Construction Project Management

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CONSTRUCTION PROJECT MANAGEMENT

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1 CONSTRUCTION PROJECT MANAGEMENT

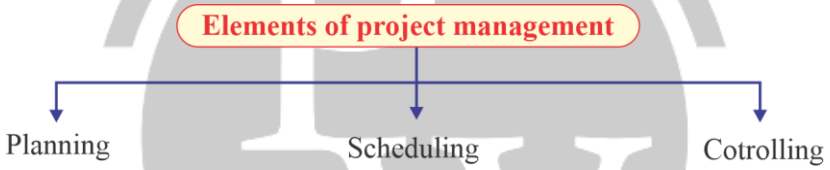
Project management is the art of organizing the components of a project, whether the project is development of a new product, launch of new service or a wedding.

1.1 Objective of Project

(a) To complete project in minimum time period

(b) Use of available manpower and local resources.

(c) Complete of project with minimum cost and without delay.



1. Project Planning:

	Tools for planning
Setting goals	Time and cost ultimates
Defining the project	Budgets
Tying needs into timed project	Cash flow charts
Activities	Material availability details
Organising the term	Engineering diagrams

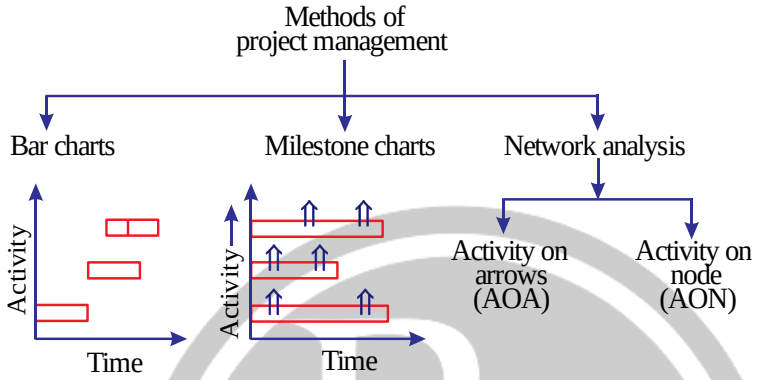
2. Project Scheduling:

	Tools for planning
Assigning resources	CPM and PERT
Relating activities to each other	Milestone charts
Updating and revising	Cash flow schedules
	Gantt chart

3. Project Controlling:

	Tools for controlling
Monitoring resources	PERT chart
Revising and changing plans	Reports of delayed activities
Shifting resources to meet time, Cost and quality demands	Slack activities and Quality of work completed

1.2 Methods of Project Management



1. **Bar charts:** Also known as Gantt chart. Introduced by Henery Gantt in 1900 AD

Advantages:

(a) Simple to draw
(b) No special skill required
(c) Progress expressed as percentage
(d) Resource requirement can be depicted
(e) Visual representation of the project

Limitations:

(a) Lack of degree of details
(b) Review of project progress
(c) Activity inter-relationship not shown
(d) Uncertainty in time determination
(e) Critical activities not shown
(f) Optimum cost cannot be found out

2. **Milestone charts:** Milestone can be considered to be specific event along the main activity. By milestone charts, the relationship b/w two specific milestones on an activity is revealed where as interdependency among milestones between different activities is not indicated.

> **Note:** Bar chart is activity oriented where as milestones chart is event oriented.

3. **Network analysis:** It is a graphical and logical model or plan which lists out the sequence of various activities (with interdependencies) which are required for completion.

> **Note:** AON is widely used for repetitive task where as AOA are considered better for complex projects where there is not a high degree of repetitive work.

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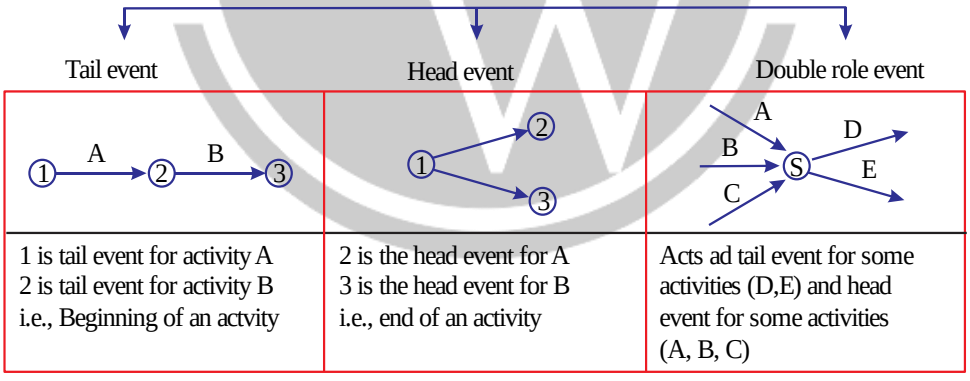
2 FUNDAMENTALS OF NETWORK

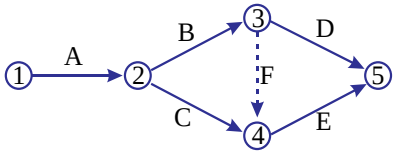
Network is a flow diagram consisting of activities and events connected logically and sequentially.

Activity: A project can be broken into various jobs in the form of operation's and each operation **consuming time or resource** is called an activity. It is denoted by an arrow, where length of arrow has no significance. Arrows are usually drawn from left to right.

Event: It's an instant of time at which some specific milestone has been achieved. An event does not consumes any time or resource. It denotes the start or completion of an activity, and is represented as nodes of different shapes like circular, rectangular, square or oval.



Dummy Activity: It is an artificial activity represented by dashed arrows which neither consumes any time nor resources.



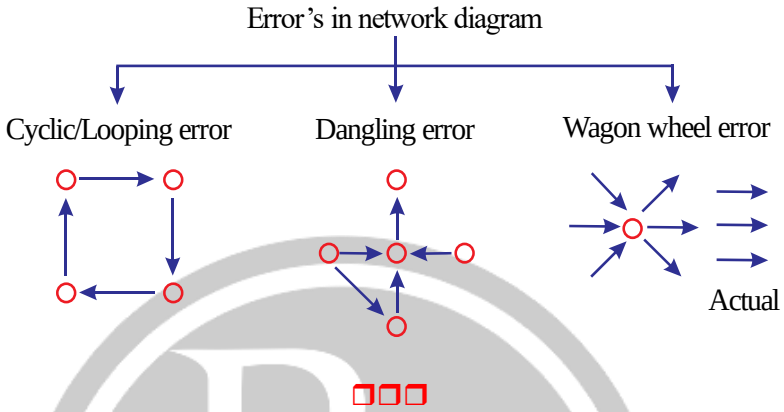
Activity *F* is a dummy activity. Dummies maintain the logic of network diagram and keeps the numbering system of the network unique.

Rules for providing dummies:

1. If dummy is the only activity coming out from a node and terminating into some other node. The dummy can be removed and the two nodes at the two ends of dummy can be merged into one.
2. If dummy is the only activity terminating into a node, then dummy can be removed and the nodes at the two ends of the dummy can be merged into one.

3. If two or more activities, emanating from different nodes and having same set of preceding activities then the two activities should emanate from a single node.
4. If two or more activities having same set of successors and succeeding activities are having other predecessors as well, the two activities should terminate into one single node.
5. Dummy activities which shows predecessor relations already implied by other activities are called asRedundant dummies and can be removed.

Note: System of numbering of events in a network diagram in order to maintain the logical sequence is given by FULKERSON'S Rule.

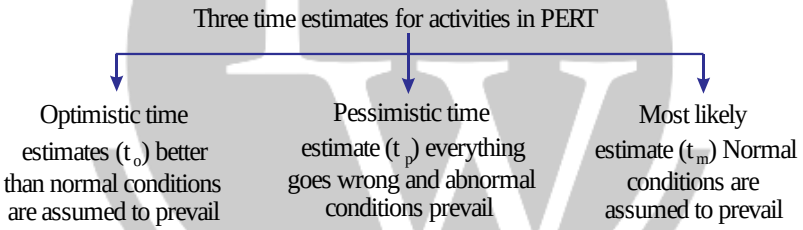


3 PROGRAMME EVALUATION REVIEW TECHNIQUES

PERT was developed by **US Navy** in late 1950's to accelerate the development of Polaris Fleet Bullastic missile.

Total project duration depends on time taken by each activity and estimation of these time estimates can be done in two ways.

Note:
PERT follows the probalistic approach and absorbs uncertainities into the time estimates for activity and project duration.



