 6750/- respectively.

5.10 TIME SCALE NETWORKS

These are also called squared networks. These networks combine the advantage of both bar charts and network charts. In these networks, activity duration is drawn to time scale. All the inter-dependencies are denoted by dropping dummy activities vertically from one event to another. Critical path will be a continuous path from start to finish without any floats. The concept of control has been revolutionised by these networks because it is now possible to use progressing and measurements techniques of the bar charts.

Inter-dependencies can be taken for tracking back the project to schedule by modifying planning, scheduling and control procedures and updating activities as appropriate. Squared networks are useful for resource levelling or resource allocation. These networks can be used with advantage for very small projects.

Procedure to draw time scaled networks

(1) Draw conventional network and mark critical path,

(2) Draw critical path on a horizontal line to time scale, i.e. critical activity durations are drawn to time scale,

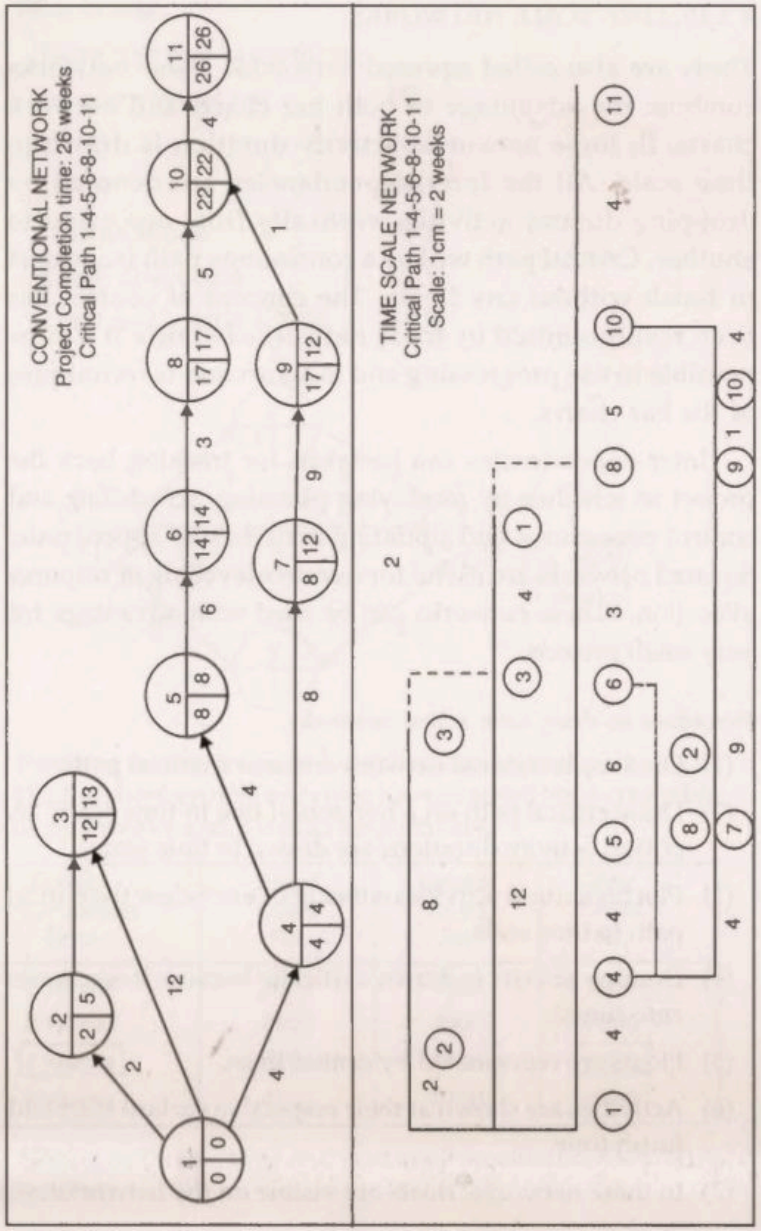
(3) Plot noncritical activities either above or below the critical path to time scale,

(4) Dummy activity is drawn vertically because it consumes zero time,

(5) Floats are represented by dotted lines,

(6) Activities are shown at their respective earliest start and finish time,

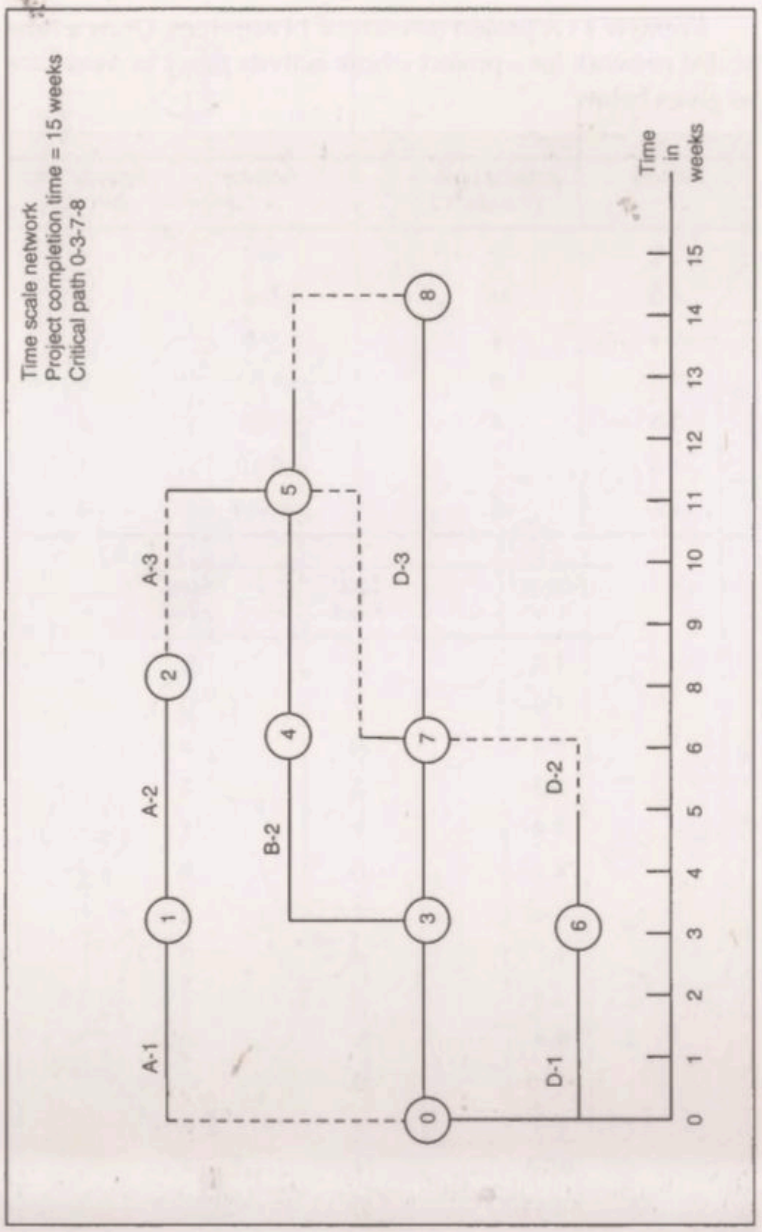
(7) In these networks, floats are visible on the networks.



Example 1 : A project consists of 14 activities. Draw a time scaled network for a project whose activity times in weeks are as given below:

Activity	Activity time (Weeks)	Activity	Activity time (Weeks)
1-2	2	4-7	4
1-3	12	5-6	6
1-4	4	6-8	3
2-3	8	8-10	5
3-8	4	7-9	9
4-5	4	9-10	1
4-6	8	10-11	4

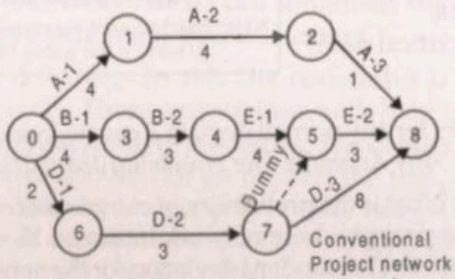
Activity	Total Float	Free Float
1-2	3	0
1-3	1	0
1-4	0	0
2-3	3	2
3-8	1	1
4-5	0	0
4-6	2	2
4-7	4	0
5-6	0	0
6-8	0	0
8-10	0	0
7-9	4	0
9-10	4	4
10-11	0	0



Example 2: A project consists of 12 activities. Their time estimates are as given below. Draw time scale network.

Adopting the procedure explained in para 5.10 the conventional network is drawn and thereafter time scale network is drawn as follow:

Activity	Description	Time (weeks)
0-1	A-1	4
0-3	B-1	4
0-6	D-1	2
1-2	A-2	4
3-4	B-2	3
6-7	D-2	3
3-7	C	3
7-5	Dummy	0
2-5	A-3	1
4-5	E-1	4
5-8	E-2	3
7-8	D-3	8



Conventional Project network

5.11 PROBABILITY OF COMPLETION OF A PROJECT

The probability of completion of a project within a certain time duration can be computed with the help of three time estimates to, tm and tp of individual activities. Generally the probability of completion of the critical path is taken as the probability of completion of the project within a given time. If the number of activities on critical path is large, one can assume normal distribution for the path with

TE = expected time for the path

= sum of expected times of all activities on the path variance σ^2 for the path = sum of activity variance for all the activities on the path standard deviation

= σ path = $\sqrt{\sigma^2 \text{ for the path}}$

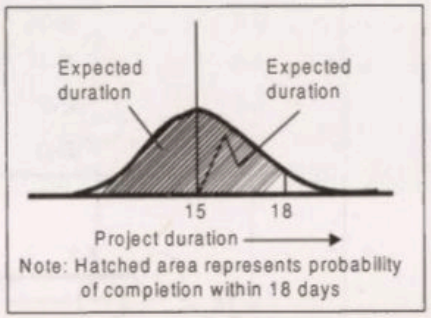
compute value of Z (Normal deviate)

$$= \frac{TS - TE}{\sigma}$$

where,

TS = Time of completion for which probability is to be found,

TE = Time of completion obtained from the network (= length of critical path)



Note: Hatched area represents probability of completion within 18 days

Probability for any normal deviate **Z** can be found from probability tables. *(refer Appendix 4 for probability distribution functions).*

Example: What is the probability of completion of a project in 18 weeks for a project whose network indicates 15 weeks as the completion period. The standard deviation for the network is 2.235.

$$\text{Compute } Z \text{ (normal deviate)} = \frac{18-15}{2.235} = 1 + 1.34$$

From probability tables probability = .91 say 91%.

- Inference drawn from probability values.

Probability	Inference
0.3	Replacing the project is necessary
0.3 to 0.4	Close scrutiny and monitoring is required
0.4 to 0.65	Satisfactory
>0.65	Excess resources. Replan them

5.12 RESOURCE ALLOCATION

In most of the analysis of networks, it is assumed that required resources can be made available as and when they are required. On this basis project completion time is computed. However, in practice, there may be constraints on availability of resources. There are two types of resource allocation problems.

(1) Resource smoothing,
(2) Resource levelling.

Resource smoothing: In this, project completion time is the constraint. The resource allocation only smoothens the demand on resources in order that the demand of any resource is as uniform as possible. Large fluctuation from very high level to very low level in consecutive weeks or days is smoothened. **Intelligent utlisation of floats can smoothen the demand of resources to the maximum possible extent.**

Resource levelling: In this the constraint is maximum resource demand. These are various activities in a project demanding varying levels of resources. The demand on certain types of resource should not go beyond the prescribed level. For example, demand on manpower shall not exceed 5 men. Monthly works expenditure shall not exceed Rs. 10 lakhs. Demand on number of masons shall not exceed 3. This method of resource allocation is called resource levelling or load levelling. In some cases project completion time may be increased.

Any project consists of several activities consuming resources such as materials, manpower, equipment, money,

Chapter 7

TENDERS AND CONDITIONS OF CONTRACT

7.01 DEFINITION

Tender is defined as an offer. In construction industry, tender means an offer made by a contractor to the owner with a view to obtain his acceptance for construction of a facility. Through tendering the owner is able to get competitive rates which may not be possible if other methods are adopted.

7.02 CHARACTERISTICS OF A TENDER NOTICE

Notice Inviting Tenders (NIT) should be clear, brief and should contain the following particulars.

(i) Brief description of the work.
(ii) Estimated cost put to tender.
(iii) Period of completion of work.
(iv) Earnest money deposit.
(v) Cost of tender documents.
(vi) Eligibility criteria for tendering.
(vii) Production of documents for obtaining blank tender documents.
(viii) Last date for receipt of applications for issue of blank tender forms.
(ix) Place and period of issue of tender documents.
(x) Last date for receipt of tenders and place of submission.
(xi) Date, time and place of opening of tenders.

Additional stipulations made in some tender notices issued by various organisations are as under.

(i) Tenders should be in duplicate.

(ii) Tenders are received at two places.
(iii) Owner will not issue any material for the work.
(iv) Programme for execution of work shall be enclosed with the tender failing which tenders will be rejected.
(v) Evidence of ownership of machinery, shall be furnished.
(vi) All the documents enclosed should be attested.
(vii) Safety measures adopted, equipment to be deployed can be had from the owner.
(viii) If the amount quoted by the tenderer is less than that of the estimated amount, he should deposit the difference of amount between the amount put to tender and the tendered amount in addition to EMD. by way of demand draft or pay order at the time of submitting the tender. The amount so deposited will be returned only after completion of the work satisfactorily (to the successful tenderer).
(ix) The work should be commenced with all earnestness within seven days from the date of work order, failing which it would be presumed that he is not interested in the work and action will be taken to get the work executed through an alternative agency at the risk and cost of former tenderer.
(x) Bids from joint ventures are not acceptable.
(xi) Minimum turnover of value equal to 1.5 times the estimated cost.
(xii) Work experience: Two works each costing more than 75% of estimated cost.
(xiii) Tender will not be sent or received by post/courier.
(xiv) Detailed bid notice can be seen in clients office or on their website.
(xv) Certificate of familiarisation should be furnished by the Contractor (*Refer Appendix 6*).

7.03 PRE-REQUISITES FOR TENDERING

(i) Availability of clear site free from legal or physical obstacles.

(ii) Adequate funds to make payment in time.
(iii) Procurement of materials stipulated for issue to the contractor.
(iv) Finalization of designs and working drawings.
(v) List of pre-qualified contractors if pre-qualification procedure is adopted.
(vi) Statutory clearances to commence the work.
(vii) Essential infrastructure at the site.
(viii) Completion of any other pre contract activity specific to the work/site.
(ix) Free accessibility to site for inspection and later if the work is awarded.
(x) Any particular problem or guideline applicable to the site /zone/area under statutory rules to be clearly mentioned as part of tender document.

7.04 TENDER DOCUMENT

Tender document consists of:

(i) **Notice inviting tenders:** This will be in an elaborate form, whereas the press notice will be in an abridged form. Additional information is incorporated as detailed below:
- Availability of site in full/parts,
- Mode of deposit of earnest money,
- Copies of drawings and documents will be open for inspection to the tenderer at the office of... architects/ consultants/owners,
- Advice to tenderers to inspect the site,
- Price preference to central/state govt./public sector enterprises, etc.,
- Validity of tenders,
- Association of agencies in respect of composite tenders,
- Eligibility or ineligibility clauses to specify as to who can apply,

- Reservation of right to reject or accept tender without assigning any reason,
- Place, mode, price, and time prescribed for purchase and submission of tender documents,
- Opening of tenders —place and time apart from who can be present at the time of opening,
- Press notice inviting tenders is given in *Appendix 7.*

(ii) **General conditions of contract:** There is no uniformity in general conditions of contract adopted by various central and state government departments. The practice adopted by central/state/public sector undertaking and consultants in private sector is also at variance.

Each construction organisation adopts a standard printed contract form containing general conditions of contract. Standard critical clauses are:

(a) Security deposit or performance bond,
(b) Compensation for delay/bonus for early completion,
(c) Intermediate payments,
(d) Completion certificate,
(e) Payment of final bill,
(f) Materials supplied by owner/government,
(g) Payment of advances,
(h) Escalation,
(i) Pricing of variations,
(j) Defective work,
(k) Defect liability period,
(l) Arbitration,
(m) Refund of security deposit,
(n) Labour clearance certificate.

Besides, particular conditions of contract specific to each work should be appended to tender document.

(iii) **Special conditions of contract:** In some contracts one or more of the following conditions are included in the light of site conditions:

- No extra payment for jungle clearance,
- Wooden shuttering is not allowed,
- Field laboratory is to be setup by the contractor,
- Cost of diversion of services to be indicated separately,
- Rates are inclusive of all taxes,
- Settlement of disputes is limited only to the value less than ..... % of the contract value,
- Contractors to make their own arrangements for water and electricity.

(iv) **Bill of quantities:** It is a normal practice to adopt bill of quantities from a detailed estimate by deleting some items which are not to be tendered. Lumpsum provisions and certain services provided in the estimate are also deleted. In item rate contracts estimated rates are deleted and the tenderer quotes his bid rates. Proforma for Bill of Quantities is given in *Appendix 8*.

(v) **Tender drawings:** These are meant to indicate the scope of work to enable tenderers to project realistic bid rates. If there is special type of foundation, structural tender drawing should also be enclosed.

