

GATE/ESE

Civil Engineering

Project Management

► Important Formula Notes



IMPORTANT FORMULAS ON PROJECT MANAGEMENT

CHAPTER-1-PROJECT MANAGEMENT

Project Management deals with both 'material' as well as 'human factors' to increase productivity.

Objectives of a Project:

- It should be completed in minimum time with minimum capital investment
- It should use available manpower and other resources optimally.

Phases of Project Management

Planning

Planning involves:

1. Defining objectives of the project.
2. Listing of jobs that have to be performed.
3. Determining gross requirements for materials, equipment and manpower and preparing estimates of costs and duration for various jobs.
4. To bring about the satisfactory completion of the project.

Scheduling

Scheduling is the allocation of resources such as time, material, space, equipment and human and technological effort.

It involves:

1. Finalizing the planned functions mechanically.
2. Assigning starting and completion dates to each activity to proceed in a logical sequence and in a systematic manner.

Controlling

Controlling involves determination of deviations from basic plan and their effects on the project.

- It should be noted that planning and scheduling are accomplished before the actual protection starts while controlling is operative during execution of the project.

CHAPTER-2-FUNDAMENTALS OF NETWORK

Event

- An event is either the start or completion of an activity.
- Events are significant points in a project which act as control points of the project.
- An event is an instant of time and it does not require time or resources.

Following are examples of an event:

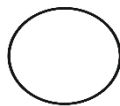
1. All parts assembled
2. A budget prepared
3. Construction completed

Following taskscannot be termed as events:

1. Prepare budget
2. Assemble pals
- 3 Excavate trench

- Events are represented by nodes in a network. It may have any of the following shapes

(I) Circular



(ii) Square



(iii) Rectangular



(iv) Oval



Different Shapes for Events

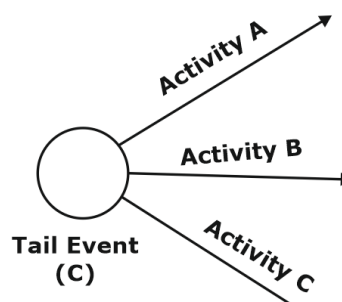
Most commonly adopted shape for events is circular shape.

• Tail event or Start event:

It is the beginning of an activity.

If it is the first event of the project then known as 'initial as start event'.

It has only an outgoing arrow. e.g., Event C is a tail event.



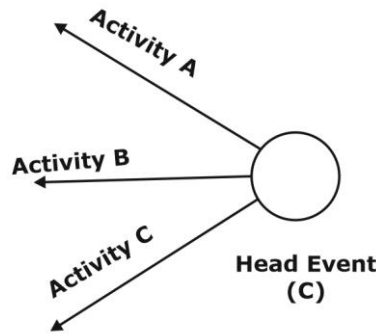
• Head event or Final event:

The event which marks the completion of an activity is known as 'head event'.

If this event represents completion of the entire project, then it is called "Finish event'.

It has only incoming arrows.

E, g.: Event C is a head event.

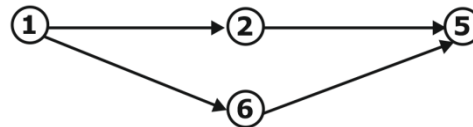


Head Event

(i) When a tail event represents the beginning of more than one activity, then the event is said to occur when the first activity starts from it.

(ii) Similarly, when a head event occurs at the end of more than one activity, the event is said to have occurred only when all the activities leading to it are completed.

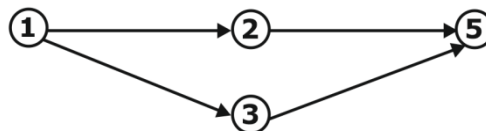
• **Dual role events:** All events except the first and the last event of a project are dual role events. They have both incoming and outgoing arrows.



Dual Role Events

e.g.: Events 2 and 6 are dual role events.

• **Successor events:** The event or events that follow another event are called successor events to that event.



Successor Events

e.g.: Event 2 and 3 are successor events of event 1

• **Predecessor events:** The event or events that occur before another event are called predecessor event to that event.

In the above figure, events 2 and 3 are predecessor to event 5.

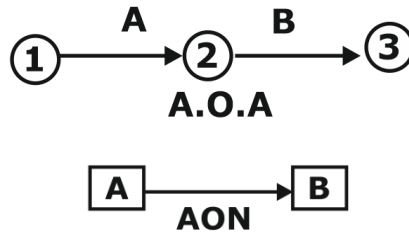
Activity

Activity is the actual performance of a job. It requires time and resources for its completion.