Mean time ($\bar{x}$): $\bar{x} = \dfrac{x_1 + x_2 + x_3 \ldots + x_n}{n} = \dfrac{\Sigma x}{n}$

Deviation (δ): $\delta = x - \bar{x}$

δ = deviation of any value x

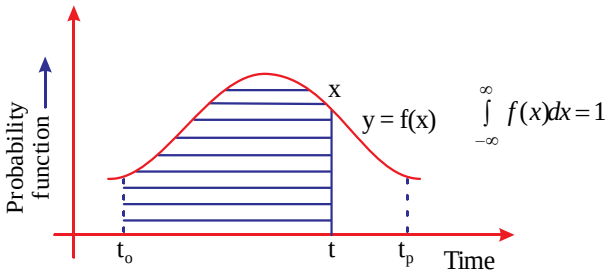
x = value under consideration

Variance (σ^2): $\sigma^2 = \dfrac{\Sigma \delta^2}{n} = \dfrac{\Sigma (x - \bar{x})^2}{n}$

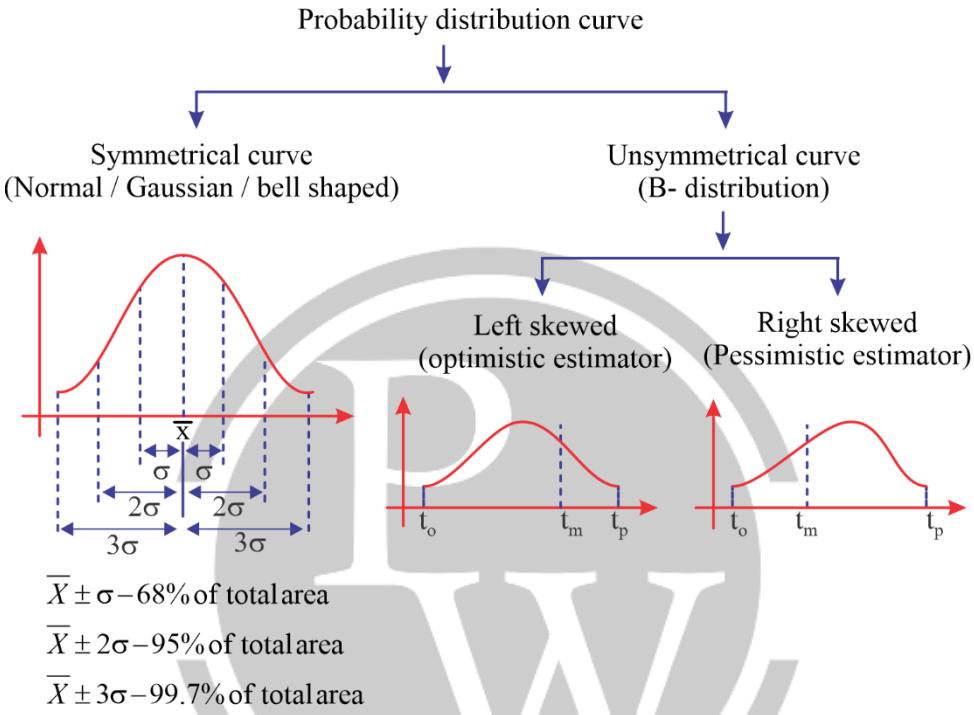
Standard deviation (σ): $\sigma = \sqrt{\sigma^2} = \sqrt{\dfrac{\Sigma (x - \bar{x})^2}{n}}$

Note: Variance is the measure of uncertainty. Greater the variance, greater will be uncertainty.

Probability distribution: It is the plot of probability density function f (x) with the height of curve standardized such that area under the curve is equal to unity.



Probability at any point x is equal to the shaded area only as the total area is equal to unity.



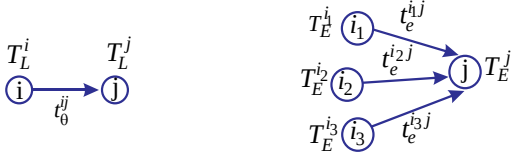
Expected time (te) of an activity: The average of mean time taken for the completion of an activity is called expected time. It is calculated by weighted average method. and the probability of completion of workon expected time is 0.5.

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

Note: According to central limit theorem, in a network of number of activities are in series (as in critical path), the expected time for the path along the activities is the sum of the expected time of activities.

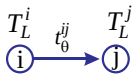
Event Time

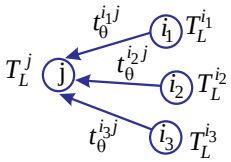
1. **Earliest expected event occurrence time (T_E):** Minimum time in which an event can occur. It is determined by forward pass method.



$$T_E^i = T_E^i + t_e^{ij} \qquad T_E^j = \text{maximum}\begin{cases} T_E^{i_i} + t_e^{i_1 j} \\ T_E^{i_2} + t_e^{i_2 j} \\ T_E^{i_3} + t_e^{i_3 j} \end{cases}$$

2. **Latest allowable occurrence time (T_L):** Maximum time of an event by which it may be allowed to occur without affecting the completion time of project. It is determined by backward pass method.





$$T_L^i = T_L^i - t_e^{ij} \qquad T_L^i = \text{Minimum of}\begin{cases} T_L^{j_1} - t_e^{ij_1} \\ T_L^{j_2} - L_e^{ij_2} \\ T_L^{j_3} - t_e^{ij_3} \end{cases}$$

Slack: It is associated with an event. It is the difference between the latest allowable occurrence time and earliest expected occurrence time of the event.

$$S = T_L - T_E$$

Types of slack

Positive Slack	Zero Slack	Negative Slack
$T_L > T_E$	$T_L = T_E$	$T_L < T_E$
Event ahead of schedule, Excess resources deployed	Event is on schedule, resources just adequate	Event behind schedule, resources not enough

Critical path: Longest path in terms of time or most time consuming path from beginning to end of the network OR. It is the shortest path in terms of time in which the project can be completed as early as possible. Events on critical path will have zero or minimum slack.

Note: Most critical path in a network diagram having multiple critical path will be the critical path which has larger variance (or larger standard deviations) along the path.

Probability of Completion of Project (Steps)

1. Determine σ along critical path

$$\sigma = \sqrt{\Sigma\left(\frac{t_p - t_o}{\sigma}\right)^2}$$

Where t_p and t_o belong to activities lying on critical path only.

2. Determine probability factor or normal deviate (Z)

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

T_S = Scheduled completion time,

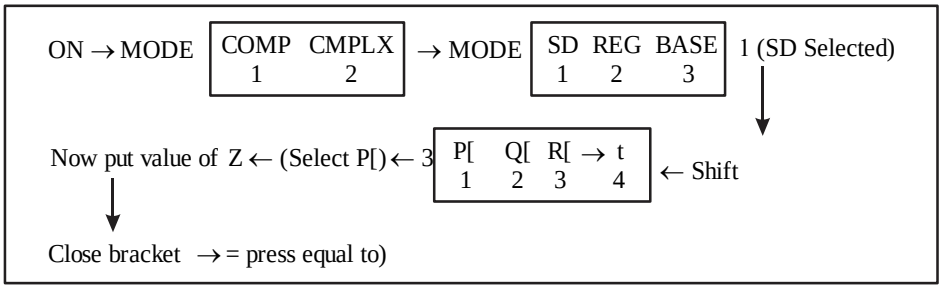
T_E = Expected completion time

where $T_E = te_A + te_B + te_C + te_D + \ldots + te_z$

$A, B, C, \ldots Z$ are activities on critical path.

3. Find % Probability with respect to normal deviate from table or calculator.

Note: Calculation of probability from CASIO Fx-991 MS (where SD = std. deviation and P = probability)
ON → MODE → MODE → 1 → Shift → 3 → 1 → Now put value of Z →Close bracket



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4 CRITICAL PATH METHOD

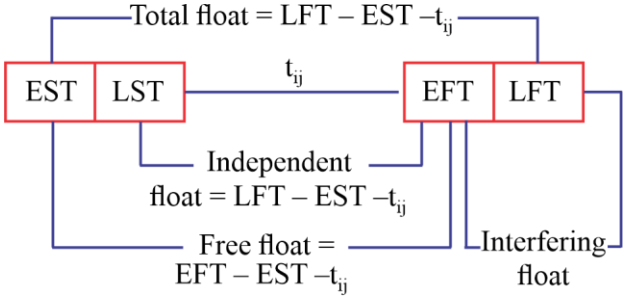
- M.R. Walker and J.E. Kelley of Ramination Rand developed CPM for the construction of chemical plants in united states.
- It is used in construction projects when there is prior experience in handling similar projects from which relationships between resources and job time are available.

Comparison between PERT and CPM

PERT	CPM
1. Probabilistic approach	1. Deterministic approach
2. Event oriented	2. Activity oriented
3. Three time estimate	3. Single time estimate
4. β-distribution	4. Normal distribution
5. Cost is proportional to time	5. Cost model is developed
6. Concept of slack	6. Concept of float
7. Critical path by joining critical events	7. Critical path by joining critical activities.

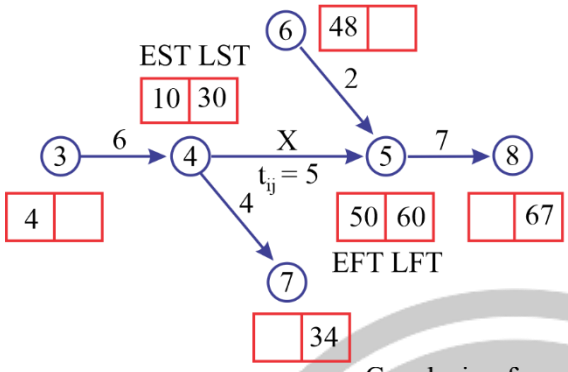
Note: Time estimate of an event has greater range of variation hence greater uncertainty and therefore probabilistic approach is used. While the time estimate of an activity has narrow range of variation hence the single timed deterministic approach is used.

Float: It indicates the time by which, starting or finishing of an activity can be delayed without affecting the project completion time.