(vi) **Specifications:** The specifications of a construction contract state its specific requirements for the quality of work. Contract drawings should be limited to show only the kinds of materials and work and their scope and extent. Specifications alone should indicate quality of work, contract sum and contract time depend on the quality of work. It should be well written and properly understood. In interpretation of contracts written words are given precedence over drawings. It should be free of ambiguity.

Quality of work can only be defined in words and training in writing and understanding specifications is one of the best ways to learn the details of construction materials. Construction specification has been neglected for too long. The published standard specifications are to be modified to suit a particular project and its location. The precedence to be followed when there are conflicting provisions is as under.

- Description of the item,
- Particular specification,
- Working drawing,
- General specification,
- Manufacturer's specification if any,
- Bureau of Indian standard specifications,
- Directions of architect/engineer-in-charge.

They shall prevail in the same order of precedence given above. Particular stipulation should be made if the use of any local material is not permitted owing to noncompliance to set specification.

Since, the work has got to be done conforming to stipulated specifications, it is considered as the most important of all the contract documents. It deals with technical matters, viz., details of construction, special features of design, the kind and quality of materials. Modern buildings are provided with superior quality products like, hardware, bath room fittings, partitions, flooring tiles, fascia tiles, cellars, architectural features, both inside and outside the building. Greater importance is given to good finishes, aesthetic values, economy in building design to improve the image and face value of the building. Printed specifications of an organisation may not be comprehensive to include above items of work. Before finalising tender document, specifications for such items should be drafted carefully. Manufacturer's specification should also be considered in such cases. Since the work has got to be done conforming to stipulated specifications, it is considered as the most important of all the contract documents.

(vii) **Form of agreement:** This is to be signed by both the parties. Proforma is given in *Appendix 10*.

(viii) **Formats and statements:** Various formats and statements required for the contract are also to be appended. Some of them are:

- Safety code,
- Model rules for the protection of health and sanitary arrangements,
- Contractor's labour regulations,

- Proforma of registers,
- Sketch of cement godown,
- Format for bank guarantee form and performance bond.

An attempt has been made to give a brief summary of critical clauses formulated by Indian Institute of Architects and adopted by many consultants and central PWD with minor modifications adopted by public sector undertakings and some State Governments. For an updated and comprehensive coverage reference may be made to (i) General conditions of contract adopted by Indian Institute of Architects, and (ii) General conditions of contract for central PWD works 2005.

(ix) **Contract data:** Summary of salient conditions of contract is given in contract data vide *Appendix 11*.

(A) General Conditions of Contract —Summary of some Critical Clauses Adopted by IIA:

The contracting system in private sector is not yet fully organised. The practice of requisitioning the services of an architect for the management of engineering contracts has recently gained its foot hold and is yet to receive wide acceptance. In this background the salient features of conditions of Contract adopted by Indian Institute of architects are discussed below. (Clause numbers are given in brackets).

- **Performance bond (security deposit):** Sum to be deposited as security is mentioned in the appendix to each contract. This deposit is to be made with architect within 10 days of signing the contract in the form approved by the architect and it shall remain till the defect liability period expires. Earnest money will become a part of security deposit (Clause 17). Owner may retain from interim payments some percentage as retention percentage till full deposit is recovered (Clause 31(3)).
- **Damages for non-completion:** Liquidated damages as mentioned in the appendix to the contract shall be recovered (Clause 41), .
- **Determination of contract:** Owner can determine the contract if contractor (i) Suspends the work, (ii) Fails to give regular progress, (iii) Fails to remove or rectify defective work or materials, (iv) Sublets the work without written permission, (v) Bankruptcy. Notice period is 14 days (Clause 48) for determination of contract.

Contractor can determine the contract if the owner (i) Fails to make payment within specified period, (ii) Interferes or obstructs issue of certificate for payment, (iii) Suspends work for a continuous period, (iv) Force majeure, (iv) Fails to issue necessary instructions and drawings, (v) Fails to decide extension of time, etc. (Clause 49).

- **Interim payment:** To be issued by the architect within the period and payment to be made by the owner as mentioned in the appendix to the contract [Clause 31(1)].
- **Completion certificate:** The architect is required to give several certificates during the execution of work. These certificates mentioned below are of special significance.
- **Virtual completion certificate:** (Building is fit for occupation though some minor works are yet to be completed) (Clause 42(1)).
- **Penultimate certificate:** This certificate is issued to enable collection of fee by a consultant from the contractor as prescribed in the agreement.
- **Interim and final certificates:** Interim certificate provides for interim payment to the contractors. It is to be honoured within specified period [Refer Appendices [Clause 31(1)]. *Retention money* is recovered from interim payments vide Clause 31(3) Ref: Appendix. Final certificate is issued to the contractor after expiry of defect liability period reckoned from date of virtual completion of work. On expiry of defects liability period plus one month for notice and rectification of defects, contract can be rescinded.

Submission of all documents containing measurements and valuation within a reasonable time from the date of virtual completion of work which ever is later. The final certificate may also authorise release of balance retention money (Clause 32).

- **Materials:** Within 30 days of signing of agreement contractor shall submit for approval of the architect a complete list of all materials he and his sub-contractors propose to use in the work of definite brand or make which differ in any respect from those specified.
- **Fluctuations:** The contractor shall not claim any extras for fluctuation of price and the contract price shall not be subject to any rise or fall of prices (Clause 34).
- **Variations:** The architect may issue instructions requiring a variation. Rates applicable are, quoted rates of similar items, based on fair valuation, day work rates or market rates (Clause 30).
- **Defective work:** All materials and workmanship shall be subject to inspection, examination and test by the Architect at any or all times during manufacture and/or construction. The architect shall have the right to reject either defective materials and workmanship or work which requires any correction [Clause 36(7)].
- **Defect liability period:** The contractor shall make good at his own cost and to the satisfaction of the architect; all defects, shrinkages or small faults, arising in the opinion of Architect from work or materials not being in accordance with drawings or specifications or schedule of quantities or the instructions of the architect, which may appear within. Defects liability period (12 months) referred to in the *Appendix* [Clause 37(1)].
- **Arbitration:** All disputes shall be referred to and settled by the architect who then states his decision in writing. Such decision may be in the form of a final certificate or otherwise. The decision of the architect with respect to any of the excepted matters shall be final and without appeal. If the decision of the architect is not acceptable to either party, a notice shall be given within 28 days after receiving the notice of the decision. The disputes or differences shall be referred to **sole arbitration of a Fellow of Indian Institute of Architect mutually agreed by the parties.** In case of disagreement, each party shall appoint one architect (Fellow of IIA) and both the

arbitrators select an umpire. They shall have the power to open up, review, and revise any certificate, opinion, decision requisition or notice except excepted matters. The arbitration shall be conducted as per the act in force (The Arbitration and Conciliation Act, 1996).

- **Excepted matters:** The decision, opinion, certification (except for payment) with respect to all or any of the matters mentioned below are final and without appeal. These are termed as ***excepted matters.***

Interpretation of drawings, specifications and bills of quantities

Architect's instructions in writing

Contractor's field organisation and equipment

Assignment or subletting

Approval of sub contractors

Approval of materials and workmanship

Extension of time due to force majeure, inclement weather strike or lockout; an act of God.

Delay caused by nominated sub-contractors or nominated suppliers.

Delay by persons engaged by the owner in executing the work not forming part of contract.

- Appedix referred to in general conditions of contract adopted by IIA: The architect is required to fill in particular stipulation in the following clauses as applicable to each tendered work. (The latest amendments if any to IIA. contract form is to be referred.)

37	(1)	Defects liability period: 12 months
31	(5)	Period of final measurement and valuation: 3 months
38	(1)	Date of commencement -----
		Date of completion ----
41		Agreed liquidated damages -----

- **Extra items:** Paid on the basis of **market rates** as determined by engineer-in-charge.
- **Substituted items:** Market rates of agreement item to be substituted shall be determined. Payment is made for the substituted items at the agreement rate ± difference between market rates of substitute Items and agreement item.
- **Deviations:** Rates determined by engineer-in-charge on the basis of market rates for the quantity in excess of deviation limit specified in the contract.
- **Action in case work not done as per specifications:** All works in course of execution or executed shall be open and accessible to inspection and supervision of engineer-in-charge, his superiors and subordinates of quality control organisation and chief technical examiner's office. If any work has been executed with unsound, imperfect or unskillful workmanship, or with materials or articles not in accordance with the contract, such work shall be rectified, removed and reconstructed in whole or part at contractor's expense. The engineer-in-charge may point out substandard quality within six months from the date of completion of work. Otherwise action to levy compensation for non-completion of work in time shall be taken. Such work may also be accepted with reduced rate where necessary.
- **Contractor liable for damages, defects during maintenance period:** The defect liability period shall be 6 months for works costing Rs. 10 lakhs and below. It shall be 12 months from the date of final completion certificate for all other works costing above Rs. 10 lakhs. Any defect, damages to the building, shrinkage or other faults appear within this period, the contractor shall make good the same at his expense.
- **Settlement of disputes and arbitration:** Except where otherwise provided in the contract, all disputes and issues shall be referred to superintending engineer in the first instance. If decision is not given or not acceptable, the contractor may appeal to chief engineer

within time limits specified. If decision is not given or decision is not acceptable, within 30 days contractor may give notice to chief engineer for appointment of arbitrator along with list of disputes and amounts claimed. Except where the decisions are final and binding as per the contract, all other disputes shall be referred to sole arbitration of a person appointed by chief engineer/ administrative head of CPWD. No other person shall act as an arbitrator. **Time limit for seeking arbitration is 120 days from the date of receipt of intimation that the final bill is ready for payment.** The arbitration shall be conducted according to provisions of the "Arbitration and Conciliation Act, 1996".

The arbitrator shall adjudicate only such disputes referred to by the appointing authority. Fees payable if any to arbitrator shall be paid equally by both the parties. Separate award for each claim and reasoned award if total claims is more than rupees one lakh shall be given by the arbitrator.

For provisions of arbitration clause adopted in some of the private sector organisations is given in *Appendix 14*.

- **Refund of security deposit:** The security deposit of the contractor will be refunded as per the provisions of the agreement, viz.,
  (1) Issue of labour clearance certificate,
  (2) After expiry of defect liability period (all defects rectified),
  (3) Finalisation of works accounts (final bill passed and paid).

7.05 EARNEST MONEY DEPOSIT (EMD)

(i) **Objective of insisting on EMD:** Earnest money is deposited by each tenderer to enable the owner to ensure that a tenderer does not refuse to execute the work if it is awarded him. It is a guarantee for due performance of the contract.

(ii) **Rates of earnest money deposit:** It varies from one or-

ganisation to another. It also varies with value of work. Normally EMD is 2% or 2½% of estimated cost put to tender. For minor works costing Rs. 1 lakhs or less EMD may not be insisted by the owner. For large project works, EMD may be limited to 1% of estimated cost put to tender.

(iii) **Mode of depositing earnest money:** EMD is given in cash, or deposit at call receipt of a scheduled bank or by bank guarantee.

(iv) **Forfeiture of EMD:** In cases where a tenderer fails to commence the work awarded to him, the earnest money along with performance guarantee is absolutely forfeited to the owner. It is also forfeited if the tenderer withdraws his tender before the expiry of validity period or makes any modification in the terms and conditions of the tender which are not acceptable to the owner. Then the owner without prejudice to any other right or remedy be at liberty to forfeit 50% of earnest money deposit. If the successful tenderer fails to furnish the security deposit then the earnest money shall be liable to be forfeited.

(v) **Refund of earnest money:** The earnest money of successful tenderer can be adjusted against the security deposit required to be furnished by him. The earnest money of all the unsuccessful tenderers should be returned as early as possible after the expiry of validity period or after award of contract whichever is earlier. Some owners refund earnest money of all tenderers except the first, second and third lowest tenderers even before a decision on tenders is taken.

7.06 SECURITY DEPOSIT

(i) **Objective of collecting security deposit:** It is a check or safeguard for the owner to ensure that contractor fulfills all terms and conditions of the contract, carries out the work to his satisfaction, maintains desired progress and completes the work as envisaged in the contract agreement.

(ii) **Rate of security deposit:** There is no uniform practice even in government departments and in private sector. Some of the stipulations are detailed below:

- Maximum security deposit is Rs. 5 lakhs. Recovery is made @ 10% of gross value from all running bills till 10% of estimated cost put to tender, or in some cases 10% of tendered value is recovered. Earnest money of the successful tenderer becomes a part of security deposit on acceptance of the tender.
- On acceptance of tender, contractor is required to deposit 5% of tendered value as performance guarantee (*Refer Appendix 12* and balance 5% of security deposit is recovered from running bills @ 10% of gross value of each running bill. (*Refer Appendix 9*).
- Maximum amount of security deposit is as specified in the contract. Recovery is made @ 10% of gross value of each bill till entire amount is recovered. Earnest money deposit initially made becomes a part of security deposit.

(iii) **Mode of deposit:** Cash, fixed deposit receipts of State Bank of India or scheduled bank or bank guarantee bond.

(iv) **Forfeiture of security deposit:** It is forfeited in full or in parts when there is a breach of contract.

(v) **Refund of security deposit:** It is refunded on

- Completion of work after expiry of defect liability period,
- On obtaining labour clearance certificate,
- On finalization of final bill and works accounts.

Some clients on successful completion of work may refund 50% of security deposit when half of defect liability period has expired.

7.07 RETENTION AMOUNT

On award of contract, the contractor is required to deposit specified amount as security deposit with the owner. Since there may be financial constraint for the contractor to deposit

such amount at one time, an alternative method of deduction from running bills is given to contractor. The amount of deductions made from running bills towards security deposit is known as retention amount. Thus retention amount is also a security deposit recovered from running bills.

7.08 PREBID CONFERENCE

For specialized works and major works, owners convene a prebid conference at about half of the bidding time given to tenderers. It is held to confirm both parties understanding of ***what is required and what is offered.*** Bidders are expected to visit the site and study tender documents prior to attending this conference. Bidders are given an opportunity to seek clarifications on scope, stipulations, constraints, time frame for completion and further assistance required from owner, etc. All important provisions made in the tender documents are explained to tenderers. If any change is considered necessary as a result of prebid conference, it is made exclusively through issuance of a corrigenda to all the tenderers which becomes a part of tender document. This conference facilitates projection of realistic bids by the tenderers. Since clarifications are given to bidders prior to submission of bids, bid evaluation would be easy for the owner's team. For best results, owner and his consultant should be fully prepared and empowered to answer all questions raised.

7.09 BID RATES

Before finalising bid rates, contractor is required to visit the site, study tender documents attend prebid conference, if convened and to do market survey for assessing prevailing rates of required materials. In practice, factors such as owner's promptness in making payments and giving decisions will have a reflection on bid rates. Bid rates consist of material cost, labour cost, hires charges of machinery, profits, overheads, and contingencies. Composition of tendered rates is shown in Fig. 13.1 (para 13.01) provision for profit and overheads is discussed below.

7.10 CONTRACTOR'S PROFIT

It reflects, rate of return on his investment. It is affected when work is delayed, claims are disallowed and when escalation is more than that reimbursed by the owners. If overheads increase, profit is reduced. In rate analysis owner provides 10% towards contractors profit and overheads.

7.11 OVERHEADS

"Overheads" are defined as all administrative or executive costs incident to the management, supervision or conduct of the capital outlay or project and is distinguished from operating costs. These are general charges which can not be charged upon as belonging exclusively to any particular item or part of the work. Provision for overheads varies from one work to another as it is dependent on several factors. For major works lesser percentage provision may be feasible. It is not realistic to specify any uniform percentage for overheads They include.

- Interest and bank guarantee charges.
- Insurance and taxes.
- Labour welfare.
- Liquidated damages,
- Idle labour and machinery.
- Mobilization and storage.
- Supervision.
- Infrastructure.
- Litigation.
- Extra escalation.
- Security

Out of combined provision of 10% towards contractor's profit and overheads, the normal break up is 7½% as profit and 2½% as overheads. However, this break up is work specific and no rigid break up can be given. In private sector provision of 15% is made for profit and overheads.

7.12 ALTERNATIVE DESIGNS AND BIDS

The standard practice is that owner or his consultant freezes basic design for invitation of tenders. With innovations in

(v) Market rate analysis is prepared on the basis of market rates at site of work as on the date of evaluation or on the eve of opening of tenders. This can be done by adopting one of the two methods:

- For all items tendered, work out material requirements and labour requirement category wise. Multiply by respective market rates. To this add overheads, contractor's profit and contingencies. This gives justified amount required to execute the work.
- Analyse the market rate for each item by adopting constants in data book and by substituting market rates in place of estimated rates. The justified amount to execute the work is worked out based on the quantities given in the schedule of quantities and market rates worked out as above.

(vi) Then compare quoted amount of the evaluated lowest acceptable tender with justified amount worked out as above in the light of market rates. If the difference is within 5% for normal works and within 10% for emergency works, the tender may be recommended for acceptance if all other factors are favourable. If the difference is more than these limits, attempt may be made to negotiate the offer. The lowest tenderer may also be asked to furnish bid rate analysis. On comparison it would be possible to reconcile the difference between the lowest quoted amount and justified amount.

If there are no other issues in the scrutiny of tenders, the above procedure can be adopted for evaluation of tenders. However, in practice, we may encounter some issues for which a fair and reasonable method of interpretation/evaluation is required. Some of the issues and suggested guidelines are given below.