Following are examples of activity:

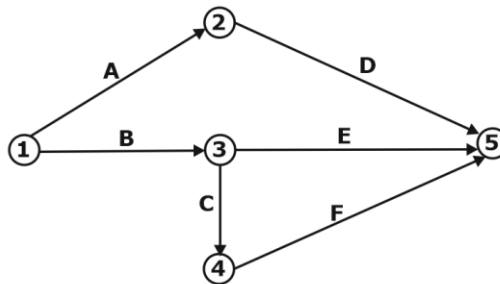
1. Excavate trench
2. Mix concrete
3. Prepare budget

In A-O-A system (Activity on Arrow network system), activity is represented by arrows between events while in A-O-N (Activity on Node system), activities are represented by nodes. In A-O-N system, events have no place.



Here A & B activities are represented in two different systems.

- The activities which can be performed simultaneously are independent of each other called parallel activities. In the above figure, activities A & B are parallel activities.
- Activities or activities that can be performed after performance of other activities are known as successor activities to that activity. Activity F is the successor activity to activity C in above figure.

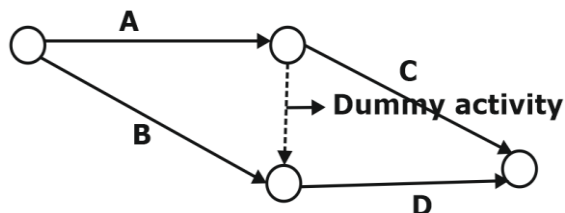


- Similarly, activities that are required to be performed before next activity can begin are called predecessor activities to that activity. Activity (A) is predecessor activity to activity D.

Dummy

- A dummy is a type of operation which neither requires time nor any resource, but it denotes dependency among the activities.
- It is represented by a dashed arrow.

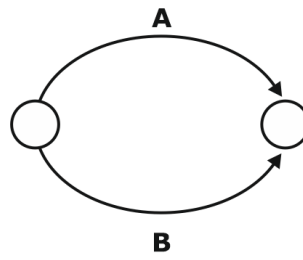
In the figure shown below, a dummy activity is shown.



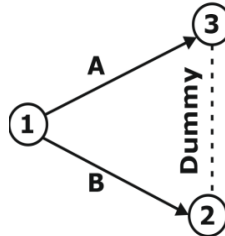
- Dummy is used to serve following purposes:

1. Grammatical purpose:

To prevent two arrows having a common beginning and common end.



(a) Ambiguous Representation

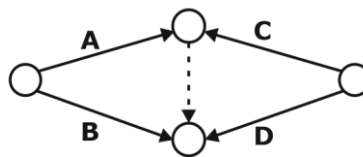


(b) Grammatically Clean Representation

2. Logical purpose:

To show relationships with other activities.

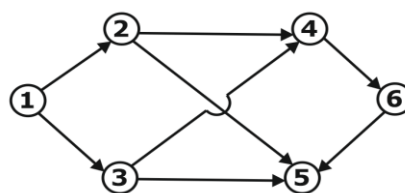
Here dummy is required to show that activity D can start after completion activities of A & B both



- Unnecessary dummies should be avoided.
- Dummies are used to show predecessor relations but if that relation is already established in the network, then that dummy is redundant and has to be removed.
- If dummy is only an incoming/outgoing arrow to/from a node then it can be removed provided there is no logical or grammatical error.

Rules of a Network

1. There can be only one initial and one final event.
2. An event cannot occur unless all preceding activities are completed.
3. An event cannot occur twice.
4. Number of arrows should be equal to the number of activities.
5. Time should always flow from left to right.
6. Length of the arrow does not show any magnitude. Straight arrows should be taken as far as possible.



7. Arrows should normally not cross each other. If it is necessary to cross, one should be bridged over the other.

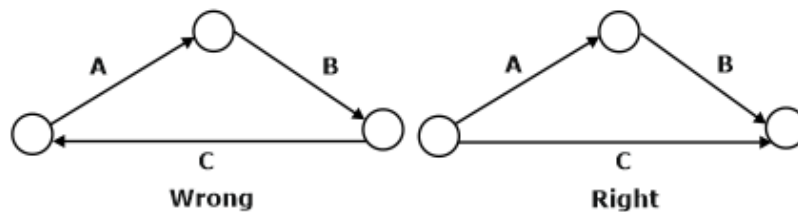
8. No activity can start until its tail event has occurred.

Fulkerson’s rule for numbering the events:

1. The single initial event is numbered as 0, 1, 10 etc.
2. All arrows emerging out of the initial event are neglected. Doing so, the created one or more new initial events are numbered as 2,3,4 or 20, 30, 40 etc.
3. Step - 2 is repeated unless all events are numbered.