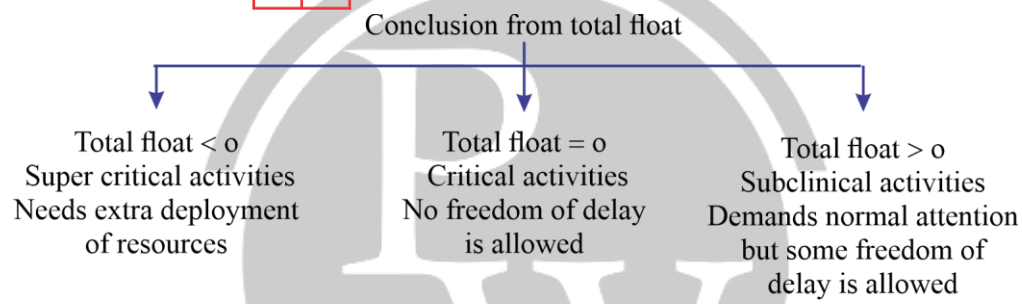


1. **Total Float:** It is the difference between **maximum time available** and actual time required for the completion of the activity. It is the measure of particular activity but depends on the succeeding and preceding activities.

2. **Free Float:** It is the amount of time by which an activity can be delayed **without affecting the EST of the succeeding activity** free float is the amount of time an activity can be delayed without affecting the commencement of a subsequent activity at its EST but may affect the float of a previous activity.
3. **Independent Float:** It is the difference of total float and free float of an activity. It is also equal to the slack of head event of head activity.
4. **Interfering Float:** It is the difference of total float and free float of an activity. It is also equal to the slack of head event of head activity.



For activity 'X' of 5 day duration.
Total float = 60 – 10 – 5 = 45
Free float = 50 – 10 – 5 = 35
Independent float = 50 – 30 – 5 = 15
Interfering float = 60 – 50 = 10
or TF – FF = 45 – 35 = 10



Note: For critical path, all the four floats are generally zero because critical path passes through those events where slack is zero and this is only a necessary condition but it is not sufficient condition.

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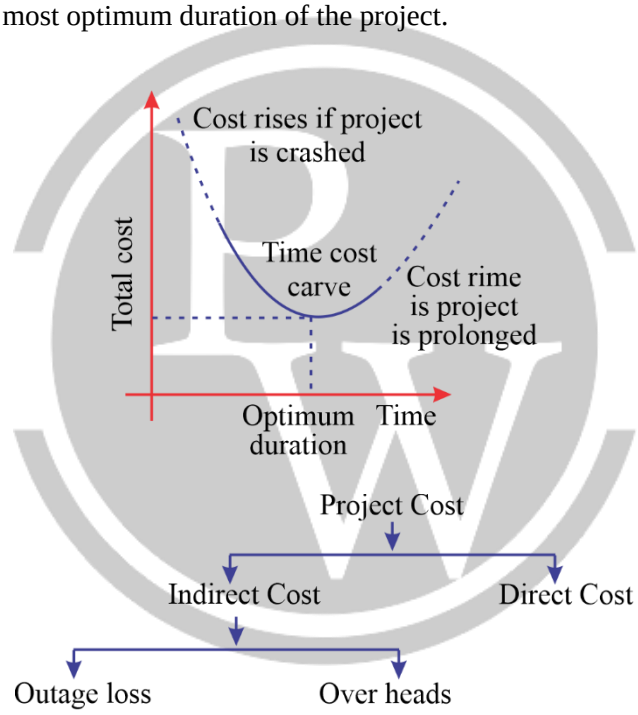
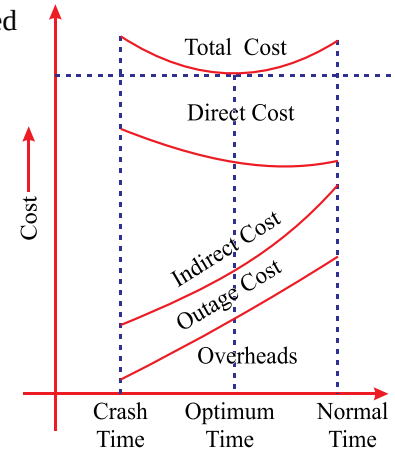
5 CRASHING

CRASHING

Cost Mode Analysis: It shows relationship of the cost versus the completion time. Project time corresponding to minimum value of the cost function gives the most optimum duration of the project.



- **Indirect cost of the project** are those expenses which cannot be associated or assigned to any individual activity of the project.
- **Outage loss:** Loss in profit, liquidity damage, or penalty for delay in project completion.
- **Overhead charges:** Establishment charges, insurance charges, expenditure for maintenance of service.

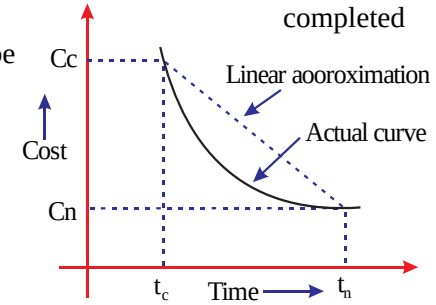


Note: Indirect cost always increases with time. Hence in crashing when we reduce time, our indirect cost is saved although it increases non linearly with time but for ease in calculation we assume that indirect cost varies linearly with time.

Direct cost: Direct cost of the project are those expenses which are directly chargeable and can be identified by **activities** e.g., cost of material, machine, labour etc. The project has highest cost corresponding to cash duration and normal cost corresponding to normal duration.

Cost Slope of Direct Cost Curve

1. **Normal time (t_n):** It is the standard time that a estimator will assign to an activity.
2. **Crash time (t_c):** It is the minimum possible time in which an activity can be completed by assigning extra resources. OR it is that time before which an activity cannot be completed even by application of infinite number of resources.
3. **Normal Cost (c_n):** It is the direct cost of an activity associated with the normal time.
4. **Crash cost (c_c):** It is the direct cost of an activity corresponding to crash time



$$\text{Cost slope} = \frac{C_c - C_n}{t_n - t_c}$$

Crashing potential of an activity = Normal time – Crash time

Cost slope indicates the increase in direct cost when the activity is reduced by one day.

Note: Optimum project duration is the time corresponding to that point on the total cost VS time curve where the tangent drawn to the curve is horizontal.

Crashing

The process of reduction of the total project duration along the longest path (time wise) of the network i.e., along the critical path to obtain the optimum project cost and optimum duration.

Important Points in Crashing

1. Crashing is always done of the activities lying on critical path.
2. Activity which has least cost slope is to be crashed first.
3. Cost of the project increases by direct cost invested and reduced by indirect cost saved.

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6 UPDATING AND RESOURCE ALLOCATION

The process of reviewing the progress of project, execution and redrafting the network according to latest requirements is called **updating.**

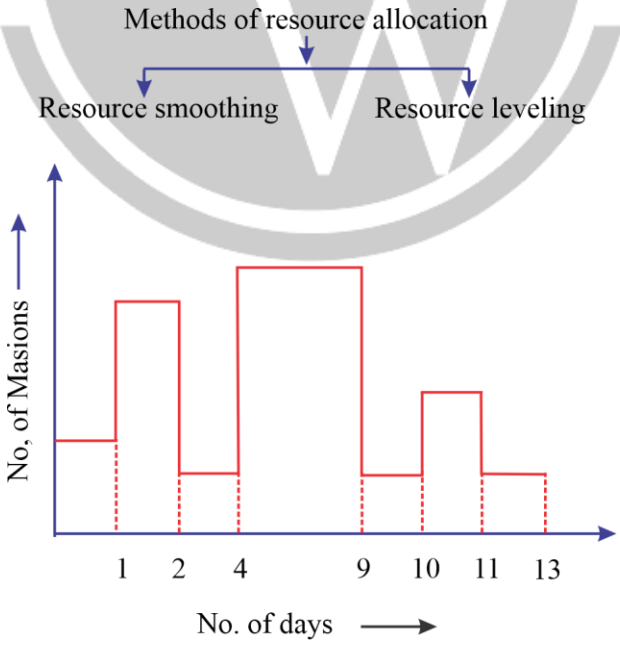
When to Update

1. It is done whenever there is a major change in the duration of any of the activity.
2. For smaller project, frequent updating is necessary because any slippage will have large impact on project duration.
3. For large project, the process of updating must be increased as the project progresses towards the completion.

Note: Updating is mandatory for critical activities.
- During updating, activities are neither added to deleted.
- Critical path as well as critical activities may get changed.

On any major change in duration, updating becomes compulsory.

Resource: It is the physical variable required for completion of activities. It can be material, man power, machinery, space, money or time. Resource allocation is deciding the resources to each activity.



Note: Fluctuations in demand of easily available resource like unskilled labour or some material will not cause much effect of the project. But if it is a rare available resource like skilled professional or some special equipment then they have to be hired or employed on permanent or semi-permanent basis.

Resource Smoothing: In this the total project duration is not changed but the activities having float are rescheduled such that a uniform demand for the resources is achieved. In this the resources are considered to be unlimited and the critical path of the project remains unchanged.

Resource Levelling: In resource levelling, the activities are so rescheduled such that maximum or peak demand of the resource does not exceed the availability of resources. In levelling, the resources are limited and the critical path may get changed (so project duration will also get changed).