7.15 ISSUES AND SUGGESTED GUIDELINES

(i) Contractor does not produce required documents for issue of tender forms —*Refuse issue of tender forms.*

(ii) Late receipt of tenders —*Return the tender without opening.*

(iii) Tender not signed by the contractor —*Not valid for evaluation and acceptance.*

(iv) Discrepancy in rates and amount —*To be dealt in the light of guidelines incorporated in tender documents.*

(v) EMD not deposited —*Reject the tender.*

(vi) Withdrawal of tender before opening —*Legally valid.*

(vii) Withdrawal before expiry of validity period —*Forfeit the EMD or part of it as per tender conditions.*

(viii) Tender accepted contractor is asked to pay security deposit. —He deposited SD; agreement not signed. signing of contract is a formality. Contract is formed.

(ix) Eligibility criteria is waived while issuing blank tender forms. —*Arbitrary and discriminatory; hence illegal.*

(x) Scope of work is altered after receipt of tenders and before decision is taken on tenders —*For evaluation consider both original scope and revised scope. If precedence of tenderers i s not altered there is no problem. If precedence is altered re-invite tenders with revised scope of work. If that is not feasible, evaluate the contract on the basis of original scope of work. Award the contract with revised scope with consent of tenderer.*

(xi) Cartel formation —*Reinvite tenders.*

(xii) Response is poor —*Reinvite tenders and liberalise eligibility criteria.*

(xiii) Bids are unbalanced —*Rationalise keeping tendered amount unaltered.*

(xiv) Some tenderers submit alternative bids —*Evaluate them.*

7.16 AWARD OF CONTRACT

It is a well settled principle that precedence for award of contract should go to the first lowest evaluated tenderer. When ever pre-qualification or post-qualification in two cover system is adopted, invariably the first lowest tenderer should be selected as contractor for work. In case of public tenders there can be discretion in the matter of award of contract in cases where NIT does not contain stipulation regarding solvency, work experience, organisation and construction machinery.

- *The lowest evaluated tenderer may not be considered for award of contract in the following cases:*

(i) The lowest evaluated offer is significantly higher than market rates and negotiations did not fructify. In such cases negotiations with the second lowest tenderer or re invitation of tenders are the alternatives. Factors contributing to higher avoidable costs should be identified. In such cases if reinviting tenders is inevitable tender conditions should be modified to get realistic and competitive offers.

(ii) When there is a strong suspicion of cartel formation among pre-qualified contractors and the lowest pre-qualified contractor may not be considered for award of contract. List of pre-qualified contractors is enlarged and tenders reinvited.

(iii) The lowest evaluated tenderer has produced false documents for eligibility which was discovered later before the award of contract.

(iv) Some of the conditions stipulated by the lowest evaluated tenderer affect the basic features of NIT and cannot be accepted. Facilitate equal opportunity to other tenderers, reinvitation of tenders would become inevitable.

(v) The lowest evaluated tender is not accepted when the owner faces funding problem, when site is not available or when the owner contemplates large scale scope variation. In such cases no tender can be accepted and scrapping of tenders becomes inevitable.

In government, contracts negotiations are discouraged. In private sector negotiations are common before award of contract. During negotiations, factors contributing to avoidable cost factors should be discovered through mutual discussions and negotiation process should ensure **win-win** situation.

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Chapter **8**

LEGAL ASPECTS OF CONTRACTS

8.01 TERMINOLOGY

- **Contract:** An agreement enforceable by law.
- **Void:** An agreement not enforceable by law.
- **Voidable contract:** An agreement which is enforceable by the law at the option of one or more of the persons thereto, but not at the option of the other(s).
- **Promisor:** The person making the proposal.
- **Promisee:** The person accepting the proposal.
- **Frustration of a contract:** Discharge of contract by reason of supervening impossibilities or illegality of the Act which was agreed to be done.
- **Damage:** Monetary compensation for the injury suffered.
- **Liquidated damages:** Amount of damages stipulated by the parties or has been ascertained by a judgement.
- **Reasonable:** Suitable under the circumstances, rational and equitable. What a prudent person uninsured would do under the same circumstances.
- **Force majeure:** An unexpected event. An irresistible and superior force.
- **Surety:** One who promises to answer for the debt, default or miscarriage of another.
- **Plaintiff or complainant or claimant:** The person who complains and brings an action.
- **Defendant or Respondent or accused:** The person defending or denying. The person against whom relief or recovery is sought.

- **Natural justice:** After due inquiry, the accused must have an opportunity of being heard, before honest decision is given.
- **Judicial review:** Only the decision making process and not the merits of the decision itself is reviewable.
- **Injunction:** It is a temporary relief granted by the court at its discretion upto a specified time or perpetually.

For constitutional provisions relating to contracts refer para 6.03 (i)

8.02 THE INDIAN CONTRACT ACT, 1872

Based on amending acts and adaptation orders, the Indian Contract Act, 1872 was passed by the legislature and received its assent on 25.4.1872. Summary of some of the clauses is as follows:

Section	Short Title	Summary
37	Obligation of parties to contract	All parties must perform their promises and obligations. If one party alone performs that party acquires a right of action against the other party who is guilty of breach.
55	(a) Effect of failure to perform at a fixed time in contract in which time is (i) essential (ii) not essential	(a) (i) The contract or so much of it as has not been performed becomes void at the option of the promisee.
	(b) Effect of acceptance of performance at time other than that agreed upon	(ii) The contract does not become voidable but the promisee is entitled to compensation from the promisor for any loss occasioned to him by such failure. (b) The promisee cannot claim compensation for any loss by the non-performance of the promisor at the time agreed, unless at the time of such acceptance he gives notice to the promisor of his intention to do so.
51	Promisor not bound to perform unless reciprocal promisee ready and willing to perform	When a contract consists of reciprocal promises to be simultaneously performed no promisor need perform his promise, unless the promisee is ready and willing to perform his reciporcal promise.
53	Liability of party preventing event on which the contract is to take effect	Contract contains receiprocal promises when one party prevents the other party from performing his promise. Contract becomes voidable at the option of the party so prevented. Prevented party is entitled to be compensated by the other party for any loss.

Section	Short Title	Summary
56	Agreement to do impossible Act	An agreement to do an act impossible in itself is void Doctine of frustration Both the parties are exeused from performance. Unforeseen acts —Acts of God —Natural disasters — War between countries — Legislative action.
73	**Compensation for loss or damage caused by breach of contract**	When a contract has been broken, the party who suffers by such breach is entitled to receive from the party who has broken the contract, compensation for any loss or damage caused to him thereby, which naturally arose in usual course of things from such breach or which the parties knew, when they made the contract, to be likely to result from the breach of it. **Such compensation is not to be given for any remote and indirect loss or damage sustained by reason of the breach.**
	Compensation for failure to discharge obligation resembling those created by contract	When an obligation resembling those created by contract has been incurred and has not been discharged, any person injured by the failure to discharge it is entitled to receive the same compensation from the party

Section	Short Title	Summary
		in default, as if such person had contracted to discharge it and had broken his contract. Explanation: In estima-ting the loss or damage arising from a breach of contract, the means which existed of remedying the inconvenience caused by the non-performance of the contract must be taken into account.
74	**Compenssation for breach of contract where penalty stipulated for**	When a contract has been broken, if a sum is named in the contract as the amount to be paid in case of such breach or if the contract contains any other stipulation by way of penalty, the party complaining of the breach is entitled, whether or not actual damage or loss is proved to have been caused thereby to receive from the other party who has broken the contract **reasonable compensation not exceeding the amount so named or as the case may be, the penalty stipulated for.**

8.03 THE SPECIFIC RELIEF ACT, 1963

Section 10 and Section 14 are relevant for administration of construction contracts.

Section 10: Except as otherwise provided in this chapter, the specific performance of any contract may, at the discretion of the court, be enforced.

(a) where there exists no standard for ascertaining actual damage caused by the non-performance of the Act agreed to be done, or

(b) where the Act agreed to be done is such that compensation in money for its non-performance would not afford adequate relief.

Section 14: The following contracts cannot be specifically enforced, namely

(a) a contract for the non-performance of which compensation, in money is an adequate relief,

(b) a contract which runs into such minute or numerous details or which is so dependent on the personal qualifications or violations of the parties, or otherwise from its nature is such, the court cannot enforce specific performance of its material terms,

(c) a contract which is in its nature determinable,

(d) a contract the performance of which involves, the performance of a continuous duty which the court cannot supervise.

Construction contracts fall within the scope of Section 14 and therefore specific performance cannot be enforced. Readiness and willingness: essential for specific performance would not be there on the part of the contractor who has abandoned the work. The client is entitled to claim damages for the losses suffered.

8.04 THE ARBITRATION AND CONCILIATION ACT, 1996

(A) Main Objectives

(1) To provide for reasoned award

(2) To ensure that arbitral tribunal remains within the limits of its jurisdiction

(3) to minimize the supervisory role of courts in the arbitral process

(4) to enforce arbitral award as if it were a decree of the court.

(B) Salient Features of the Act

(1) Arbitration agreement as a clause in a contract or as a separate agreement shall be in writing (Sec. 7)

(2) The parties are free to determine number of arbitrators (odd number) failing which tribunal consists of sole arbitrator (Sec. 10)

(3) In case of disagreement, the chief justice of high court or an institution named by him shall appoint an arbitrator.

(4) Equal treatment of parties (Sec. 18)

(5) The parties are free to agree to a procedure to be followed by the tribunal in conducting the proceedings, failing which the tribunal may decide its own procedure (Sec. 19)

(6) Place of arbitration: Parties are free to agree failing which tribunal will decide (Sec. 20)

(7) Arbitral proceedings commence from the date on which request for arbitration is received by the respondent (Sec. 21)

(8) Reasoned award to be given to provide transparency in decision making by the tribunal [Sec. 31(3)]

(9) No time limit is prescribed in the Act for pronouncing arbitral award. .

(10) The Act seeks to minimize the supervisory role of courts. Special jurisdiction conferred by the constitution on the Supreme Court and the High Court remains undisturbed.

(11) A sum directed to be paid by an arbitral award carries 18% p.a. interest from the date of award to date of payment [Sec. 31-7(b)]

(12) The Act enables the tribunal to order interim measures (Sec. 17)

(13) Grounds for challenging the award are made very specific in the Act (Sec. 34)

(14) The Act permits an arbitration tribunal to use mediation, conciliation or other procedure during the arbitral proceedings with a view to encourage settlement of disputes (Sec. 30)

(15) Any decision of arbitral tribunal shall be by majority.

(16) The award is final and binding. It is enforced as if it were a decree of court.

8.05 SALE OF GOODS ACT, 1930

Section 12: Condition and Warranty

A condition is a stipulation essential to the main purpose of the contract, the breach of which gives rise to a right to treat the contract as repudiated.

A warranty is a stipulation collateral to the main purpose of the contract, the breach of which gives rise to a claim for damages but not a right to reject the goods and treat the contract as repudiated.

Express warranty: The seller expressly guarantees or assumes responsibility for some special quality or characteristics of the goods, such as performance, speed, capacity etc.,

Implied warranty: (1) Goods should correspond to description if purchase is agreed to by description and to sample if agreed to by sample. If the buyer makes known to the seller the particular purpose for which goods are required, the goods supplied shall reasonably be suitable for such purpose.

Section 59: Four Remedies for Breach of Warranty

- Deduction in price..... (loss is < the price)
- Refusal to pay the price..... (loss = the price)
- Refusal to pay the price &

Claim for damages..... (loss is > the price)

- Pay the price and sue the seller.

Measure of damages: (As per Sec. 73 of the Indian Contract Act, 1872).

The measure of damages for the breach of warranty is the estimated loss directly and naturally resulting in the ordinary course of events.

Caveat emptor: The buyer is relying on his own skill and judgement when he effects a purchase. (Exception: Manufacturer)

8.06 SERVICE TAX ACT, 2004

(Refer contract agreement for revisions, if any)

Construction Services (Commercial and Industrial Building or Civil Structures)

Construction service has been defined under section 65 (309) as follows:

(a) Construction of new building or civil structure or a part thereof;

(b) Repair, alteration or restoration of or similar services in relation to building or civil structure which is (i) used or to be used, primarily for or (ii) occupied or to be occupied, primarily with or (iii) engaged or to be engaged primarily in commerce or industry or for work intended for commerce or industry but does not include road, airport, rail, transport terminal, bridge, tunnel, or long distance pipe and dam.

- Taxable service is defined under Section 65(105) (ZZQ) of the Act as the services provided "to any person by a commercial concern in relation to construction service".
- Persons excluded: (i) Persons engaged in constructing the building or civil structure in his own land for self use. (ii) Persons constructing building meant for residential purpose. (iii) Persons engaged in construction of road, bridges, airport, railways, transport terminals, tunnel, laying distance pipelines

- In case the contractee supplies materials (cement, steel, etc.) free of cost, without recovery of price thereof, no tax is leviable at the hands of the contractor.
- Hire charges borne for machinery and tools used for execution of works contract, is an allowable deduction.

8.08 LABOUR LAWS

(Refer contract agreement for revisions, if any)

Introduction: Both central and state governments are empowered to enact labour laws. Labour laws relating to construction industry is not incorporated in one legislation but a cluster of acts enacted and amended from time to time. Labour laws regulate labour welfare, conditions of work, provident fund, workmen's compensation, and maternity benefits. Salient provisions of some of the acts relating to construction industry are as given below. For details relevant acts are to be referred.

(i) The Contract Labour (Regulation and Abolition) Act, 1970

The objectives of the Act were dealt by the supreme court (in the case of Gammon India Ltd. and others *vs.* Union of India and others vide 1974 (28) FLR 406(SL) 1974 (1) Sec. 96) as given below.

"The Act was passed to prevent the exploitation of contract labour and also to introduce better conditions of work. The Act provides for regularisation and abolition of contract labour. **The underlying policy of the Act is to abolish contract labour, wherever possible and practicable and where it cannot be abolished altogether, the policy of the Act is that the working conditions of the contract labour should be so regulated as to ensure payment of wages and provision of essential amenities.** That is why the Act provides for regulated conditions of work and contemplates progressive abolition to the extent contemplated by Section 10 of the act. Section 10 of the Act deals with abolition while the rest of the Act deals mainly with regulation. The dominant idea of Section 10 of the Act is to find out whether contract labour is necessary for the

industry, trade, business, manufacture or occupation which is carried on in the establishment."

- This Act is applicable to contractors and establishments wherein 20 or more workmen are or were employed on any day of the preceeding 12 months. Act excludes supervisors and others drawing wages exceeding Rs. 1600/- p.m. It also excludes "out-workers" engaged in processing at their own premises.
- Section 10 of the Act is reproduced below.

Prohibition of employment of contract labour

(1) Not withstanding any thing contained in this act, the appropriate government may after consultation with the central board, or as the case may, a state board, prohibit by notification in the official gazette, employment of contract labour in any process, operation or other work in any establishment.

(2) Before issuing any notification under sub-section (i) in relation to any establishment, the appropriate government shall have regard to the conditions of work and benefits provided for the contract labour in that establishment and other relevant factors such as:

(a) Whether the process, operation, or other work is incidental to or necessary for, the industry, trade, business, manufacture or occupation that is carried on in the establishment,

(b) Whether it is of perennial nature, that is to say it is of sufficient duration having regard to nature of industry, trade, business, manufacture, or occupation carried on in that establishment,

(c) Whether it is done ordinarily, through regular workmen is that establishment or an establishment similar thereto,

(d) Whether it is sufficient to employ considerable number of whole-time workmen.

Explanation: If a question arises whether any process or operation or other work is of perennial nature, the decision of the appropriate government therein shall be final.

- Obligations of employers/contractors.

The principal employer should apply for registration and obtain "registration certificate". A contractor should apply for license and obtain the same to employ contract labour.

- A canteen (when labour strength exceeds 100), rest room, drinking water, washing place, creches, latrines and urinal and first aid box should be provided as amenities for the contract labour.
- Contract labour displaced on the expiry of contract period do not get statutory right for absorption in regular service.
- In respect of principal employer, if the contract labour has worked for more than 240 days, he will become employee of the principal employer.
- There is no automatic obligation on the principal employer to absorb all the contract labour if the government prohibits such type of contract labour.
- The Act covers rights of employers/contractors and penalties for various offences.
- Wages shall be paid as per provision in the Act included in schedule I of "labour laws (Exemption from furnishing returns and maintaining registers by certain establishment) Act, 1988". For prescribed forms *refer Appendix 15*. For contract labour (RCA) central rules 1971 *Refer Appendix 16*.

(ii) The Minimum Wages Act, 1940

- The state government is empowered to fix minimum wages and to revise the same at intervals not exceeding 5 years, on the basis of change in price index and dearness allowance for skilled, unskilled, clerical supervisory, etc. in employments listed in the schedule contained in the act. This includes construction and maintenance of roads or buildings.
- Number of working hours, rest day with wages for every 7 days period, overtime rates, etc., are covered in this Act.

- The employer should maintain prescribed registers and furnish an annual return in form III by 1st february of the succeeding year.