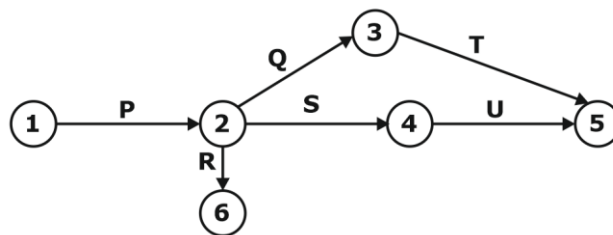
Errors in Network

1. Looping error: Loops should not be formed.



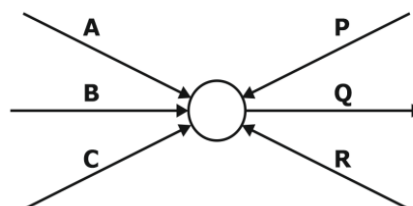
2. Dangling error:

Project is complete only when all its activities are complete but the duration of activity 'R' has no effect on the project time as shown in figure.



To avoid dangling error, the network must be examined in such a manner that all events except initial and final events must have at least one activity entering and one activity leaving them.

3. Wagon wheel error: As shown in figure below, each of the activities P, Q and R cannot start until all the three activities A, B and C are completed. But in reality, this may not be the situation. There is no error visible in the construction of the diagram but logical error has crept into it.



CHAPTER-3

PROGRAMME EVALUATION & REVIEW TECHNIQUE (PERT)

INTRODUCTION

- For PERT. Employs **Beta-distribution** for the **time** – expectation for **an activity**.
- The limits within which the duration will lie, is estimated.
- Pert follows the probabilistic approach and absorbs the uncertainties into the time estimates for activity and project durations.
- Therefore, PERT is well suited for those projects where there is insufficient or no background information for estimation of time duration
- PERT is used in R&D type projects such as space industry, defense industry etc. As such projects are of non-repetitive type or once-through type for which correct time estimates cannot be made.
- Further a PERT analysis is event oriented i.e. in this analysis interest is more focussed on the PERT (start or completion of activity) rather than the activities

TIME ESTIMATES

In order to take into account, the uncertainties involved in the activity times three kinds of time estimates are made for each activity in PERT.

(i) Optimistic time (t_o): If everything in the project goes well, it is the minimum time required for an activity if everything goes perfectly well without any problems or adverse conditions developed during the execution of the activity. In this time estimate, no provisions are made for delays or setbacks and better than normal conditions are assumed to prevail during the execution of the activity.

(ii) Pessimistic Time (t_p): It is the time for completing an activity that is best. It is the maximum time required for an activity if everything goes wrong and abnormal situations prevail. This time estimate does not include the possible effects of major catastrophes such as flood earthquakes, fire, labor-strikes etc.

(iii) Most Likely Time (t_m): It is the time required to complete the activity if normal conditions prevail. This time estimate lies between pessimistic and optimistic time estimates.

- In PERT activity time is probabilistic but in **CPM** activity time is **deterministic**.
- The other difference: PERT is Event – Oriented. While the CPM is Activity – Oriented (in CPM we actually know the Activity time)

(i) Expected completion time of an Activity: (t_E)

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

Where, t_0 = Optimistic time

t_p = Pessimistic time

t_m = Most likely time

(ii) Standard deviation of an Activity (σ)

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

(iii) Variance of an activity: (σ^2)

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

(iv) Central limit theorem:

(a) The mean time of the project as a whole is $t_E = t_{E1} + t_{E2} + \dots$ along the critical path. Probability of completion of project in time t_E is 50%.

(b) The standard deviation of the project as a whole is $\sigma = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \dots}$ along the critical path.

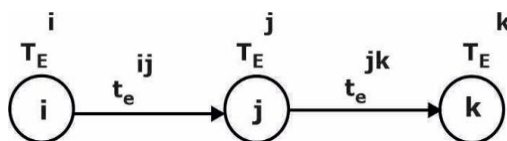
Critical Path: The time wise longest path is called critical path. In this path any type of delay in any event will cause delay to the project. These are shown by double lines or dark lines in a network.

An event is critical if its slack is zero.

Event Time:

(i) Earliest expected event occurring time (T_E)

$T_E^j = T_E^i + t_e^{ij}$ When there is only one path.



Where, t_s^{ij} = Expected completion time of an activity I - j

$$T_E^j = (T_E^i + t_s^{ij})_{\max} \dots \text{when there is more than one path.}$$

Where T_E^i = Earliest expected time of event i.

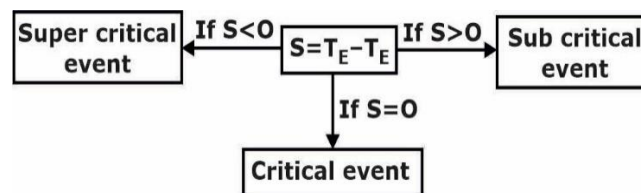
T_E^j = Earliest expected time of event j.