Note:

- **Smoothing :** Floats are re-scheduled.
- **Leveling :** Resources are limited

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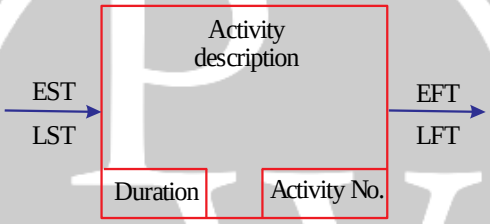
7 PRECEDENCE DIAGRAM

Precedence Diagram

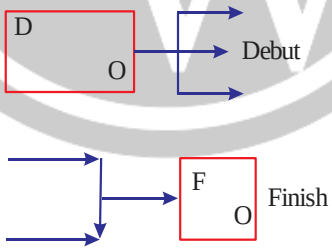
It is activity on nodes network system (AON) where nodes represent the activities and the arrow represent their interdependence or precedence relationship. It represents the logical and sequential inter-relationship between various components or activities.

Representation of Nodes

Usually square or rectangular shapes are to be used but circles and other geometrical shapes can also be used.



When a number of activities start simultaneously, an activity called **DEBUT** (D) is provided as the first activity, though such an activity may not exist similarly when a number of activities finish together an activity is called **FINISH** activity.



Note: Both Debut and Finish activities do not consume time.

Advantages of AON over AOA

1. It Eliminates use of dummies
2. Easy revision and modification
3. Pre and post operation activities are clearly depicted.
4. It is self sufficient and self explanatory as all activity times are shown on network itself.
5. Overlapping and separation of activities is easily shown.

Note: As Events have no place in AON network, hence it cannot be used in PERT analysis.

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8 ENGINEERING ECONOMY

ENGINEERING ECONOMY

- **Time Value of Money:** It means that two equal amount at different points of time do not have equal value if the interest rate is greater than zero. Therefore the value of money is not constant. The rate of interest is used to determine the difference between what is borrowed and what is to be repaid.
- **Interest:** It is the rent paid for use of resource. It is expressed as a percentage of principal amount of an asset or a resource for its use over a period of time.
- **Simple Interest:** When the total interest earned or charged is directly proportional to the principal involved, the interest rate and the no of interest periods for which the principal is committed, the interest is called simple interest.

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

SI = Simple Interest

P = Principal

n = no of years

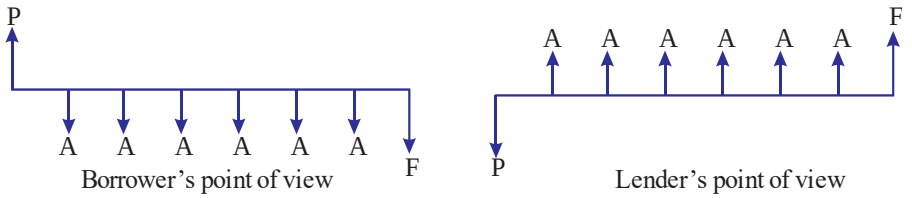
i = rate of interest per year

- **Compound Interest:** Whenever the interest charged for any interest period is based on the remaining principal amount plus any accumulated interest charges upto the beginning of that period, the interest is said to be compound interest.

Note: During simple interest calculation, principal amount remains same as the 1st basic principal amount. But during compound interest principal amount various as the interest period vanes.

Cash Flow Diagram

The graphical presentation of each value plotted as appropriate time is called cash flow diagram. In cash flow diagram, usually time is drawn on horizontal axis on an appropriate scale here as the y-axis represents the amount involved in the transaction, with the receipts (benefit) on the positive side and disbursement (cost) being drawn on the negative side of the y-axis.



Notations:

i = Annual interest rate.

n = Number of annual interest periods

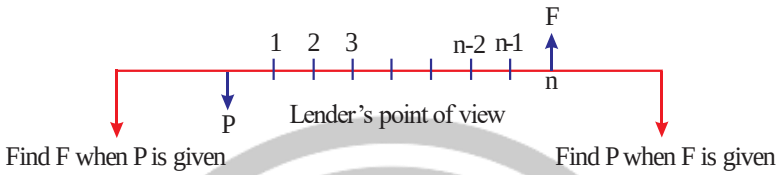
p = Present sum of money

F = Future sum of money

A = A single payment, in a series of n equal payments.

G = Uniform period by period increase or decrease in amount (the arithmetic gradient)

Interest Formula for Single Payment Series



$$\frac{F}{P} = (1+i)^n = \text{SPCAF}$$

SPAC = Single payment compound amount factor

$$\frac{P}{F} = \frac{1}{(1+i)^n} = \text{SPPWF}$$

SPPWF = Single payment present worth factor

Interest formula for equal payment series

1. Find P when A is given

$$\frac{P}{A} = \left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] = \text{USPWF}$$

USPWF = Uniform series present worth factor.

2. Find A when P is given

$$\frac{A}{P} = \left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] = \text{CRF}$$

CRF = Capital recover factor

3. Find F when A is given

$$\frac{F}{A} = \left(\frac{(1+i)^n - 1}{i}\right) = \text{USCAF}$$

USCAF = Uniform series compound amount factor

Uniform series also known as equal series.

4. Find A when F is given

$$\frac{A}{F}=\left[\frac{i}{(1+i)^n-1}\right]=\text{SFF}$$

SFF = Sinking fund factor

Compound Interest Factor					
Single payment	To find	Given	Factor by which to multiply with given	Factor name	Functional rotation
	P	P	$(1+i)^n$	Single payment compound amount factor	$\left(\frac{F}{P}, i, n\right)$
Uniform series payment	P	F	$\frac{1}{(1+i)^n}$	Single payment present worth	$\left(\frac{P}{F}, i, n\right)$
	P	A	$\frac{(1+i)^n-1}{i(1+i)^n}$	Uniform series present worth factor	$\left(\frac{P}{F}, i, n\right)$
	A	P	$\frac{i(1-i)^n}{(1+i)^n-1}$	Capital recovery factor	$\left(\frac{A}{P}, i, n\right)$
	F	A	$\frac{(1+i)^n-1}{i}$	Uniform series compound amount factor	$\left(\frac{F}{A}, i, n\right)$
	A	F	$\frac{i}{(1+i)^n-1}$	Sinking fund factor	$\left(\frac{A}{F}, i, n\right)$

Interest Formula for Uniform Gradient Series

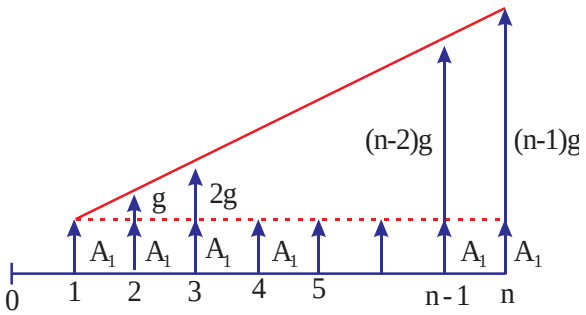
Certain economic analysis problems involve receipt or disbursement that are projected to increase or decrease by a uniform amount each period, hence forming an arithmetic series for e.g.: Maintenance and repair expenses on specific equipment may increase by a relatively constant amount each period, increase in rent each year,

If, g = Annual change in gradient

n = number of years

A_1 = Payment at the end of first year

A_2 = Equivalent annual payment of gradient series $(0, g, 2g \ldots (n-1)g)$ at the end of successive years.



Uniform gradient series

A = Equivalent annual payment of the series.

$A = A_1 + A_2$

where $A_2 = g\left(\frac{1}{i} + \frac{n}{i}\left(\frac{P}{(1+i)^n - 1}\right)\right)$

$\frac{A_2}{g}$ = Gradient factor for annual compounding interest.

An equivalent equal annual payment series

Nominal and Effective Interest Rate

If the interest is compound twice or thrice or more than once in a year then effective interest rate becomes greater than nominal interest rate.

$$\text{Effective Interest rate} = \left(1 + \frac{i}{c}\right)^c - 1$$

i = nominal annual interest rate

c = number of times interest calculated in a year

Capitalised Cost: It is the present worth of a uniform series of amount payed till infinite time (or perpetual service)

$$P = A \lim_{n \to \infty}\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]$$

$$P = A \lim_{n \to \infty}\left[\frac{1 - \frac{1}{(1+i)^{\infty}}}{i}\right]$$

$\Rightarrow$ $P = \frac{A}{i}$

P is called as capitalized value of A.

Comparison of Alternatives

Generally the comparison is done between processes which involve high initial cost and low operation and maintenance cost and the one which involves low initial cost and high operation and maintenance cost.

Methods of comparison are as follows:

1. **Present worth amount:** Present worth of the cash flow in the form of equivalent single sum is calculated using a discounted interest rate. This method is used when cash flow and interest rate is known

Alternative with equal service life	Alternative with unequal service life
Process having lower present worth is termed economical	Common life period is taken by taking the LCM of life periods of both processes and then present worth is calculated.

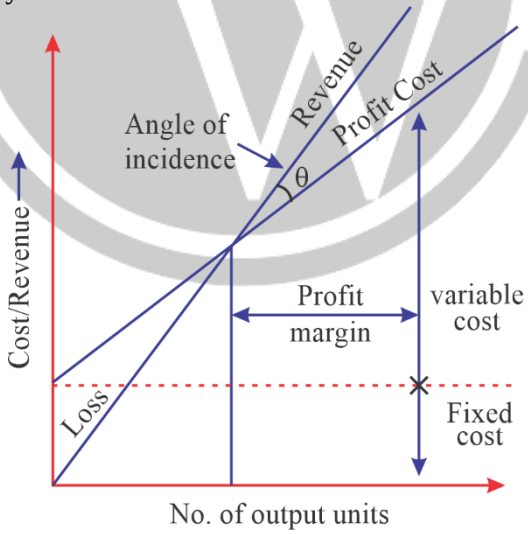
2. **Annual Equivalent Amount:** **(Most Widely Used)** cash flow is converted into a series of equal amount by at first calculating the present worth amount and then multiplying it with capital Recovery factor.
3. **The capitalized amount:** **(Used for long term projects).** The annual equivalent amount obtained is assumed to extend for infinitely long period and then capitalized amount is obtained as $\frac{A}{i}$.
4. **Rate of return method:** Rate of return is the interest earned on the unrecovered balance of an investment such that unrecovered balance is zero at the end of investment life. It represents the interest rate which reduces the present worth amount of a series of receipts and disbursements to zero for each alternative.