(iii) The Workmen's Compensation Act, 1923

- The Act as amended w.e.f. 8.23.2000 covers casual labourers also. Employees employed by contractor are also covered under this act. Person entered into a construction contract and agreed to work himself and employs his own labour (construction material is supplied free by the owner) to assist him is also covered by this Act for compensation.
- Compensation is to be paid under this Act by the employer to an employee who has suffered an accident arising out of and in the course of his employment, resulting with (a) death, (b) permanent total disablement, (c) Permanent partial disablement, (d) temporary disablement, whether total or partial and for person who has contacted an occupational disease.
- Tests to determine whether accident arose out of employment (i) At the time of injury workman must have been engaged in the work of employer, (ii) Accident occurred at the place of his duty, (iii) Injury resulted from risk incidental to his duty of service.

  The principal employer is liable to pay compensation to contract labour also.

(Compensation is related to loss of earning capacity before and after the accident.)

The compensation is to be deposited with commissioner who will pay to the workman. The Act specifies penalties for various offences.

(iv) The Maternity Benefit Act, 1961

- This benefit is not available for women employees who are eligible for such benefits under ESI Act, 1948. Benefit is available for women employees who have worked for atleast 80 days during the 12 months immediately preceding the date of her expected delivery.

- Maternity benefit: Total leave period of 12 weeks preceding and following the day of her delivery with payment at average daily wages. Notice of claim shall be given by employee during the pregnancy or as soon as possible after the delivery.

(v) The Payment of Gratuity Act, 1972

This is compulsory, statutory retrial benefit. Every employee is eligible to receive gratuity after rendering 5 years continuous service. It is payable either on superannuation or retirement or resignation or death or disablement due to accident or disease. Gratuity is calculated on the actual wages last drawn by the employee at the rate of 15 days wages for every completed year of service. Maximum amount of gratuity shall not exceed Rs.3,50,000/-. An Apprentice is not eligible for gratuity.

(vi) The Payment of Bonus Act, 1965

Every employee drawing salary or wages upto a specified monetary limit is eligible for bonus. Apprentice is not eligible for bonus. Employees of some establishments are not eligible for bonus under this act. What they are paid as bonus is called exgratia payment. Minimum bonus is specified % of salary or wages or Rs. 100/- in case of employees above 15 years and Rs. 60/- in case of employees who were below 15 years at the beginning of the accounting year whichever is higher. Maximum bonus: 20% of salary or wages.

(vii) The Equal Remuneration Act, 1976

The Act provides for payment of equal remuneration to men and women workers for same work or for a work of similar nature. There shall not be any discrimination on grounds of sex.

(viii) The Payment of Wages Act, 1936

Wage period may be day or week or month (not exceeding one month). Wages to be paid within 7 days of expiry of wage period if number of employees are less than 1000 and in other cases, wages are to be paid within 10 days of the expiry of wage period.

(ix) The Employees' State Insurance Act, 1948

This Act applies to factories employing more than 10 persons and carrying on manufacturing process with the aid of power (and 20 persons without the aid of power). Workers under this Act are eligible to get medical relief, sickness cash benefits, pension to dependents of deceased, maternity benefit to women workers, compensation for fatal and other employment injuries and occupational diseases. These benefits are given from ESI contribution fund. Employees covered under this scheme are not eligible for benefits under Workmen's Compensation Act 1923 and Maternity Benefit Act, 1969.

Employee's contribution 1.75%
Employer's contribution 4.75%
Employees include contractor's labour.

The principal employer may deduct both the contributions payable in respect of employees engaged through a contractor from the bills paid to the contractor.

Employer is responsible to deposit both the contribution into ESI account. The employer is required to maintain (i) Register of employees (ii) Accident book and inspection book. A return of contributions is to be submitted to regional office of ESI within 30 days of the end of contribution period.

8.09 COURT JUDGMENTS

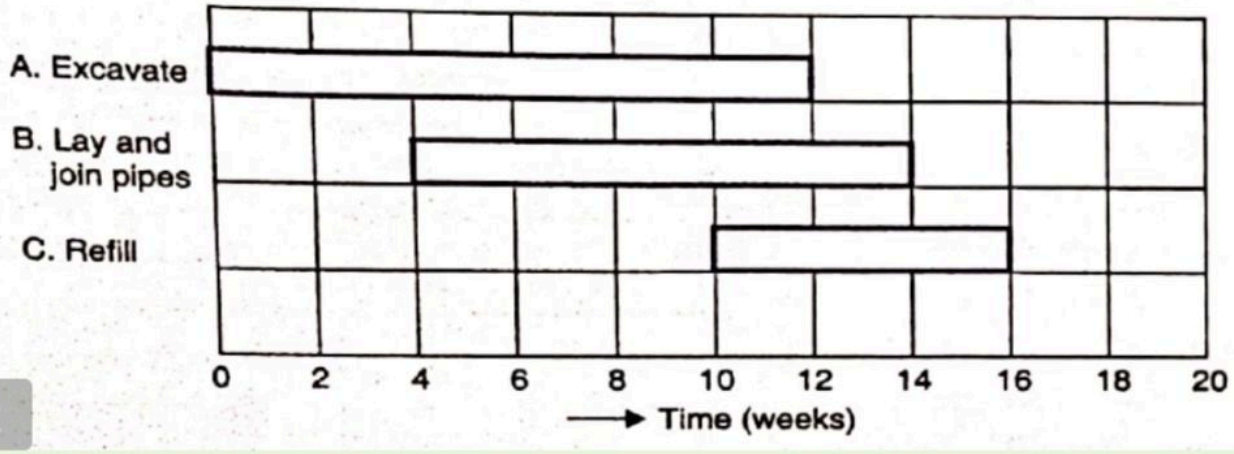
(i) Time is the essence of contract: (Chandiramani AIR 1993 SC 1742)

It will be clear from the aforesaid statement of law, that even where the parties have expressly provided that time is the essence of contract, such a stipulation will have to be read along with other provisions of the contract and such other provisions may on construed of the contract exclude the inference that completion of work by a particular date was to be fundamental, for instance, if the contracts were to include clauses providing for extension of time in certain contingencies or for payment of fine or penalty for every day or week the work undertaken remains unfinished on the expiry of time

ACTIVITY INTER-RELATIONSHIP

- In a project, there may be large number of activities which can start with a certain degree of concurrency.
- Eg: Take a project of laying a pipe line,

A. Excavating the trench 12 weeks
B. Laying and joining the pipe 10 weeks
C. Refilling and compacting 6 weeks.



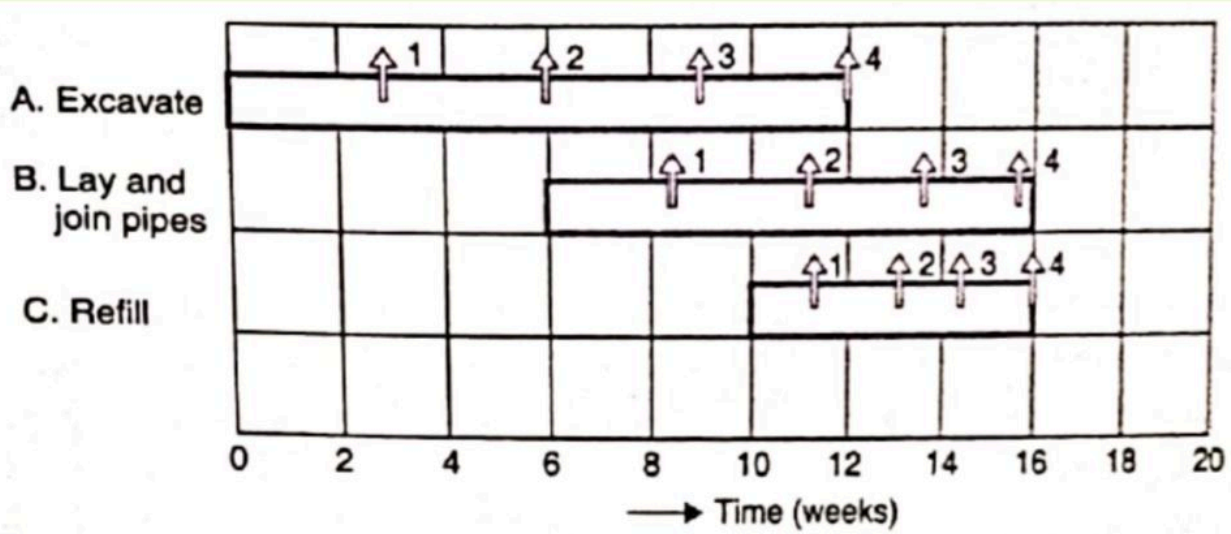
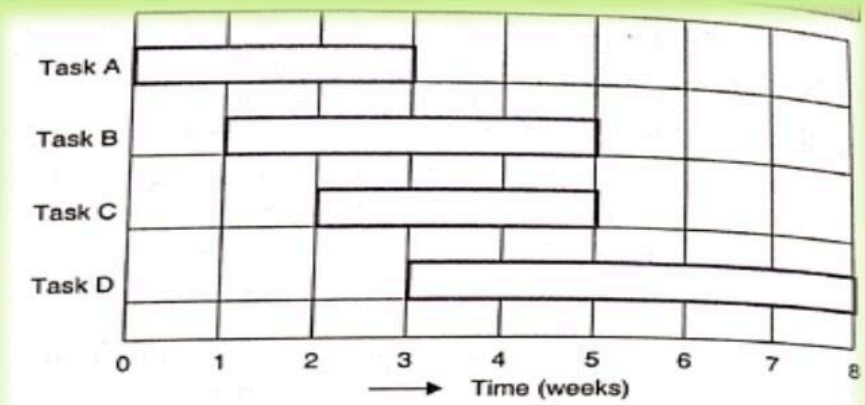


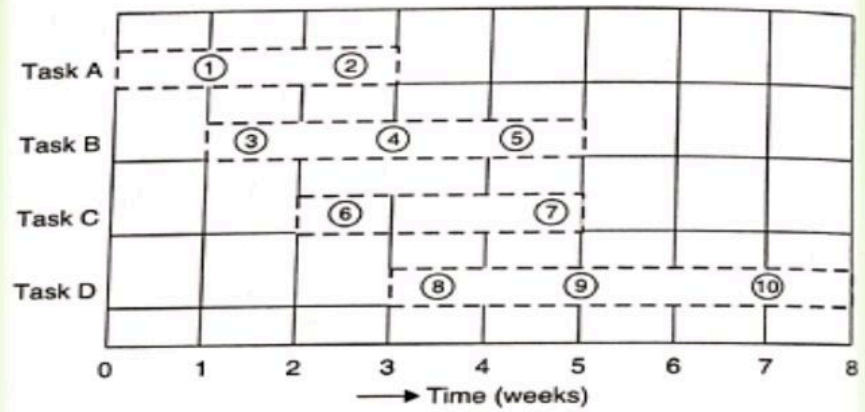
Figure 29.7. Modified Bar Chart

MILESTONE CHARTS

- Milestone chart is a modification over the original Gantt chart.
- Milestones are the key events of a main activity represented by a bar; these are specific points in time which mark the completion of certain portions of the activity.
- When a bar chart-big-details-not clear-hence-broken down into number of sub-activities-control and establish inter-relationship.
- The beginning and end of these sub divided activities or tasks are termed as milestones.



(a) Gantt bar chart



(b) Gantt milestone chart

Figure 29.8. Modification of Bar Chart into Milestone Chart

MILESTONE CHARTS

- Each main task contains some specific points in time which can be easily recognised, and through which controlling can be achieved.
- Each milestone can be considered to be specific event along the main activity or job or task.
- This chart is therefore called the milestone chart. Each milestone is represented either by a circle or by a square, and is serially marked.

CPM & PERT

CPM & PERT

7

PERT/CPM

Network models are used as an aid in the scheduling of large complex projects that consist of many activities.

Critical Path Method (CPM)

- duration of each activity is known with certainty.
- used to determine the length of time required to complete a project.
- CPM can also be used to determine how long each activity in the project can be delayed without delaying the completion of the project.
- CPM was developed in the 1950's.

8

Program Evaluation and Review Technique (PERT)

- duration of each project is not known with certainty.
- used to estimate the probability that the project will be completed by the given deadline.
- PERT was developed around the same time as CPM.

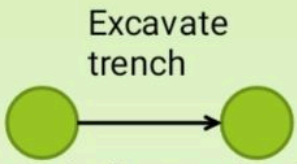
9

Terminologies in PERT and CPM

- **Activity** – an effort that requires resources and takes a certain amount of time for completion.
- **Activity** is defined as a project that can be broken down in to various operations and process necessary for its completion. Each of these operations and processes, which consume time and possibly resources, is called activity.

- **Critical Activity** – is an activity that, if even slightly delayed, will hold up the scheduled completion date of the entire project.

- **Event** – a specific accomplishment at a recognizable point in time; a milestone, checkpoint. Events do not have a time duration per sec. To reach an event, all activities that precede it *must* be completed.
- **Event –** is the state between completion of a preceding activity and the beginning of the succeeding one. It has no duration. An event s shown by a circle or ellipse.



- **Network** – a logical and chronological set of activities and events, graphically illustrating relationships among the various activities and events of the project.

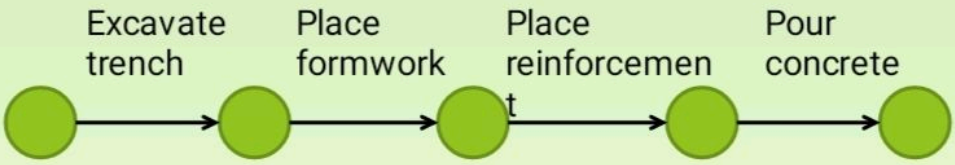
- **Path** – sequence of adjacent activities that form a continuous path between two events.
- **Critical Path** – sequence of critical activities that forms a continuous path between the start of a project and its completion.
- **Critical Path** – The longest path through the network.

Significance of critical path

- It is the longest path in the network; however it is possible for an network to have more than one critical path. The sum of the durations of critical activities along the critical path determines the duration of the project.
- It is the most sensitive path; any change in duration of critical activities along the critical path is bound to effect the duration of the entire project.

Precedence relationship

- Precedence relations between activities signify that the activities must take place in a particular sequence. Numerous natural sequences exist or construction activities due to requirements for structural integrity, regulations and other technical requirements.
- For example,



PERT vs CPM

- PERT and CPM are very similar in their approach; however two distinctions are usually made between them.
- The first distinction relates to the way in which activity duration are estimated:
- In PERT, *three* estimates are used to form a weighted average of the expected completion time of each activity, based on a probability distribution of completion times. Thus, PERT is considered a probabilistic tool.
- In CPM, there is only one estimate of duration; that is, CPM is a deterministic tool.
- The second distinction is that CPM allows an explicit estimate of costs in addition to time.
- Thus, while PERT is basically a tool for planning and control of time, CPM can be used to control both the time and the cost of the project.

A PERT / CPM program provides management with the following information:

- What are the critical activities or tasks in the project.
- Which activities are non-critical.
- The amount of slack (or *float*) on each non-critical activity.
- When will the entire project be completed.
- What is the probability that the project be completed by specific date.
- If project is on schedule, behind schedule, or ahead of schedule at any particular date.
- If money spent equal to, less than, or greater than the budgeted amount on any given date.
- if there are enough resources available to finish the project on time.
- The best way to accomplish the project at the least cost, if the project is to be finished in a shorter amount of time.

PERT / CPM PROCESS

1. Analysis of the project
   Define the project and all of its significant activities or tasks.
2. Sequence the activities
   Develop the relationships among the activities. Decide which activities must precede others.
3. Draw the network connecting all of the activities.
4. Assign time and/or cost estimates to each activity.
5. Compute the longest time path through the network, known as the critical path.
6. Use the network to help plan, schedule, monitor, and control the project.