Break Even Analysis

It is done to find out the point at which total revenue equals total cost and profit potential under varying conditions of output and cost.

Break even point: is the point of no profit no loss.

Also called as cost-volume-profit Analysis.



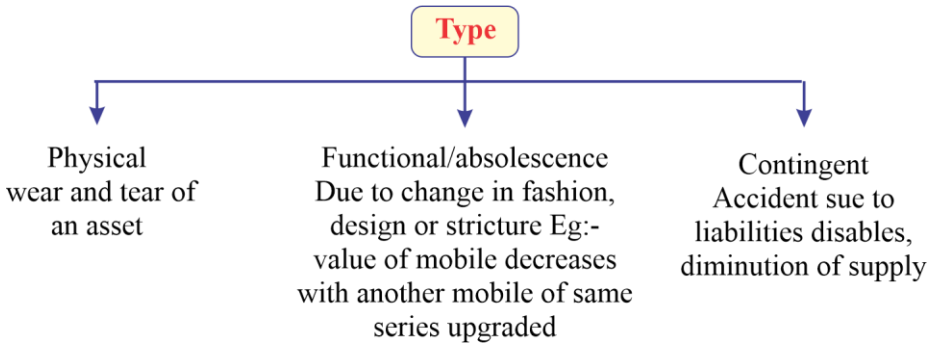
Functions:

1. Helps in selection of favourable business option
2. Possibility of profit is determined at any rate of production
3. Greater the angle of incidence more will be the profit margin.

Limitations:

1. Used generally for small business
2. Does not accounts for different varieties of product produced by the company.
3. Cost/Revenue related to No of output units only, no relation with time.
4. Market conditions do not remain static. Hence, not much useful in that case.

- **Depreciation:** It's the loss in value of asset with passage of time. It is used to calculate, the recovery that has been involved in the possession of the physical property. Or it can be said that, it signifies that an equal amount of fund that should be created out parallely out of profit, so that at the end of service life of the equipment we can buy another one.



- **Salvage Value (Resale Value):** Value of asset at the end of utility period. It implies that asset has further utility but due to some reason it is selling E.g: Selling of household items due to relocation.
- **Scrap Value:** The value of asset when its utility is considered to be as junk or scrap for E.g;: Selling of vehicles after severe accidents, now vehicle cannot be used as whole while some parts can be used.
- **Book Value:** It is the value of asset shown in account books in a particular year. At the end of utility period book value = Scrap value

Book value = Initial cost – Depreciation cost

Note: Not all the assets do not depreciate with time, example land and sometime even gold, platinum etc.

C_i = Original cost or initial cost (cost of asset + Transportation charges + Installation charge + Any other specific charges)
C_s = Salvage/scrap value at the end of utility period
n = Life of the asset
B_m = Book value at the end of period 'm'
D_m = Depreciation charge during period 'm'

Methods of calculating depreciation:

1. **Straight time method:** Asset looses its value by a fixed amount every year

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

$$D_m = D_1 = D_2 .. = D_n$$

$$B = C_i - m\left(\frac{C_i - C_s}{n}\right)$$

2. **Decline Balance method/constant percentage method:** Assets loose their value at constant percentage of its book value.
   Fixed declining balance

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

Note: This method cannot be used when salvage value is zero.

3. **Double decline balance method:** Assets looses its value by a fixed factor of the book value.
   Fixed factor for double decline balance method = FDDB

$$\text{FDDB} = \frac{2}{n}$$

$$B_n = C_i\,(1 - \text{FDDB})^n$$

4. **Sum of year digit method:** Value of asset decreases at an decreasing rate. The digits corresponding to the number of each year of life are listed in reverse order and then sum of these digits in calculated.

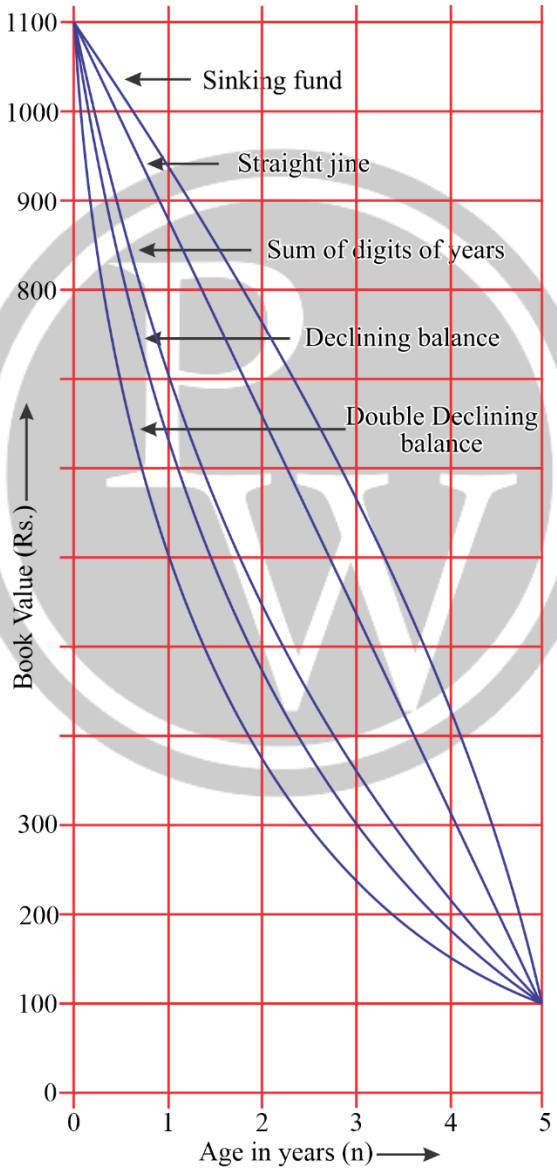
$$D_m = (C_i - C_s)\left(\frac{i}{(1+i)^n - 1}\right)$$

and

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

$$D_1 = D$$

$$D_n = D(1+i)^{n-1}$$



Depletion:

$$\text{Depletion for a year} = \frac{\text{cost of property} \times \text{units sold during that year}}{\text{No. of units in the property}}$$

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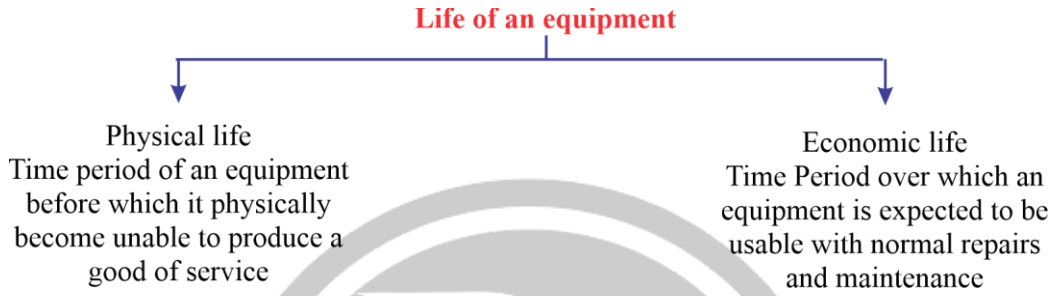
9 FUNDAMENTAL OF EQUIPMENTS



Cost Related to An Instrument

1. **Investment Cost:** It is the fixed cost which is incurred at the time of purchasing equipment, interest on the money invested in buying the equipment, taxes pertaining to the ownership of the equipment, insurance and storage.
   (a) When there is no salvage value

$$P_{av} = \frac{p + \frac{p}{n}}{2}$$

   (b) When there is salvage value

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

   Where, P = Total initial cost
   n = Life in years
   P_{av} = Average value
   S = Salvage value
   Here, book value is based on straight line depreciation.
2. **Depreciation and Replacement costs:**

$$\text{Annual depreciation} = \frac{\text{Initial value} - \text{salvage value}}{\text{Useful life of equipment}}$$

   Replacement cost of the equipment is to be increased by certain percentage every year to balance the increase in cost of equipment every year.
3. **Maintenance and repair cost**
4. **Downtime cost:** Downtime the time when machine is not working because it is undergoing repairs or-adjustments.
5. **Obsolecence Cost:** It by installation of new machine the production cost is reduced by some amount as compared to the production cost of existing machine, then existing machine is said to suffer a loss of that amount and its called obsolescence cost.

Fundamental of Equipment:

1. **Rolling Resistance:** It is a measure of force that must be overcome to pull roll a vehicle over the surface. It is analogous to dynamic coefficient μ

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

R = Rolling resistance (kg/tonne)
P = Required tractive force (kg)
W = Gross weight of vehicle (tonnes)

2. **Grade Resistance:** It is the measure of force that is required to overcome or assist the vehicle up or downhill respectively. Grade resistance is taken as 10 kg/tonne of total weight of unit for each 1% of grade.