PERT / CPM PROCESS

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   Define the project and all of its significant activities or tasks.
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PROJECT NETWORK

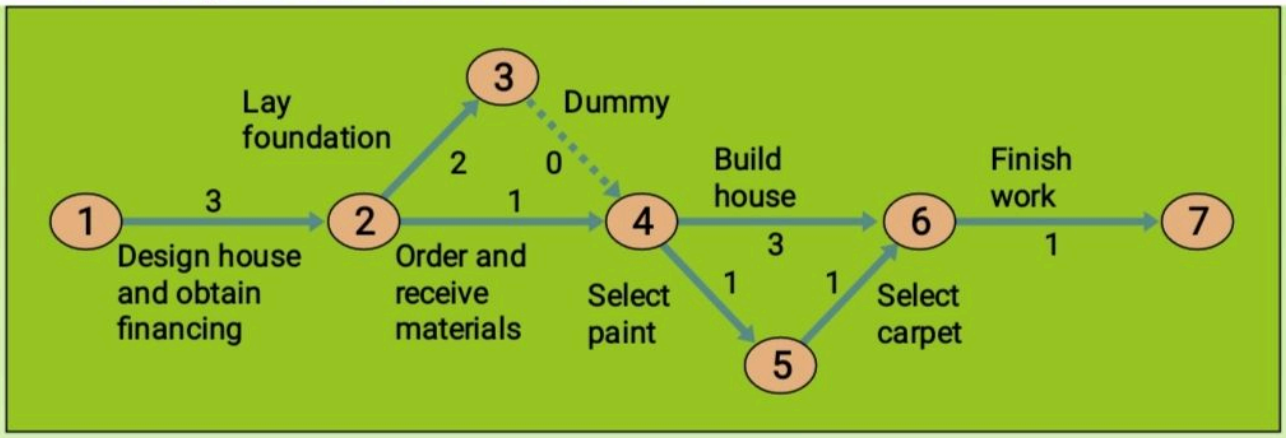
- Activity-on-node (AON)

  nodes represent activities, and arrows show precedence relationships

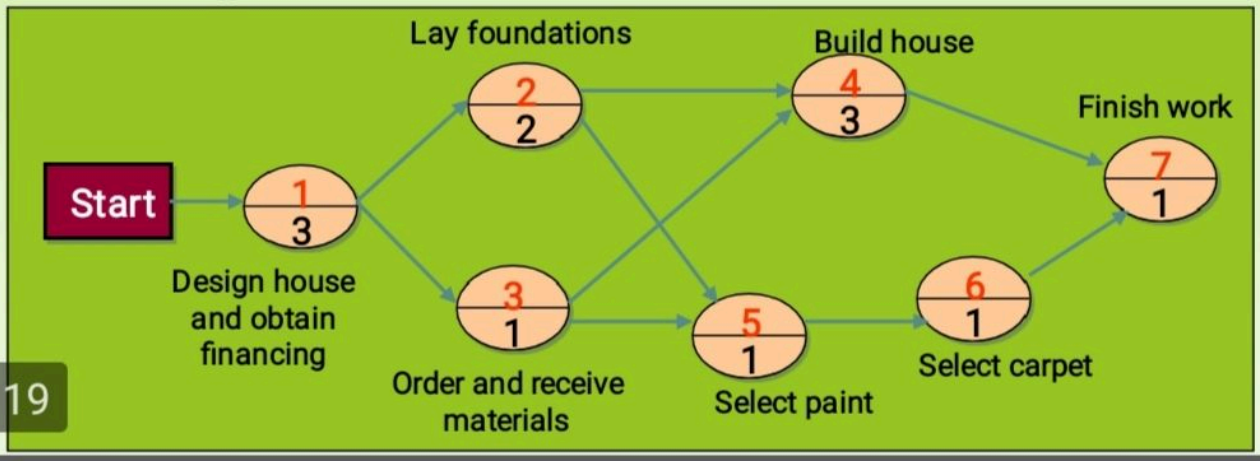
- Activity-on-arrow (AOA)

  arrows represent activities and nodes are events for points in time

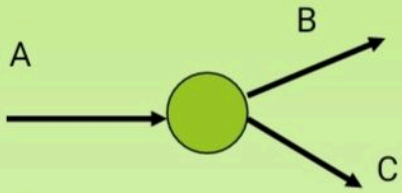
AOA Project Network for House



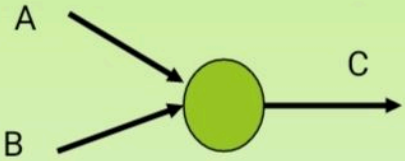
AON Project Network for House



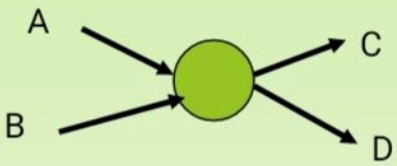
Situations in network diagram



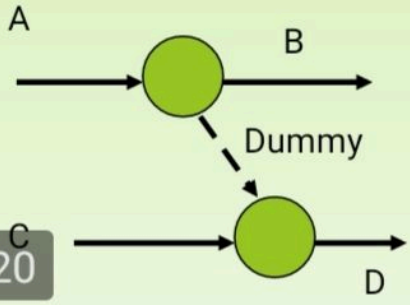
A must finish before either B or C can start



both A and B must finish before C can start



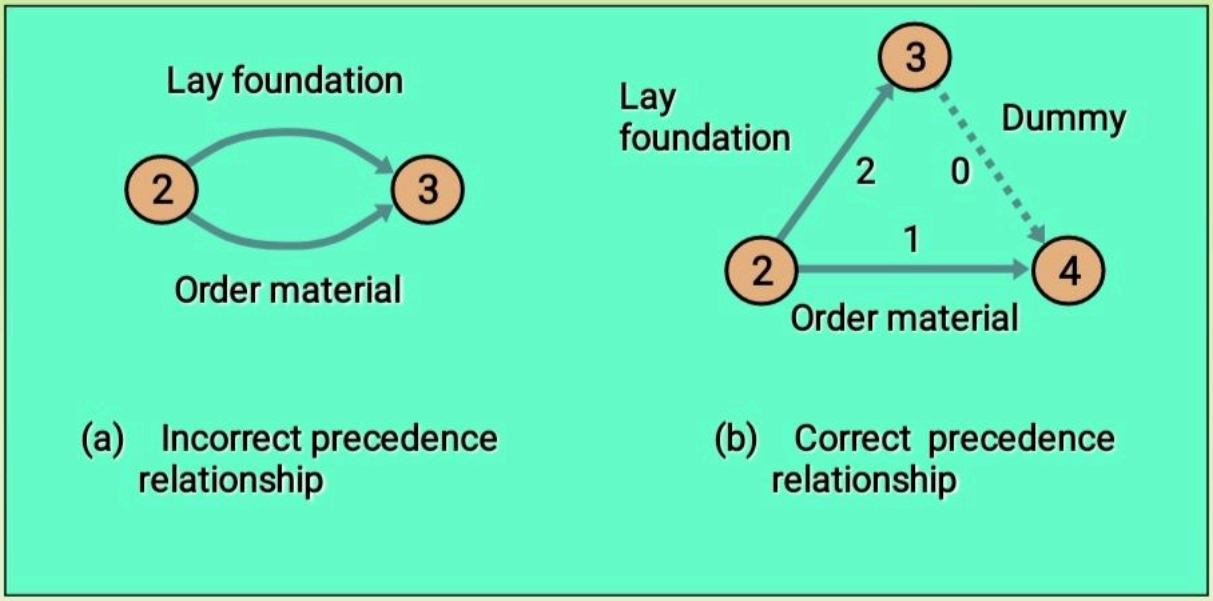
both A and C must finish before either of B or D can start



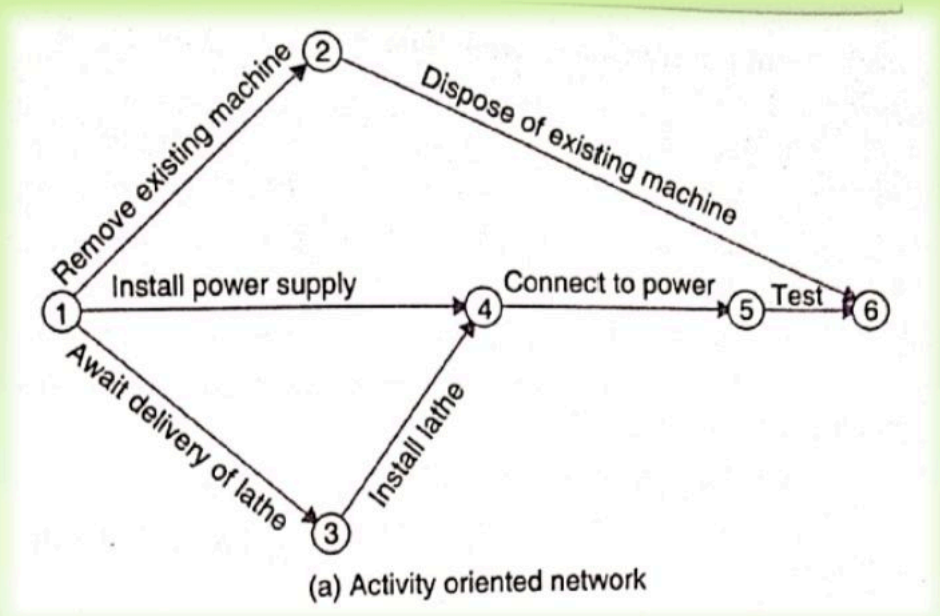
A must finish before B can start

both A and C must finish before D can start

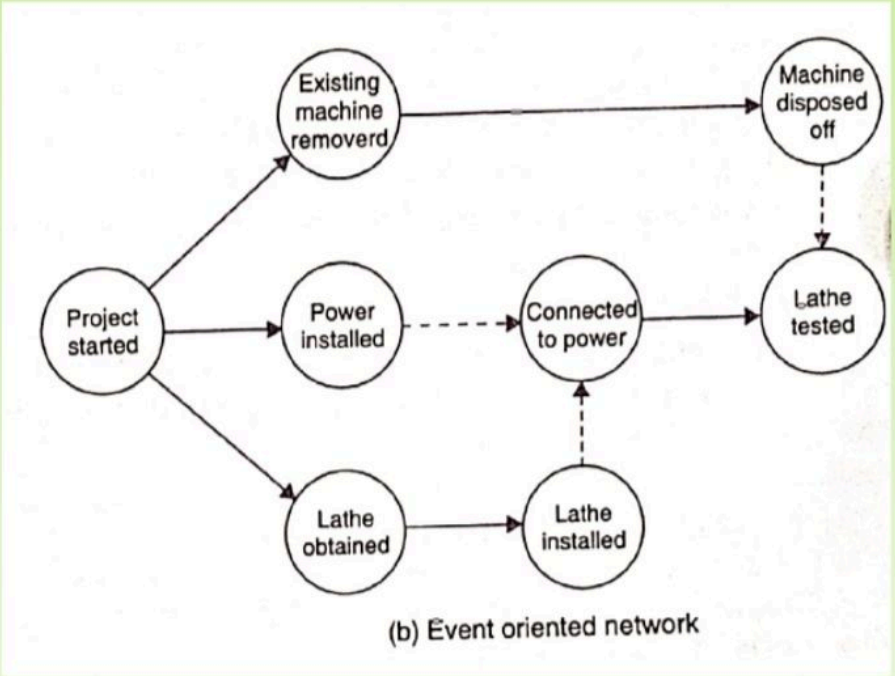
Concurrent Activities



NETWORK DIAGRAMS



NETWORK DIAGRAMS



(b) Event oriented network

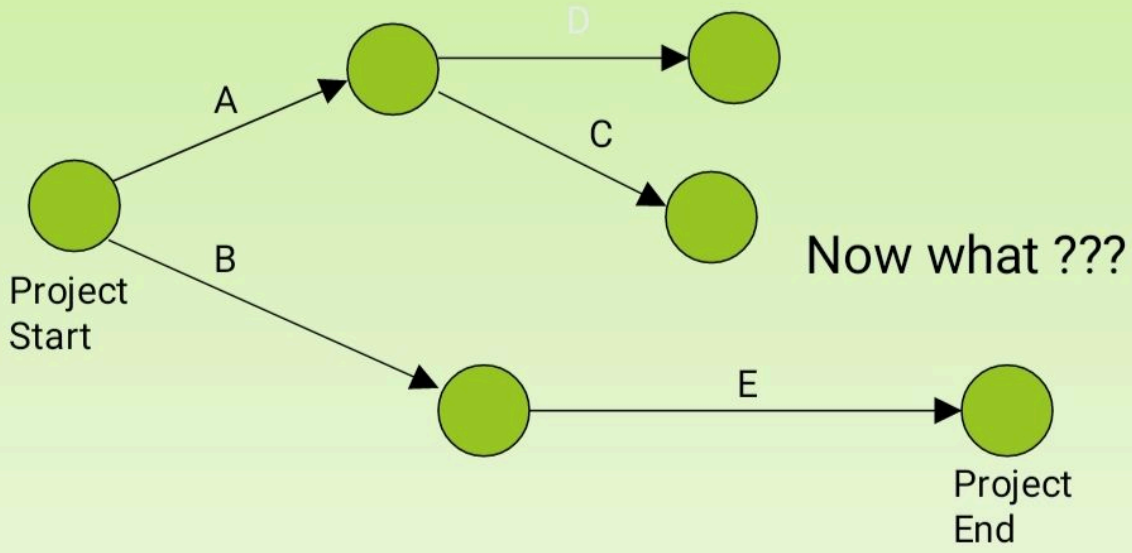
Critical Path Method

Example

Activity	Duration	Precedence
A	4	-
B	5	-
C	3	A
D	3	A
E	2	B, C

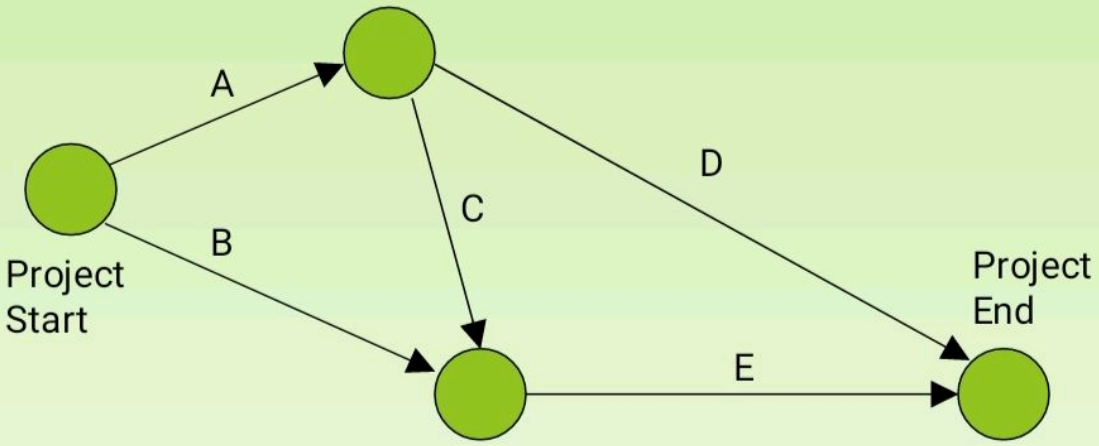
Critical Path Method (CPM)

The project sequence graph is constructed:



Critical Path Method (CPM)

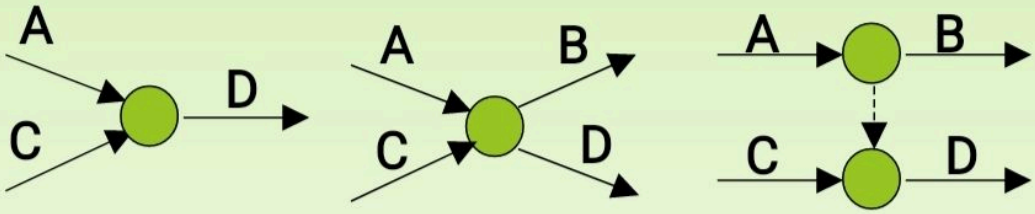
- Events are consolidated to provide the specified precedence.
- "Dummy" activities are added if necessary.



Dummy Activity Example

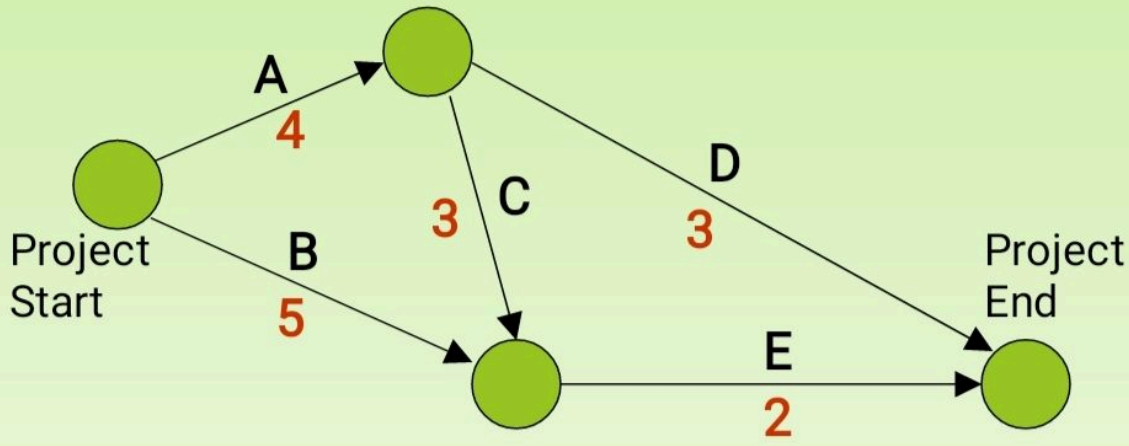
To be able to bolt a bracket to a panel, the operations required are :

- Design bracket A -
- Build bracket B A
- Build panel C -
- Drill holes in panel D A,C



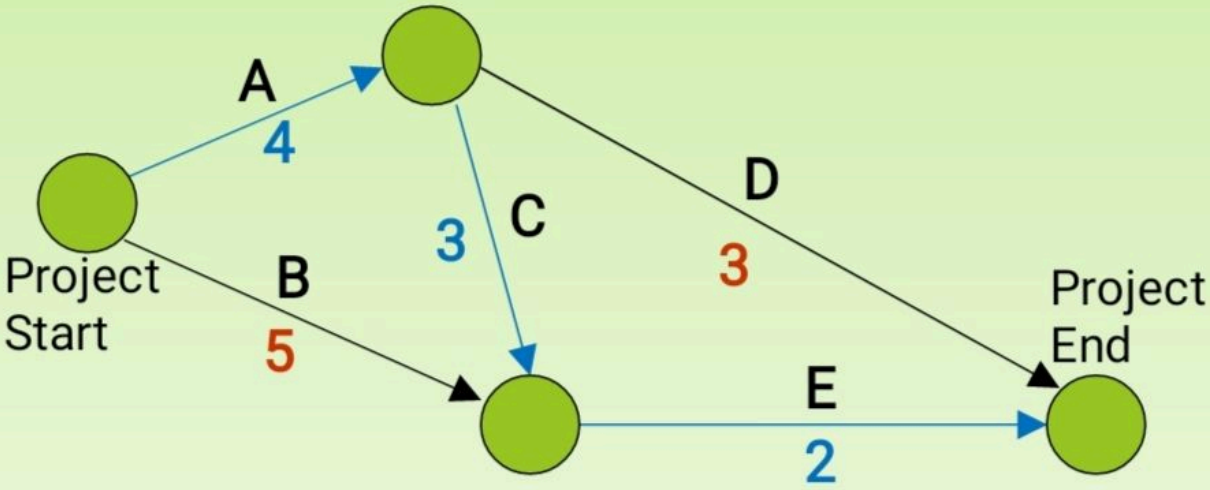
Critical Path Method (CPM)

- Activity times (duration) are added next :



Critical Path Method (CPM)

The CRITICAL PATH is the path through the project on which any delay will cause the completion of the entire project to be delayed:



Critical Path Method (CPM)

- For fairly simple projects, the critical path is usually the longest path through the project.
- For projects with several parallel and interlinked activities, this may not always be the case.
- For more complicated projects, the critical path can be determined with an 'earliest time' forward sweep through the diagram followed by a 'latest time' reverse sweep.