> **Note:** Grade resistance is overcome with the help of **drawbar pull (crawler)** or **Rimpull (Rubber tyred)**. It acts against the total weight of both tractor and loading unit.

Total Resistance = Rolling Resistance ± Grade Resistance
Usable Tractive effort = Available tractive effort – Total resistance.

3. **Coefficient of traction:** Maximum fractional force produced between the surface without pulling. (Same as limiting friction) Usable Traction = Coefficient of traction × weight
4. **Drowbar Pull:** It is the pulling force in kg which a crawler tractor can expert on a trailing load (to be pulled). It varies inversely with the speed of each gear. It being highest in the lowest gear and lowest in the top gear.
5. **Rimpull:** It is the force (in kg) that a rubber tyred tractor can exert between the rubber tyres of driving wheels and the surface on which they travel. It is expressed in kg.
   (a) When slippage is eliminated

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

   efficiency ranges 0.80 to 0.80
   (b) When slippage starts before its rated capacity
   Maximum effective rimpull = Total pressure between tyres and surface × coefficient of friction
6. **Combined effect of pressure and temp on I.C. Engine**
   The rated horse power of an I.C. Engine is the power tested under standard conditions of temperature (15.5°C or 60°F) and pressure.

$$H_C = H_O \frac{P_S}{P_O} \sqrt{\frac{T_O}{T_S}}$$

H_C = Corrected horse power for standard condition

H_O = Observed horse power as determined for test.

P_S = Standard barometric pressure (760 mm of Hg)

P_o = Observed barometric pressure in mm of kg

T_o = Absolute observed temp. (Temp in °C + 273)

T_o = Absolute observed temp. (Temp in °C + 273)

Swell and Shrinkage

Bank Volume is the volume of earth measured in situ. It is the volume on which payment is usually made.

Loose Measure Volume is the volume of earth after it has been removed from its natural position and deposited in truck, scrapers or spoil banks.

Compacted Volume or fill Volume, is the volume of earth it has been placed in a fill and compacted.

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

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

$$\text{Swell factor} = \frac{W_i}{W_u} = \frac{100}{100 - \% \text{ of swell}}$$

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

W_u = density of undisturbed earth.

W_i = density of loose earth.

W_c = density of compacted earth.

Capacity of Earth Moving Equipment

- **Struck capacity:** Volume in the body at level measure or water level capacity.
- **Heaped Capacity:** Total volume of material as it is heaped up over the sides with 1 : 1 inclusive of struck volume.

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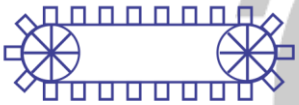
10 EARTHWORK EQUIPMENT

Tractor: The primary purpose of a tractor is to pull or push loads and it may be also used as mount for many types of equipment such as bull dozer, dragline, hoe, trenchers etc.

Crawler tractor

It is the tractor mounted on crawler where crawler is an endless chain consisting of steel links mode of steel plates connected together by pins and bushings



Wheel Tractor

Tractor on wheel's is wheel tractor, in order to attain a higher speed, a wheel tractor mist sacrifice its puling effort and the speech is increased by help of higher gears.

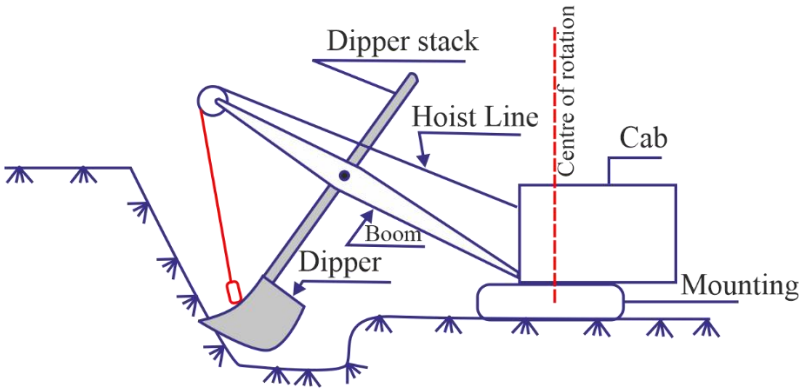
Speed × rim pull = constant

When engine is operated at a rated power

Comparison of Crawler and Wheel Tractor

1. Wheel tractors travel faster.
2. Crawler units are costly, compact, powerful and can handle heavier loads.
3. Wheeled units may slip over smooth surface.
4. Crawler units are controlled by stick hence need greater skill in operation.
5. Crawler units when transported over long distances, they are loaded over trailers as there speed is slow and they are likely to damage pavement.
6. Operational cost of crawler's is much higher as compared to wheeled units.

Power shovels: Shovel is an instrument used for digging, lifting and moving bulk materials. When a shovel is mounted on a power vehicle, its called power shovel.

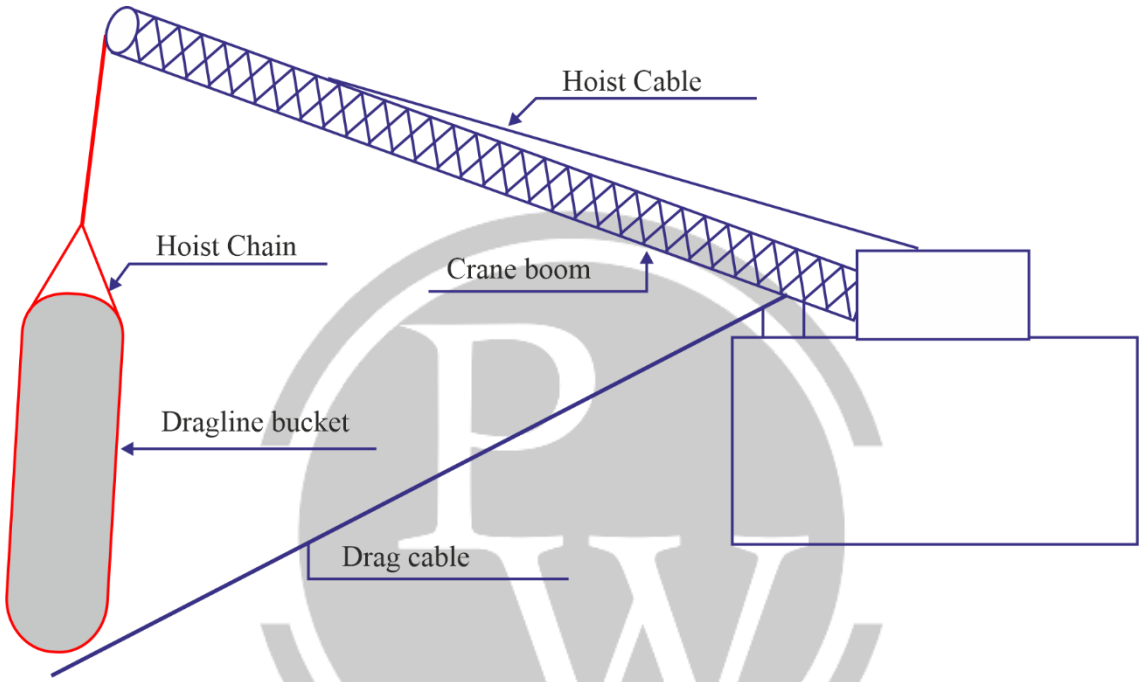


These are mainly used to excavate earth except solid rock without prior loosening and load it into trucks.

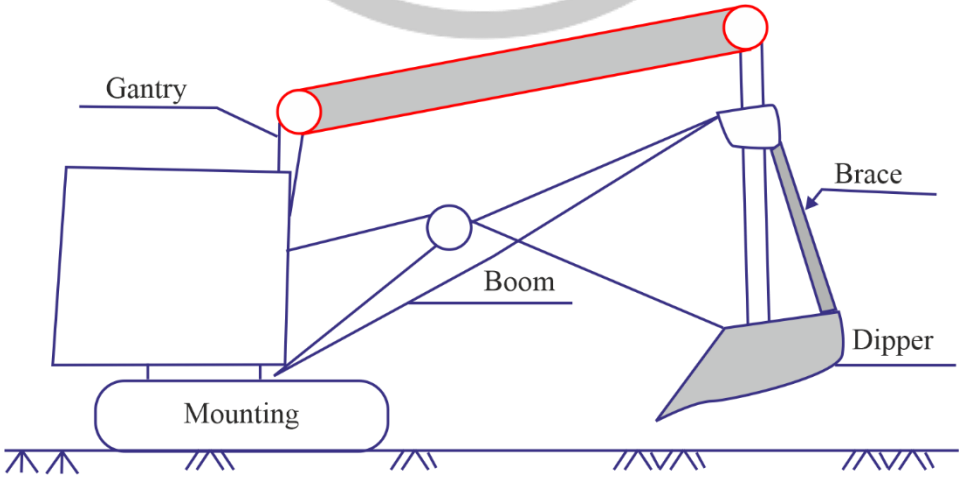
Note: For excavating hard and tough soil, the dipper of large shovel can exert greater downward pressure will be more suitable.

$$\text{Output of shovel} = \frac{\text{Loose volume of dipper}}{1+\text{swell fraction}} \times \frac{\text{Actual time in sec's per hr}}{\text{cycle time in sec's}} \times \text{Efficiency}$$

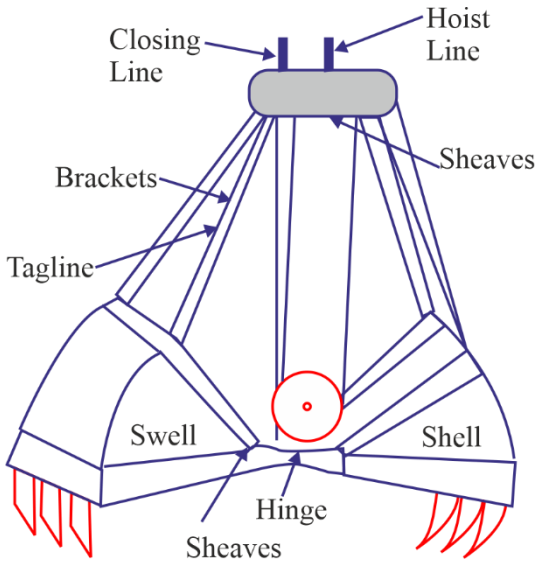
Drag lines: Drag lines are used to excavate earth and load it into hand units. Such as trucker or to deposit it on spoil banks and embankments near the place from where it is excavated. It has long boom to dispose of the earth without any hauling unit. It can excavate below its level and under water, and can also excavate trenches without shoring.



Hoes: Hoe is it long-handle hand equipment having a light blade to dig, scrap, till or weed. Similar machine of a power shovel group is also known as back hoe, back shovel and pull shovel. It is primarily used to excavate below ground level, or below machine track level.



Clamshells: It's a machine having characteristics of crane and dragline. Digging is done like dragline and when bucket is full it works like crane. Especially suited to vertical lifting of materials from one location to another.



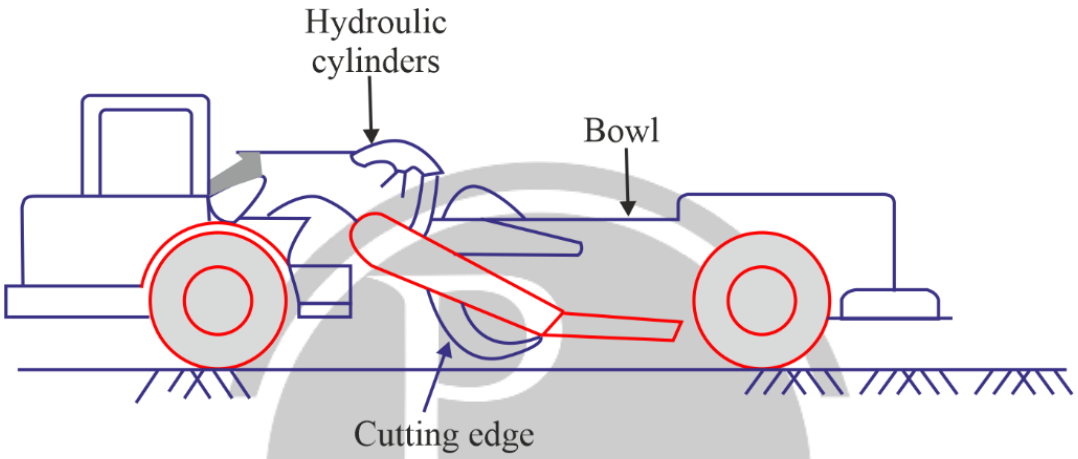
Sl. No.	Items of comparison	Power Shoevel	Back Hoe	Drag line	Clam shell
1.	Excavation in hard soil or rock	Good	Good	Not Good	Poor
2.	Excavation in wet soil or mud	Poor	Poor	Moderately good long	Moderately good long
3.	Distance between footing and digging	Small	Small		
4.	Loading Efficiency	Very Good	Good	Moderately good	Precise but slow
5.	Footing required	Close to work	Close to pit	Fairly away from pit	Fairly away from pit
6.	Digging level	Digs at or above footing	Digs below footing level	Digs below footing level	Digs at or below footing level
7.	Cycle time	Short	Slightly more than power shovel	More than the power shovel	More than the other equipment

Bulldozers: A heavy steel blade mounted on the front of a tractor. This blade pushes the material from one place to another. These are efficient excavating tools for short hauling application upto 100 m.

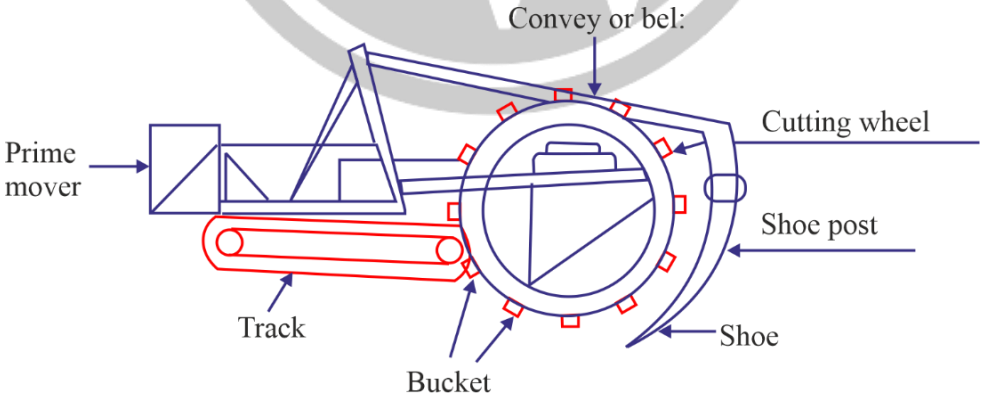
$$\text{Output of a bull dozer in bank measure volume/hour} = \frac{\text{Loose volume of dipper}}{1 + \text{swell fraction}} \times \frac{\text{Actual time in sec's per hr}}{\text{cycle time in sec's}} \times \frac{\text{Actual operating time in minutes per hour}}{\text{Time required per trip in minutes}}$$

Scrapers: Self operating earth moving equipment designed to dig, load, haul and discharge material over the required area without depending on other equipment thesefore its also called as carry all. Equipment. But it is not used for Hard rock, sand which will not pile up into a scraper, wet and muddy material which make discharging of a scraper difficult.

Output = Optimum loose volume per trip × Swell factor × 60 × Efficiency cycle time per trip (in minute)



Trenchers: These provide fast digging with control of depth and width. These can dig any type of material **except rock**. Generally used to dig utility trenches for water, gas and oil pipelines, telephone cables, drainage ditches and sewers. These can also not to be used when there is large quantity of ground water as unstable soil will prevent the trench wall in remaining in its place.



Note: In cohesive soil. It will require more power so better use power shovel or Backhoe.

Motor Graders: Generally used in making and maintaining road projects and land reclamation for earth construction. It is mainly used for levelling or finishing earthwork but sometimes also used for mixing gravel and trimming slopes.

Note: It's output is usually expressed in units of area covered by machine per hour.

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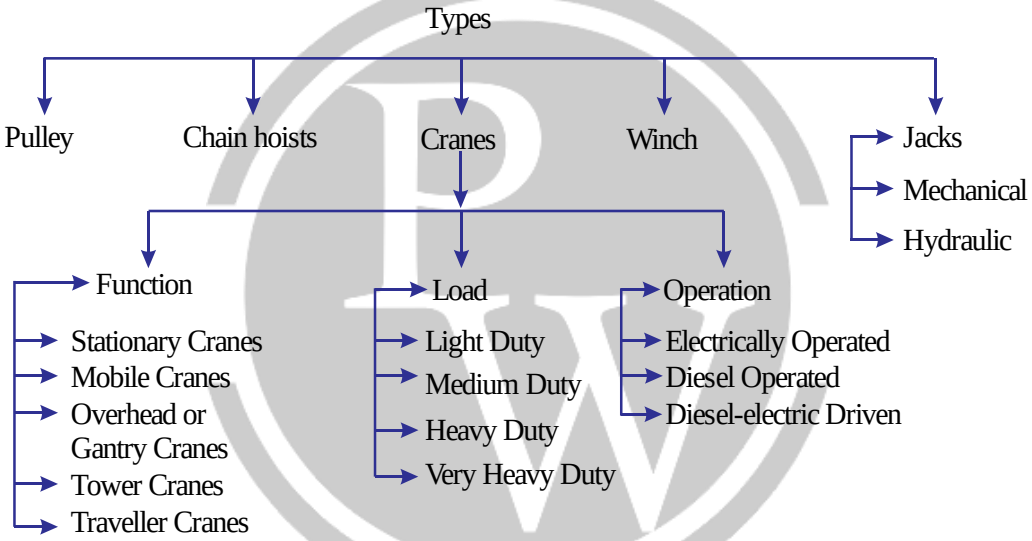
11 HOSTING EQUIPMENTS

Hosting Equipments

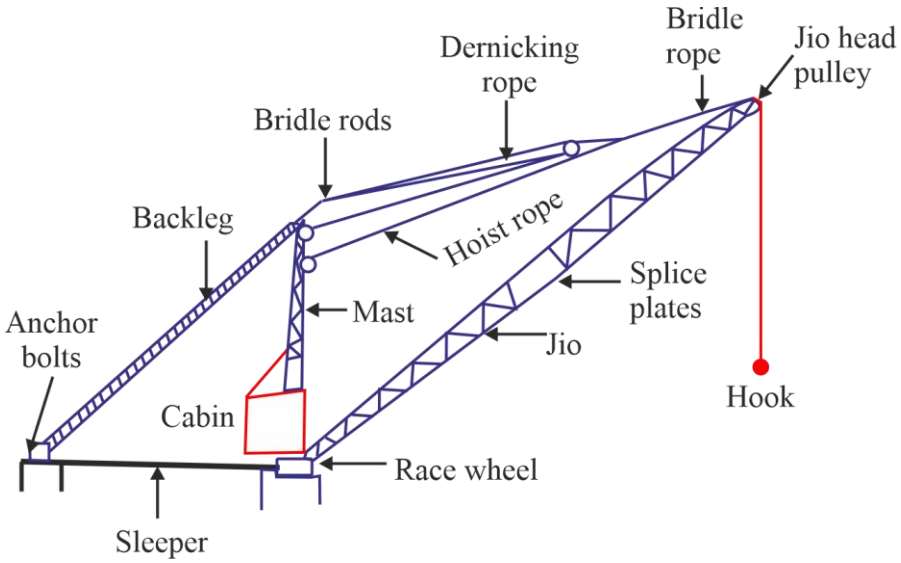
- It is the operation of lifting a weight from one location and moving it to another location which is at reasonable distance and then dumping it.