Planning for network construction

- FORWARD PLANNING:
- Plan starts from the initial event and builds up the events and activities logically and sequentially until the end is reached.
- What events comes next?
- What are dependent events?
- What events can take place concurrently?
- $ES_j = Max_i (ES_i + D_{ij})$

- BACKWARD PLANNING
- Plan starts with the end event, and arranges the events and activities until the initial event is reached.
- Keeping the goal in view, the planner asks himself 'if we want to achieve this, what events or activities should have taken place?'
- $LC_i = Min_j (LC_j - D_{ij})$

Forward Pass

- Earliest Start Time (ES)
  - earliest time an activity can start
  - ES = maximum EF of immediate predecessors
- Earliest finish time (EF)
  - earliest time an activity can finish
  - earliest start time plus activity time

$$EF = ES + t$$

Backward Pass

- Latest Start Time (LS)

  Latest time an activity can start without delaying critical path time

  $$LS = LF - t$$

- Latest finish time (LF) or Latest Completion time (LC)

  latest time an activity can be completed without delaying critical path time

  LS = minimum LS of immediate predecessors

CPM analysis

- Draw the CPM network
- Analyze the paths through the network
- Determine the float for each activity
  - Compute the activity's float

    float = LS - ES = LF - EF
  - Float is the maximum amount of time that this activity can be delay in its completion before it becomes a critical activity, i.e., delays completion of the project
- Find the critical path is that the sequence of activities and events where there is no "slack" i.e.. Zero slack
  - Longest path through a network
- Find the project duration is minimum project completion time

Critical Path Method
Example

Activity	Duration	Precedence
A	4	-
B	5	-
C	3	A
D	3	A
E	2	B, C

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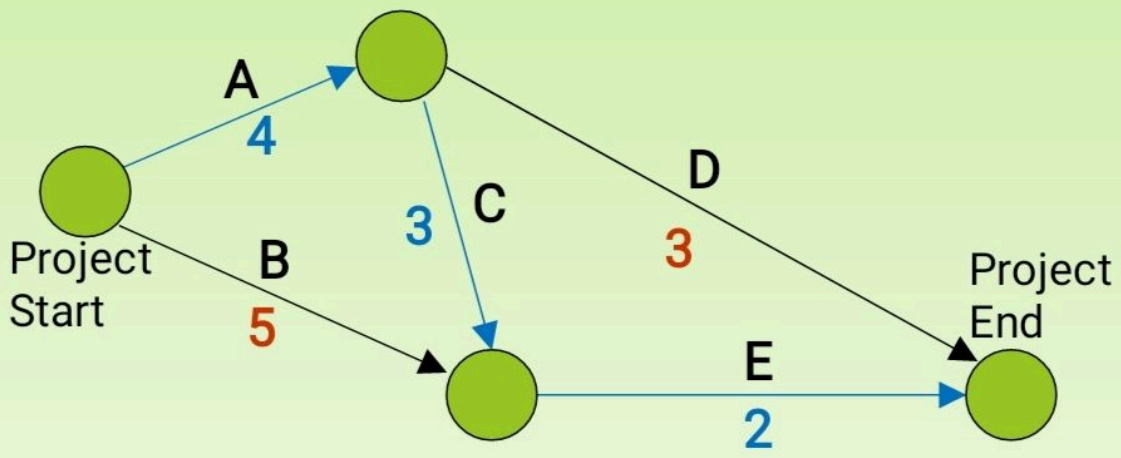
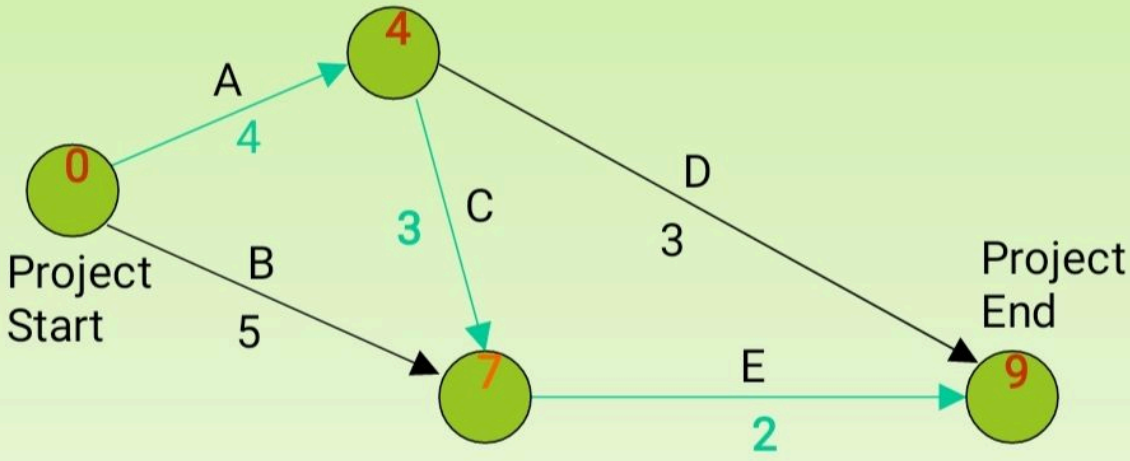


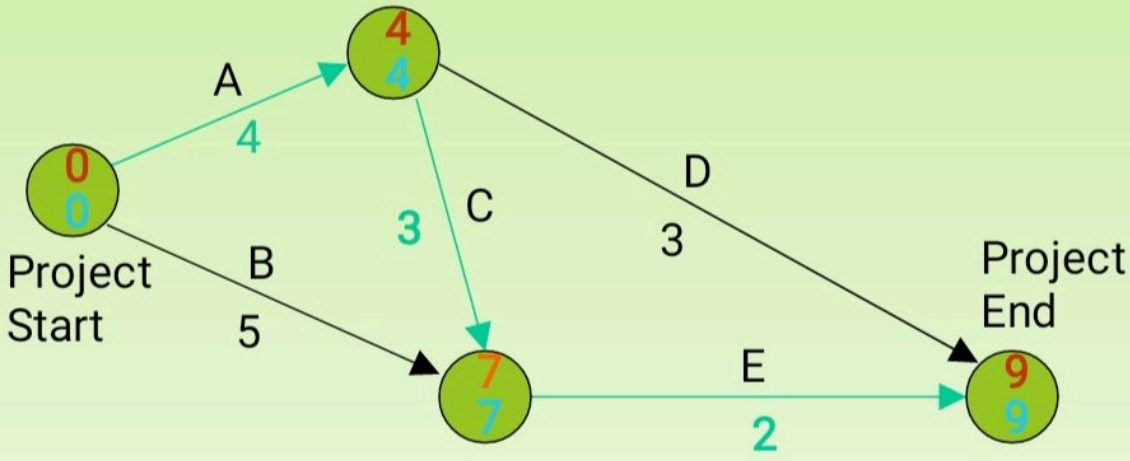
Critical Path Method (CPM)

The EARLIEST starting time of each activity is associated with the events. It corresponds to the longest time of any path from any previous event.



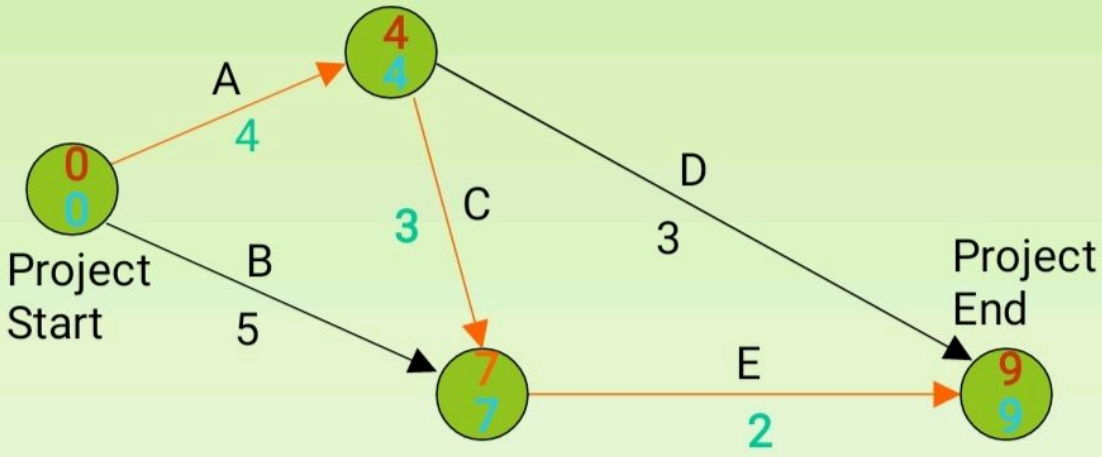
Critical Path Method (CPM)

The LATEST starting time of each activity is also associated with the events. It corresponds to the longest time of any path from any subsequent event.



Critical Path Method (CPM)

The CRITICAL PATH is the path along which the earliest time and latest time are the same for all events, and the early start time plus activity time for any activity equals the early start time of the next activity.



Conditions for critical path

i. $ES_i = LC_i$

ii. $ES_j = LC_j$

iii. $ES_j - ES_i = LC_j - LC_i = D_{ij}$ or t

Total Float

- It is the amount of time that the completion time of any activity can be delayed without affecting the project completion time.

$$TF_{ij} = LC_j - ES_i - D_{ij}$$

Free Float

- It is the amount of time that the activity completion time can be delayed without affecting the earliest start time of immediate successor activities in the network.

$$FF_{ij} = ES_j - ES_i - D_{ij}$$

Problem on CPM:

- Consider the details of a project as shown in the table.

a) Construct the CPM network
b) Determine the critical path and project completion time
c) Compute the total floats and free floats for non-critical activities.

Problem on CPM:

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a) Construct the CPM network

b) Determine the critical path and project completion time

c) Compute the total floats and free floats for non-critical activities.

Activity	Immediate Predecessors	Duration (months)							
A	-	2							
B	-	5	C	-	4				
D	B	5							
E	A	7							
F	A	3							
G	B	3	H	C,D	6				
I	C,D	2							
J	E	5							
K	F,G,H	4							
L	F,G,H	3	M	I	12	N	J,K	8	

Real World Example

- Vignette: Meet the Newest Entrepreneur – The Project Manager
- According to William Dauphiman at Price Waterhouse, "Project management is going to be huge in the next decade"
- "Everything has become projects, and that is the way we do business" - Fannie Mae's CIO
- "Project management is the wave of the future" - newsletter from General Motors
- "Project management Salaries are Hot News" - PMI

Managers

- Project managers often need temporal skills that enable them to:
  - Recapture past information and incorporate it into current problem-solving strategies
  - Predict the future for scheduling purposes or contingency planning
  - Create a vision for the future
  - Cognitively bring the past or future closer to the present

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Responsibilities of the Project Manager

•The project manager's responsibility is to ensure the customer is satisfied that the work scope is completed in a quality manner, within budget, and on time.

- Provides leadership in planning, organizing, and controlling the work effort
- Coordinates the activities of various team members
- Does not try to do it alone
- Involves the project team to gain their commitment

Manager's duties/responsibilities

- **Activity and resource planning**
- **Organizing and motivating a project team**
- **Controlling time management**
- **Cost estimating and developing the budget**
- **Ensuring customer satisfaction**
- **Analyzing and managing project risk**
- **Monitoring progress**
- **Managing reports and necessary documentation**

• Managing reports and necessary documentation

5

Key duties – Construction Project Manager

- Establish communication procedures, including the appropriate chain of command for all communications for projects and set up an appropriate tracking system for necessary approvals.
- Develop and periodically update CPM schedules.
- Establish meeting procedures and timetables.
- Negotiate and prepare agreements for successful execution of work → bid packages & contract documents.
- Review and understand construction documents and cost estimates.

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Key duties – Construction Project Manager

- Supervise the construction activities → coordination of crews
- Develop and prepare request for Periodic payment and Review of Subcontractor and Vendor Pay requests for accuracy, etc.
- Assist management in risk identification as it applies to understanding and interpreting contracts and disputes.
- Inspection of construction work for conformance with the contract requirements.
- Have working knowledge and ability to manage and enforce quality control and quality assurance from the beginning to the end of a project.

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Skills of the Project Manager

The project manager is a key ingredient in the success of a project.

- Strong leadership ability
- Ability to develop people
- Excellent communication skills
- Good interpersonal skills
- Ability to handle stress
- Problem-solving skills
- Time management skills

Strong Leadership Ability

Leadership is getting things done through others.

- Inspire the people assigned to the project
- Create vision of the result and benefits of the project
- Participative and consultative leadership style
- Establishes the parameters and guidelines for what needs to be done
- Does not tell people how to do their jobs

Leadership Ability (Cont.)

- Involves and empowers the project team
- Involves individuals in decisions affecting them
- Empowers individuals to make decisions within their assigned areas
- Understands what motivates team members and creates a supportive environment
- Does not create situations that cause individuals to become discouraged
- Fosters motivation through recognition

Leadership Ability (Cont.)

- Sets the tone of trust, high expectations, and enjoyment
- Has high expectations of themselves and of each person on the project team
- Is optimistic and positive
- Encourages the same positive attitude
- Is highly motivated and sets a positive example
- Has self-confidence and inspires confidence
- Leads by making things happen

Ability to Develop People

- Committed to the training and development of people
- Uses the project to add value to each person's experience base
- Believes that all individuals are valuable to the organization
- Stresses the value of self-improvement

Ability to Develop People (Cont.)

- Provides opportunities for learning and development by encouraging individuals to assume the initiative, take risks, and make decisions
- Provides assignments that require individuals to extend their knowledge
- Identifies situations in which less experienced people can learn from more experienced people
- Has people attend formal training sessions
- May provide coaching

Communication Skills

Effective and frequent communication is crucial.

- Communicate *regularly* with the project team, subcontractors, customer, and own upper management
- A high level of communication is especially important early in the project
- Good oral and written communication skills
- Spend more time listening than talking

Communication Skills (Cont.)

- Establish ongoing communication with the customer
- Communication should be timely, honest, and unambiguous
- Effective communication establishes credibility and builds trust
- Provide timely feedback to the team and customer
- Create an atmosphere that fosters timely and open communication

Interpersonal Skills

- Good interpersonal skills are essential
- Develop a relationship with each person on the project team
- Try to learn about the personal interests of each individual without being intrusive
- Should use open-ended questions and do a lot of listening
- Empathize with individuals when special circumstances arise

Interpersonal Skills (Cont.)

- Maintain relationships throughout the duration of the project
- Use good interpersonal skills to try to influence the thinking and actions of others
- Use good interpersonal skills to deal with disagreement or divisiveness

Ability to Handle Stress

- Cannot panic; remain unruffled
- Able to cope with constantly changing conditions
- Act as a buffer between the project team and the customer or upper management
- Have a good sense of humor
- Stress is likely to be high when a project is in jeopardy of not meeting its objective

Problem-Solving Skills

- Early identification of a problem or potential problem is important
- Encourage project team members to identify problems early and solve them on their own

Time Management Skills

- Have self-discipline
- Be able to prioritize
- Show a willingness to delegate

Developing the Skills Needed to Be a Project Manager

- Gain experience — work on as many projects as you can; each project presents a learning opportunity
- Seek out feedback from others
- Conduct a self-evaluation and learn from your mistakes
- Interview project managers who have skills that you want to develop
- Participate in training programs

Developing the Skills Needed to Be a Project Manager (Cont.)

- Join organizations, such as the Project Management Institute
- Read and subscribe to journals
- Volunteer and contribute to the community or a specific cause to develop leadership skills
- Learning and development are lifetime activities—there's no finish line

Solution

- Any critical activity ill have zero total float and zero free float, based on this property we can determine the critical activities
- Critical path: 1-3-4-6-8-9
- Critical path: B-D-H-K-N: 5+5+6+4+8=28 weeks

PERT NETWORKS

Solution

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- Critical path: B-D-H-K-N: 5+5+6+4+8=28 weeks

PERT NETWORKS

PERT

- Time is the most essential and basic variable in PERT system of planning and control.
- In general, two approaches may be used for the assessment of duration for activity completion.
- The first approach is the deterministic approach in which a single estimate of time gives reasonably accurate results, and this approach is followed by CPM users.