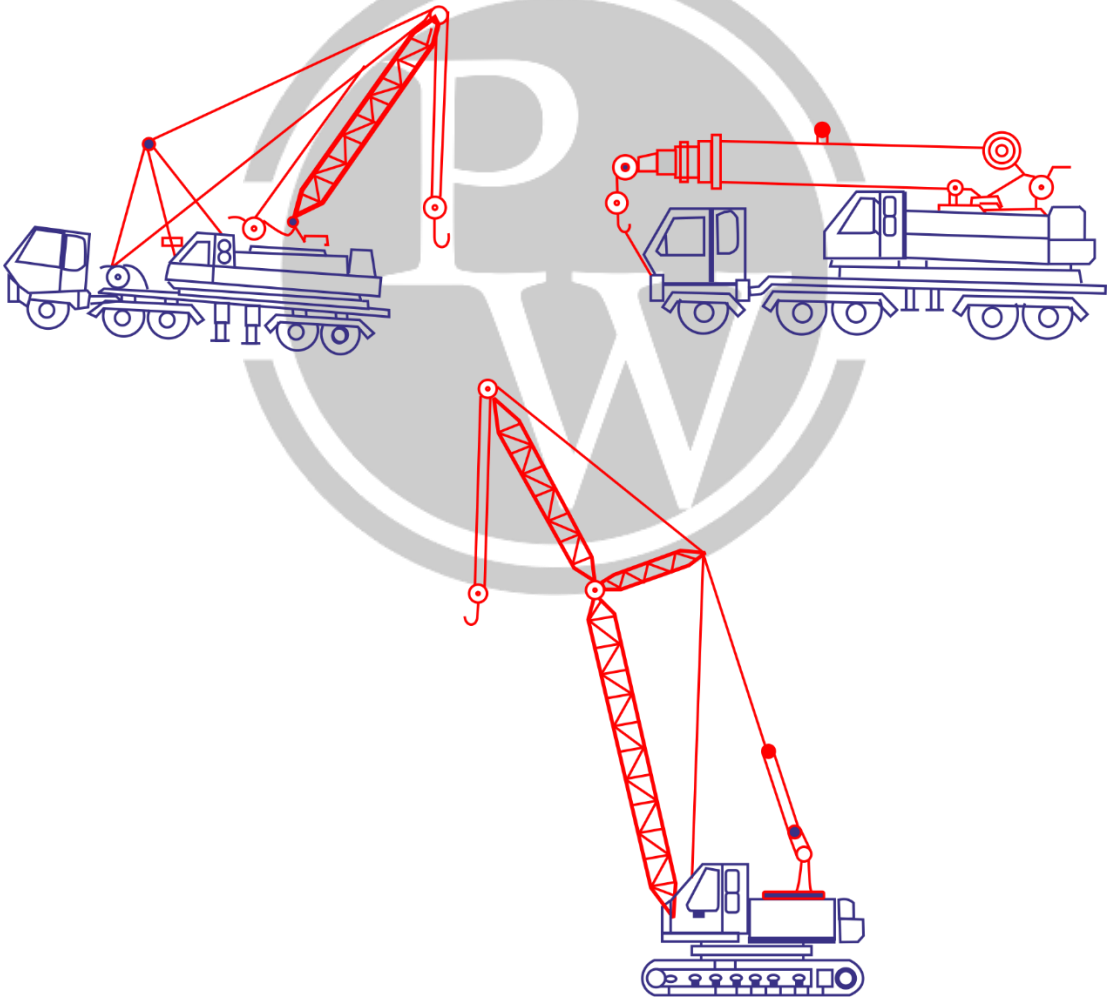
- Pulley and sheaves are used for lifting rough surfaced and heavy objects.
- Chain hoists are used for lifting loads upto 50 tonnes.
- Winch is combination of gears, clutches and brakes. Commonly used in lifting railway gates and its operation is controlled through series of levers.
- Jacks is the short name of screw jack and generally its capacity varies from 5 to 100 tonnes.
- Cranes are the only hosting equipment which is capable of providing three dimensional movement of the weight. Lifting capacities varies from 0.5 to 500 tonnes.

(a) Derrick cranes or stationary cranes:

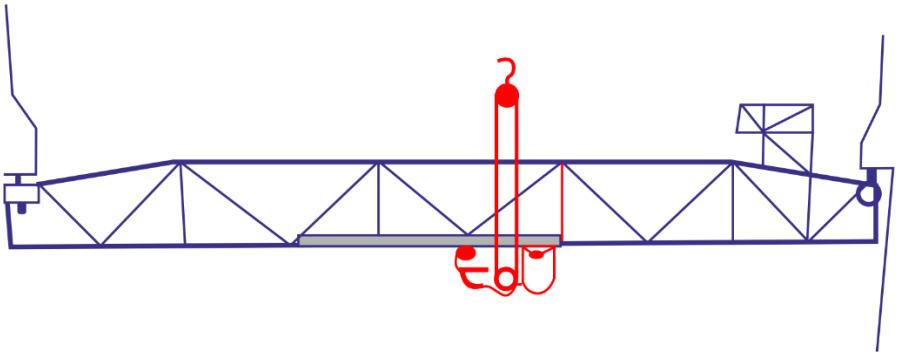
- **Guy derrick:** Used for heavy loads upto 200 tons with 360° rotation.
- **Stiff leg derrick:** Used for load from 7 to 50 tons with 270 – 290° rotation.



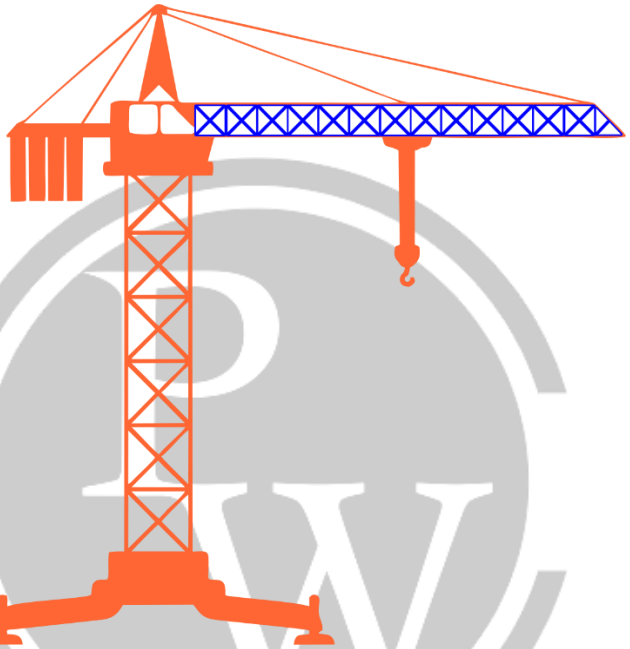
(a) Mobile cranes: These cranes are mounted on mobile Units like rubber tyred track or a crawler. Crawler cranes are economical where ground conditions are poor and operation is to be done with in small area.



(b) Overhead or Gantry Cranes: These type of cranes have freedome from floor obstruction three way motion and can cover large service area hence mostly used in factories, steel plants, storage yards, welding yards, etc.



(c) Tower cranes: Usually employed in erection of high industrial and residential buildings. Also used in assembling high industrial plants and element of steel stricture.



(d) Traveller cranes: A crane mounted on wheels especially an overhead crane consisting of a cab or other hoisting apparatus travelling on rails or beams fixed overhead.

They have their crabs moving on girders which are supported on legs instead of an overhead gantry track as in gantry grider.

Note: It's output is usually expressed in units of area covered by machine per hour.

(a) Manually Operated Vibratory Tamping Compactors: They have an engine drive reciprocating mechanism which acts on a spring system through which vertical oscillation with amplitude of about 10 – 80 mm are set up in the base plate. The most commonly used machines have a mass in the range of 50 – 150 kg and usually operated at frequency of about 10 Hz.

(b) Manually Operated Rammer Compactors: These are self propelled in which each blow moves them ahead slightly to contact new soil. These units range in impact from 40 to 120 per sec at an impact rate upto 850 per min.

Estimated Production of Rollers

$$Q = \frac{\text{Shlnpt}}{N}$$

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

Q = Quantity of compacted earth m^3

S = Speed of roller, m/min

h = Time of rolling, min

l = Length of strum, m

n = No. of drums

p = Percentage fraction of overlap

t = Layer thickness

N = No. of passes required

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