PERT

- The second approach is the probabilistic approach in which one may only be able to state limits within which it is virtually certain that the activity duration will lie.
- Between these limits, we must guess what is the probability of executing the activity. The second approach is followed by PERT planners.

PERT

- Thus, to take the uncertainties into account, PERT planners make three kinds of time estimates:

i. The optimistic time estimate
ii. The pessimistic time estimate
iii. The most likely time estimate

- The optimistic time estimate (t_o)
  - This is the shortest possible time in which an activity can be completed, under ideal conditions.
  - This particular time estimate represents the time in which we could complete the activity if everything went along perfectly, with no problems or adverse conditions.
  - Better than normal conditions are assumed to prevail.

- The pessimistic time estimate (t_p)
  - It is the best guess of the maximum time that would be required to complete the activity.
  - This particular time estimate represents the time it might take us to complete a particular activity if everything went wrong and abnormal situations prevailed.
  - However, this estimate does not include possible effects o highly unusual catastrophies such as earthquakes, floods, fires, etc.

- The most likely time estimate (t_L)
  - The most probable time is the time that, in the mind of the estimate represents the time the activity would most often require if normal conditions prevail.
  - This time estimate lies between the optimistic and pessimistic time estimates. This time estimate reflects a situation where conditions are normal, things are as usual and there is nothing exciting.

PERT

- PERT is based on the assumption that an activity's duration follows a probability distribution instead of being a single value
- Three time estimates are required to compute the parameters of an activity's duration distribution:
  - pessimistic time (t_p) - the time the activity would take if things did not go well
  - most likely time (t_L) - the consensus best estimate of the activity's duration
  - optimistic time (t_o) - the time the activity would take if things did go well

Mean (expected time): $t_e = \frac{t_o + 4t_L + t_p}{6}$

Variance: $V_t = \sigma^2 = \left(\frac{t_p - t_o}{6}\right)^2$

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PERT analysis

- Draw the network.
- Analyze the paths through the network and find the critical path.
- The length of the critical path is the mean of the project duration probability distribution which is assumed to be normal
- The standard deviation of the project duration probability distribution is computed by adding the variances of the critical activities (all of the activities that make up the critical path) and taking the square root of that sum
- Probability computations can now be made using the normal distribution table.

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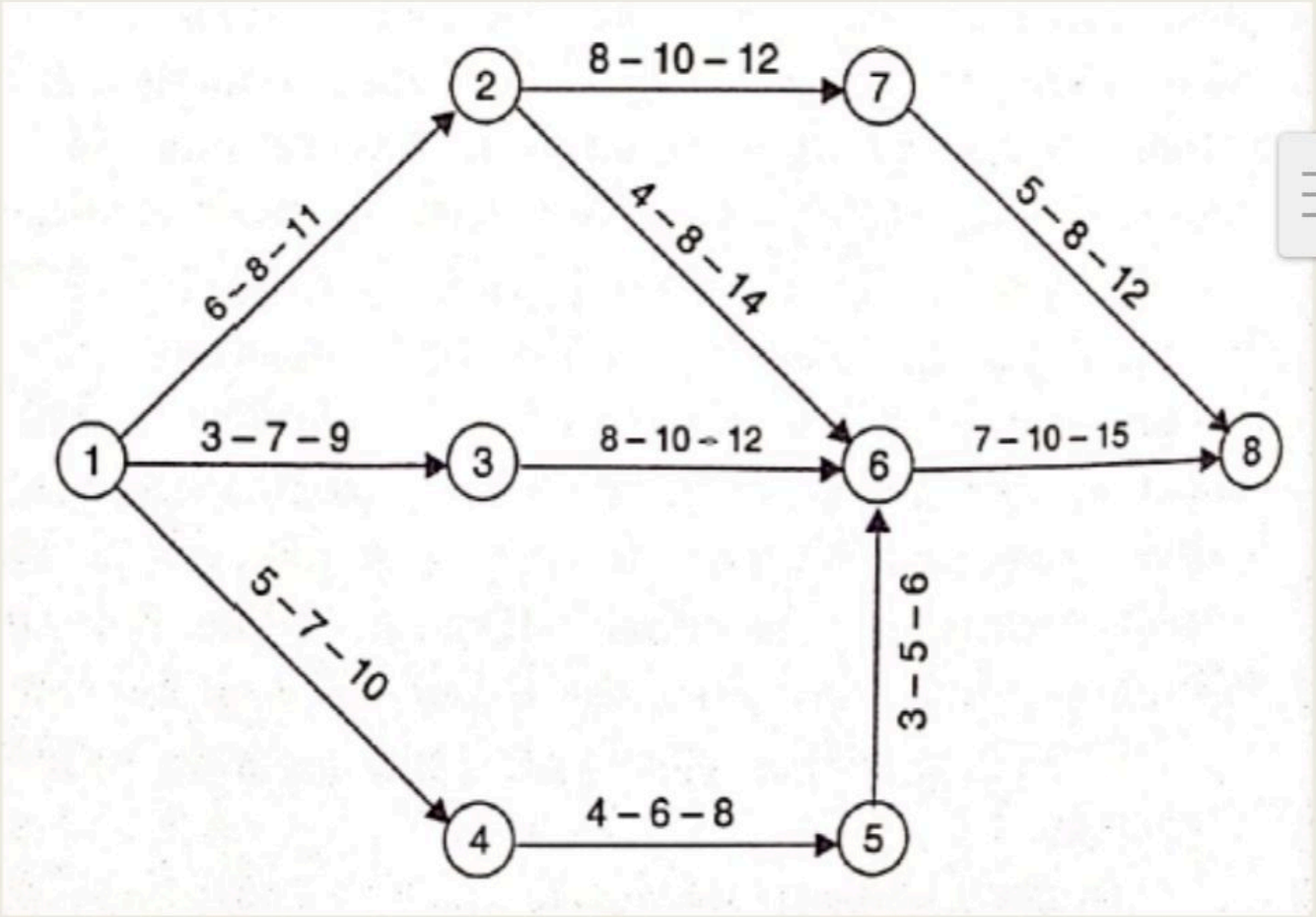

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Solution

- In the network, event 1 is the starting event while event 8 is the end event. There are following four paths from the starting event to the end event:
- Path A: 1-2-7-8
- Path B: 1-2-6-8
- Path C: 1-3-6-8
- Path D: 1-4-5-6-8

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Solution

- In the network, event 1 is the starting event while event 8 is the end event. There are following four paths from the starting event to the end event:
- Path A: 1-2-7-8
- Path B: 1-2-6-8
- Path C: 1-3-6-8
- Path D: 1-4-5-6-8

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- In PERT analysis, the expected time t_E is taken as the basis for finding the critical path. The expected time t_E for each activity can be found from the equation

- $t_E = \frac{t_o + 4t_L + t_p}{6}$

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Path	Activity	t_o	t_L	t_P	t_E	Σt_E
A	1–2	6	8	11	8.17	
	2–7	8	10	12	10.00	26.34
	7–8	5	8	12	8.17	
B	1–2	6	8	11	8.17	
	2–6	4	8	14	8.33	26.83
	6–8	7	10	15	10.33	
C	1–3	3	7	9	6.67	
	3–6	8	10	12	10.00	27.00
	6–8	7	10	15	10.33	
D	1–4	5	7	10	7.17	
	4–5	4	6	8	6.00	
	5–6	3	5	6	4.83	28.23
	6–8	7	10	15	10.33	

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- From the table, column seven shows the expected time calculated for the completion of the activity. The path D shows the maximum of 28.23days and it is found to be the Critical path.

Critical path: 1-4-5-6-8

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Problem 2:

- The activity along with the predecessor are listed in the table below. The optimistic, most likely and pessimistic time estimates are listed in the table. Determine the expected time for each of the activity. Calculate the variance and standard deviation.

Activity	Predecessor	t_o	t_L	t_p
A	-	2	4	9
B	A	5	8	14
C	B	4	10	13
D	B	4	7	10
E	C	11	14	20
F	D	9	13	16
G	E,F	2	4	6

SOLUTION

- FORMULA USED

$$t_E = \frac{t_o + 4t_L + t_p}{6}$$

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

- Standard deviation = $\sigma = \sqrt{\sigma^2}$

SOLUTION

Activity	Predecessor	t_o	t_L	t_p	t_E	σ^2	σ
A	-	2	4	9	4.5	1.36	1.17
B	A	5	8	14	8.5	2.25	1.50
C	B	4	10	13	9.5	2.25	1.50
D	B	4	7	10	7	1	1
E	C	11	14	20	14.5	2.25	1.50
F	D	9	13	16	12.8	1.36	1.17
G	E,F	2	4	6	4	0.44	0.67

PROJECT COST

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Cost consideration in project

- Project managers may have the option or requirement to crash the project, or accelerate the completion of the project.
- This is accomplished by reducing the length of the critical path(s).
- The length of the critical path is reduced by reducing the duration of the activities on the critical path.
- If each activity requires the expenditure of an amount of money to reduce its duration by one unit of time, then the project manager selects the least cost critical activity, reduces it by one time unit, and traces that change through the remainder of the network.
- As a result of a reduction in an activity's time, a new critical path may be created.
- When there is more than one critical path, each of the critical paths must be reduced.
- If the length of the project needs to be reduced further, the process is repeated.

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COST MODEL

- The object of the network analysis is also to assess the possibility of arriving at a feasible and desirable time-cost relationship.
- The overall project duration can be reduced by reducing the duration of only the critical activities in the project network.
- Total project cost is the sum of the following
  - Direct cost
  - Indirect cost

Direct cost

- Are those expenditures which are directly chargeable to and can be identified specially with the activities of the project.
- These include labour cost, material cost, equipment cost, etc.

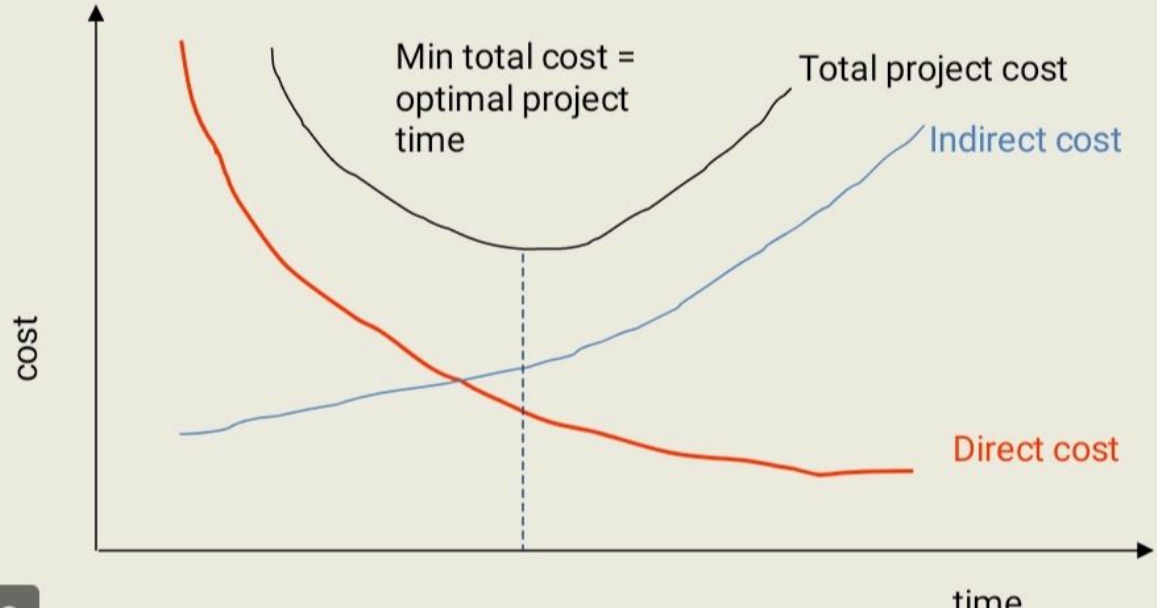
Indirect Cost

- The indirect costs on a project are those expenditures which cannot be apportioned or clearly allocated to the individual activities of a project, but are assessed as a whole.
- The indirect cost includes the expenditure related to administrative and establishment charges, overhead, supervision, expenditure on a central store organization, loss of revenue, lost profit, penalty, etc.

Time-Cost Relationship

- Crashing costs increase as project duration decreases
- Indirect costs increase as project duration increases
- Reduce project length as long as crashing costs are less than indirect costs

Time-Cost Tradeoff



Project Crashing

- Crashing
  - reducing project time by expending additional resources
- Crash time
  - an amount of time an activity is reduced
- Crash cost
  - cost of reducing activity time
- Goal
  - reduce project duration at minimum cost

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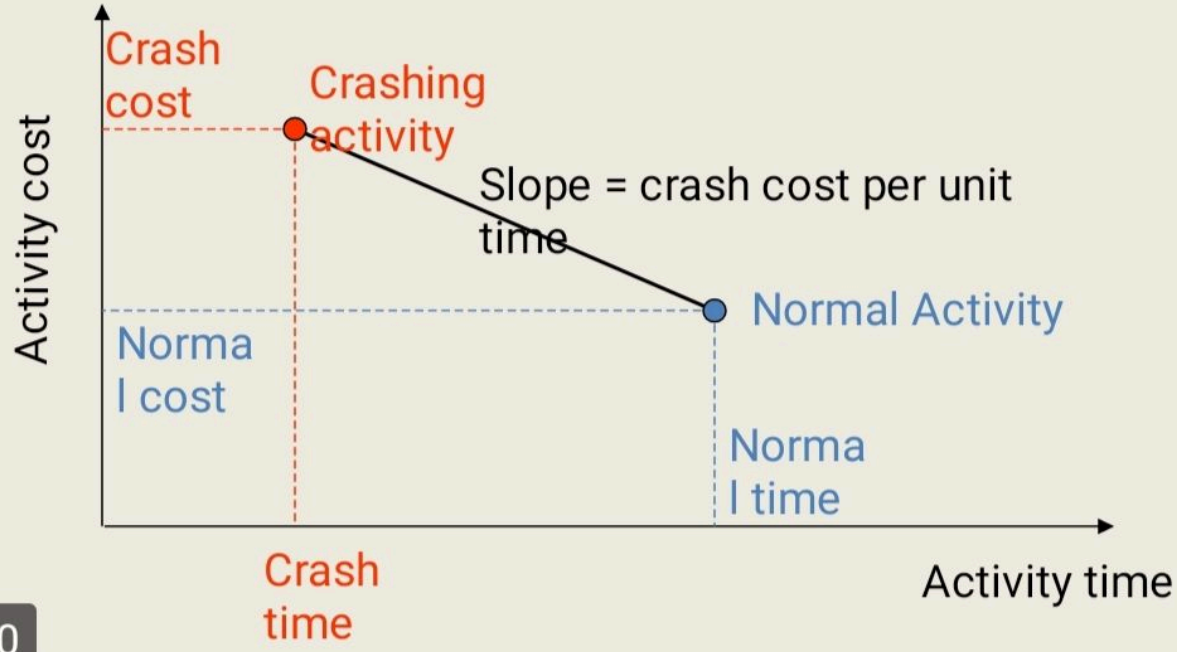
Activity crashing



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Definitions

- Normal time- is the standard time that an estimator would usually allow for an activity.
- Crash time- is the minimum possible time in which an activity can be completed, by employing extra resources. It is that time, beyond which the activity cannot be shortened by any amount of increase in resources.
- Normal cost- is direct cost required to complete the activity in normal time duration.
- Crash cost- is the direct cost corresponding to the completion of the activity within crash time.

- Cost slope= (Crash cost – Normal cost) / (Normal time- Crash time)
- $CS = \frac{C_c - C_n}{t_n - t_c}$
- $CS = \Delta C / \Delta t$

Benefits of CPM/PERT

- Useful at many stages of project management
- Mathematically simple
- Give critical path and slack time
- Provide project documentation
- Useful in monitoring costs

CPM/PERT can answer the following important questions:

•How long will the entire project take to be completed? What are the risks involved?
•Which are the critical activities or tasks in the project which could delay the entire project if they were not completed on time?
•Is the project on schedule, behind schedule or ahead of schedule?
•If the project has to be finished earlier than planned, what is the best way to do this at the least cost?

Limitations to CPM/PERT

- Clearly defined, independent and stable activities
- Specified precedence relationships
- Over emphasis on critical paths
- Deterministic CPM model
- Activity time estimates are subjective and depend on judgment
- PERT assumes a beta distribution for these time estimates, but the actual distribution may be different
- PERT consistently underestimates the expected project completion time due to alternate paths becoming critical

To overcome the limitation, Monte Carlo simulations can be performed on the network to eliminate the optimistic bias

MACHINERY FOR CONSTRUCTION ACTIVITIES

EARTHWORK PLANNING

- Projects are executed under conditions that vary immensely from one project to another.
- Therefore, before a project is undertaken it is necessary to systematically analyze project conditions and develop alternatives that potentially provide success.
- Every construction project is a unique undertaking. Although similar work may have been performed previously, no two projects will have identical job conditions.

EARTHWORK PLANNING

- The pace, complexity and cost of modern construction are incompatible with trial and error corrections as the work proceeds.
- Therefore, planning is undertaken to understand the problems and to develop courses of action.
- The goal of planning is to minimize resource expenditures required to successfully complete the project and to ensure that the work is accomplished in a safe manner.

EARTHWORK PLANNING

- Planning is necessary in order to
  1. Understand project objectives and requirements
  2. Define work elements
  3. Develop safe construction methods and avoid hazards
  4. Improve efficiency
  5. Coordinate and integrate activities
  6. Develop accurate schedules
  7. Respond to future changes
  8. Provide a yardstick for monitoring and controlling execution of project activities.

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Typical constraints are:

- Contract requirements prescribed in the drawings and technical specifications, including time duration or requirements as to completion dates.
- Legal requirements (OSHA, licensing, environmental control)that must be satisfied.
- Physical/environmental limits of the job, which may necessitate off-site fabrication and material storage, or sequencing of construction operations (traffic control).
- Climatic conditions that limit when certain activities can be performed, such as paving or stabilization operations, or that limit earthwork operations because of moisture content and the inability to dry the material.

EARTHWORK OPERATIONS

- A solid foundation must be prepared to support:roads, runways, buildings, and other temporary or permanent structures.
- To accomplish this task, one must perform earthwork operations, often referred to as horizontal construction.

Earthwork Equipment

- Earthmoving is the process of **moving soil or rock** from one location to another and **processing** it so that it meets **construction requirements** of location, elevation, density, moisture content, and so on.
- Activities involved in this process include **excavating, loading, hauling, placing (dumping and spreading), compacting, grading, and finishing**

Selection depends on the following criteria:

- Qnt of material to be excavated
- Duration available
- Soil type
- Job condition – space for loading, dumping, accessibility of site, traffic flow and this mainly determines whether to use track mounted or wheel mounted equipment.
- Compaction factors

EARTHMOVING OPERATIONS

- In construction projects that involve earthmoving operations, project managers are under pressure to improve productivity, efficiency, and safety. Achieving these goals requires an effective planning, tracking and control system.
- The main goals of planning earthmoving operations are to: (1) optimize the use of available resources; (2) balance resources throughout the project duration and/or its development stage; (3) select suitable equipment for the work at hand, taking into consideration construction site conditions and the mechanical specifications of equipment to maximize productivity and consequently maximize profit of contractors; and (4) complete projects with least cost and within the given targeted project duration.

Earthwork

Clearing & Grubbing

- removal of trees, shrubs, and other vegetation
- removing stumps and root mat at least 2’ (600mm) below subgrade
- less removal required for embankment heights > 5’
- topsoil striping
- muck excavation

Earthwork

Prior to starting any earthwork:

- Install all required E&SC devices
- Review soil borings and other geotechnical information
- Observe existing drainage patterns
- Plan access and excavation patterns
- Determine handling of spoils
- Verify original ground surfaces (compare against existing contours or cross sections shown on the plan)

Keys to Successful Earthwork Operations

1. control surface and subsurface water
2. maintain optimum moisture range by drying, mixing, or wetting
3. identify and monitor cut & fill quantities
4. good layout (horizontal & vertical control)
5. minimize handling - minimize stockpiling

Keys to Successful Earthwork Operations

6. optimize haul lengths
7. minimize cycle time
8. proper selection and sizing of excavators and haul units
9. alternate haul unit wheel paths
10. experienced personnel in the field

Equipment Functions

- Excavating
- Loading
- Hauling
- Placing (dumping & spreading)
- Drying
- Ripping
- Boring or tunneling
- Compacting
- Grading
- Finishing

Equipment Classifications

- Function
- Configuration
- Power Units – Gas vs. diesel vs. gas turbine
- Running Gear – track (crawler) vs. wheel (rubber tire)
- Activation - conventional (gears, pulleys, cable) vs. hydraulic

Diesel vs. Gas Power Units

Advantages of diesel over gas

- Less need for servicing
- Longer life
- Lower fuel consumption
- Lower- priced fuel
- Lower fire hazard
- Low CO emissions

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Running Gear

Tracks

- greater traction
- less ground pressure
- better on steep grades
- not prone to damage from surface

Wheels

- greater mobility
- greater speed
- does not scar or damage paved surfaces
- encounters rolling resistance
- rimpull force

17

17 surface • Tirnpull force

EXCAVATORS

- Excavators are basically digging machines and are classified as:
  - Crawler mounted excavators
  - Truck mounted excavators
  - Self propelled excavators, and
  - Excavators mounted on barge or rail

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Earthwork Equipment

For deciding the no. of equipments, the following things must be determined

1. Suitable class of equipment
2. Appropriate model within that class of equipment
3. Cycle time calculation and no. of equipments require
4. Associated equipments required and their nos.

Excavator:

- An excavator is defined as a **power-driven digging machine**.
- The major types of excavators used in earthmoving operations include **hydraulic excavators and the members of the cable-operated crane-shovel family** (shovels, draglines, hoes, and clamshells).
  - Dozers, loaders, and scrapers can also serve as excavators.

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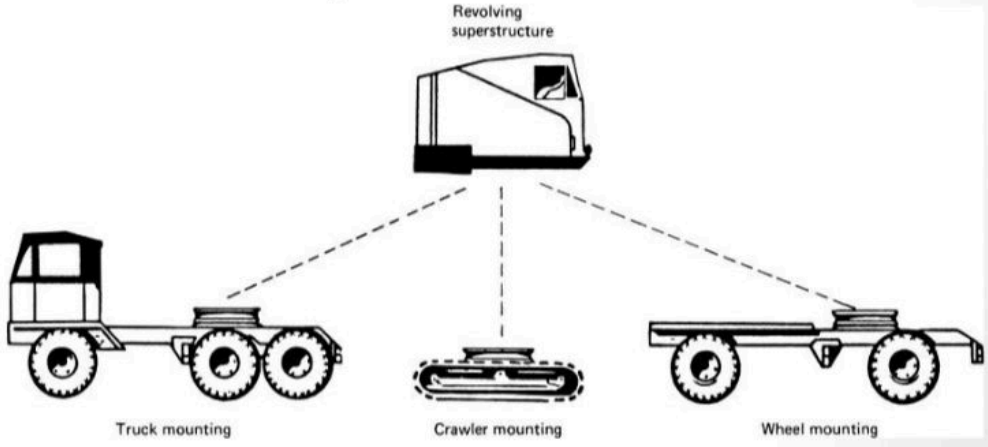
Parts of Earthmoving Equipments:

- Excavators and crane-shovels consist of **three major assemblies**:

1. a carrier or mounting,
2. a revolving superstructure containing the power and control units (also called the revolving deck or turntable), and
3. a front-end assembly.



Hydraulic Excavator or Back hoe:

- The original and most common form of hydraulically powered excavator is the hydraulic excavator equipped with a hoe front end.
- This machine is also called a hydraulic hoe or hydraulic excavator-backhoe.
- A backhoe (or simply hoe) is an excavator designed primarily for excavation below ground
- Suitable for cutting trenches, pits, leveling and loading

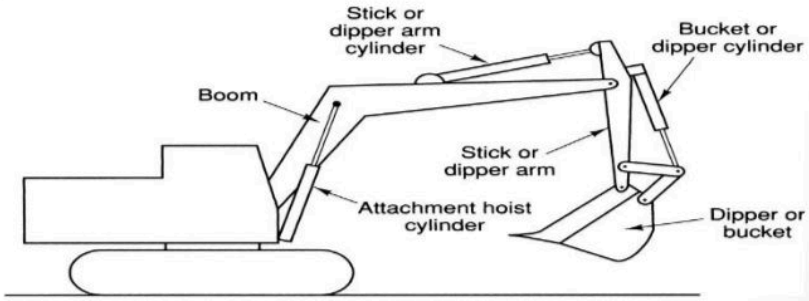


FIGURE 3-3. Components of a hydraulic excavator backhoe.

FIGURE 3-4. Telescoping-boom hydraulic excavator. (Courtesy of JLG Industries, Inc.)

FIGURE 3-5. Mini-excavator. (Courtesy of JCB Inc.)

Excavating Equipment

Crawler mounted
Hydraulic Excavator

Wheel Excavator

Shovel or Front Shovel:

1. Front-dump and
2. bottom-dump buckets are available for hydraulic shovels.

- Bottom dump buckets are more versatile, provide greater reach and dump clearance, and produce less spillage.
- Most efficient when **digging above track level**
- Generally used for cutting and loading
- Suitable fo

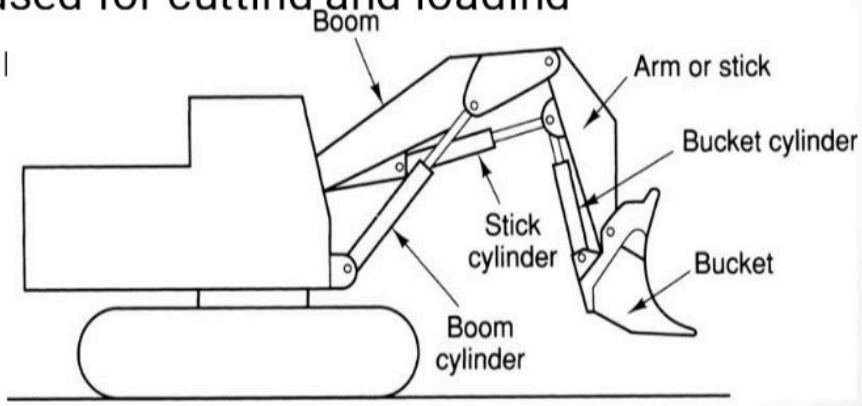


FIGURE 3-7. Components of a hydraulic shovel.

Front Shovel

Front Shovel

Dragline:

- The dragline has the longest reach for digging and dumping.
- It can dig from above machine level to significant depths in soft to medium-hard material
- Generally used for bulk excavation in loose soils below its own track level and in marshy lands and areas containing water
- t excavation, cutting and

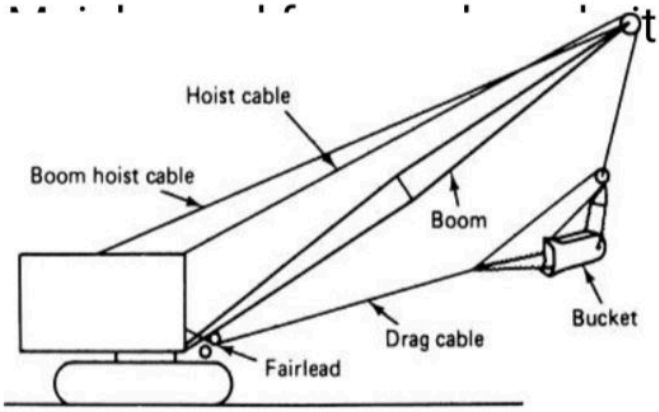


FIGURE 3-10. Components of a dragline.

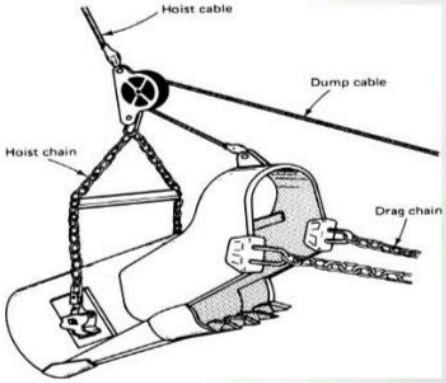


FIGURE 3-11. Dragline bucke

FIGURE 3-10. Components of a dragline.

Clamshell or grab

- Clamshells are commonly used for excavating vertical shafts (confines cuttings) and footings, unloading bulk materials from rail cars and ships, and moving bulk material from stockpiles to bins, hoppers, or haul units
- Heavy buckets: medium soils.
- Medium buckets: general-purpose work,
- Light buckets: For handling bulk materials such as sand and gravel

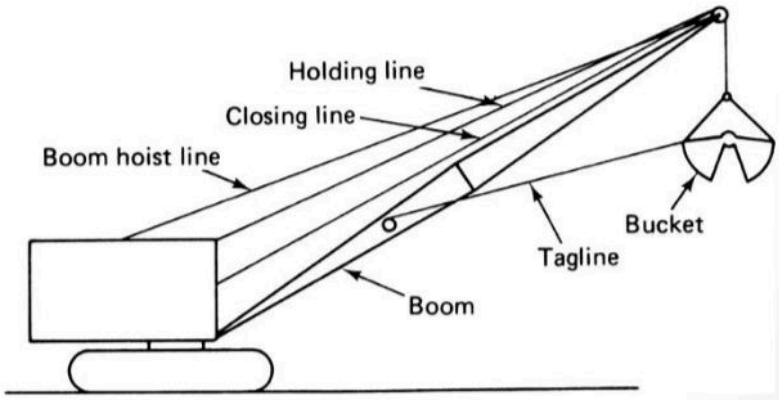


FIGURE 3-13. Components of a clamshell.

Clamshell or grab

- When the **closing line is released**, the counterweights cause the bucket halves to open as the bucket is held by the holding line. Bucket penetration depends on bucket weight assisted by the bucket teeth.

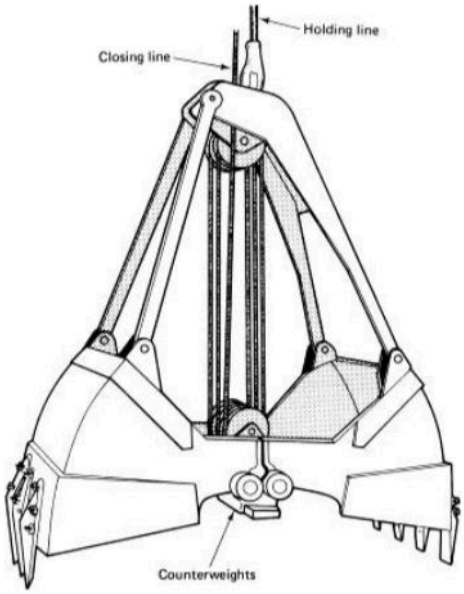


FIGURE 3-14. Clamshell bucket.

FIGURE 3-15. Orange peel bucket. (Courtesy of ESCO Corporation)

PLACING

- **Bull-Dozer : designed primarily for cutting and pushing the material over relatively short distances.**
- **Scrapers : to scrap the ground and load it simultaneously and transport it over the required distance, dump and spread the material over the required area.**

Dozers:

- Dozers can be track laying crawlers or wheel tractors equipped with a blade. Crawler tractors exert low ground-bearing pressure.
- Dozers are standard equipment for land clearing, dozing, and assisting in scraper loading.
- The main purpose of dozers is to move earth and can be used in shallow excavation and can also act as a towing tractor
- They can be equipped with rear mounted winches or rippers.
- Blades can be

1. Normal blades
2. Angle blades
3. Special purpose blades

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Scraper:

- Used for site stripping and levelling, loading and hauling over long distance.

OPERATION OF SCRAPER

A scraper is pushed forward by a Dozer

It's blade cuts a thin slice of a earth usually between 100 mm to 250 mm thick over a distance of nearly 30 m.

The earth is automatically collected in the bowl located at the centre of the machine.

The bowl capacity ranges from 5 cum to 20 cum and takes nearly half to one minute for loading.

When the scraper is fully loaded its bottom opening is closed through a table operated by the operator.

At the dumping yard as the Scraper moves, the bottom opening of bowl is opened, and the contents of earth are unloaded in the layer

COMPACTION

- **Can be defined as process of densifying or increasing the unit weight of a soil mass through the application of static or dynamic force, with the resulting expulsion of air and in some cases moisture.**

Roller Compactor:

- For compaction of earth or other material.
- Used for large works of highways, canals and airports.
- Various types of rollers are

1. **Smooth wheeled** - for consolidating stone soling, gravel, sand, hard core, ballast and surface dressings, and for **compacting silty and sandy soils**
2. **Vibratory rollers -** for compacting granular base courses
3. **Pneumatic tyred rollers** - for compacting cold laid bituminous pavements, soft base course materials or layers of loose soil. Also suitable for compacting **closely graded sands, and fine-grained cohesive soils**
4. Sheep foot roller - used for compaction of cohesive soils such as **heavy clays and silty clays**. Not effective with sandy soils

Pneumatic Roller

Field Compaction

Smooth Wheeled Roller

Compacts effectively only to 200-300 mm; therefore, place the soil in shallow layers (lifts)

Field Compaction

Vibrating Plates

- for compacting very small areas
- effective for granular soils

Field Compaction

Sheepsfoot Roller

Provides kneading action; “walks out” after compaction

- Very effective on clays

Field Compaction

Impact Roller

- Provides deeper (2-3m) compaction. e.g., air field

GRADERS

- Graders are used for leveling and smoothening the earth work, spreading and leveling the base courses in the construction of roads and air field pavements.
- It can also be used for land reclamination, snow clearance and stabilization

Grader:

- Grader can be used for **crowning and levelling** roads, mixing and spreading materials, ditching and bank sloping, blade mixing asphalt materials, snow removal, and scarifying.
- Used in construction and maintenance of roads and runways, moving large amounts of materials laterally by side casting.

Dumpers:

- For horizontal transportation of materials on and off site.
- Side and rear dump trucks dispose of materials through the body attached to the chassis of the truck.
- Bottom dump trucks have two gates that open from the bottom to dispose of materials. For tougher terrain, articulated dump trucks are used.

Rippers

- Characteristics of material to be ripped influence the selection of ripper type, number of shanks required, ripping speed and amount of ripper penetration. For hard material single shank is preferred, but where material is easily penetrated and fractured into small pieces, a two or three shank ripper is used.
- The rippability of material is related to speed of a sound wave travels through the medium.