(ii) Latest allowable occurrence time (T_L):

$$T_L^i = T_L^j - t_s^{ij} \text{ When there is only one path.}$$

$$T_L^i = (T_L^j - t_s^{ij})_{\min} \text{ When there is more than one path.}$$

(iii) Slack (s): This is the time by which an event may be delayed without affecting the completion time of the project.



• **Probability Factor (z)**

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

Where, T_S = Given scheduled completion time of the project

T_E = Expected completion time of the project.

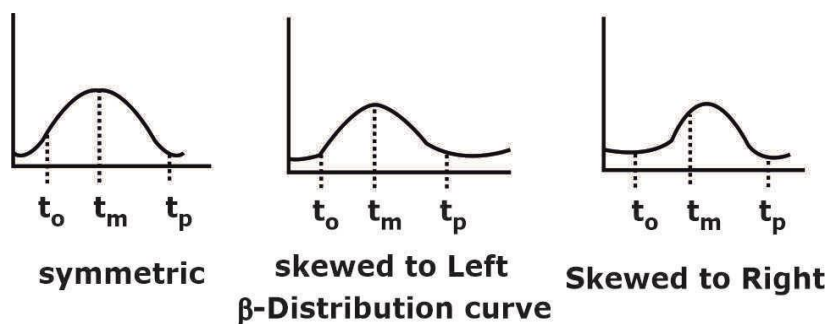
σ = Standard deviation

z	P
0	50%
+1	84.13%
+2	97.72%
+3	99.87%

z	P
0	50%
-1	15.87%
-2	2.28%
-3	0.13%

Frequency Distribution Curve for PERT

It is assumed to be a β - distribution curve with a unimodal point occurring at t_m and its end points occurring at t_o and t_p . The most likely time need not be the midpoint of t_o and t_p and hence the frequency distribution curve may be skewed to the left, skewed to the right or symmetric.

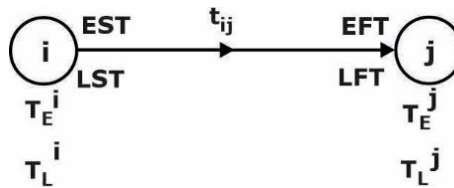


CHAPTER-4-CRITICAL PATH METHOD (CPM)

Critical Path Method (CPM)

1. A network diagram in CPM is activity oriented.
2. Cost is the most important criteria. Minimum is found corresponding to optimum time.
3. There is only a single time estimate for each activity.
4. The probability of completion of activity in this estimated duration is 100%.
5. It is based on a deterministic approach.
6. Suitable for repetitive types of work.
7. Normal distribution is followed.

Activity times:



(i) Earliest Start Time (EST)

$$EST = T_E^i$$

(ii) Earliest FinishTime (EFT) = EST + Activity time

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

(iii) Latest Finish Time (LFT) = TL of head event

$$LFT = T_L^j$$

(iv) Latest StartTime (LST) = LFT - t_{ij}

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

Float:

Float denotes the range within which activity time or its finish time may fluctuate without affecting the completion of the project.

(i) Total Float (F_T):

$$F_T = LST - EST \text{ or } F_T = LFT - EFT$$

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

(ii) Free Total (F_F):

$$F_T = T_E^i - T_E^i - t_{ij} \text{ Or } F_F = F_T - S_j$$

Where S_j = Head event slack

(iii) Independent Float (F_{ID}):

$$F_{ID} = T_E^j - T_L^i - t_e^{ij}$$

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

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

Where S_i = Tail event slack

F_T = 0 – for critical path F_T > 0 –for subcritical path

F_T < 0 – for Supercritical path

(iv) Interfering float (F_{IN})

It is another name for head event slack.

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

CHAPTER-5-CRASHING

Cost Model Analysis

- In CPM, time is related to cost and the object is to develop an optimum time-cost relationship.
- The overall project duration can be reduced by reducing the duration of only the critical activities in the project network. The durations of such activities may be reduced in two ways.
 - (a) By deploying more resources for the early completion of such activities.
 - (b) By relaxing the technical specifications for such activities.
- In the CPM Cost model, we will be assuming that project duration is reduced by deploying more resources on critical activities.
- In CPM, there are two time and cost estimates for each activity: 'normal estimate' and 'crash estimate' in the normal estimate, the emphasis is on cost with time being associated with minimum cost. The 'crash' estimate involves the absolute minimum time required for the job and the cost necessary to achieve it. Here the emphasis is on 'time'.

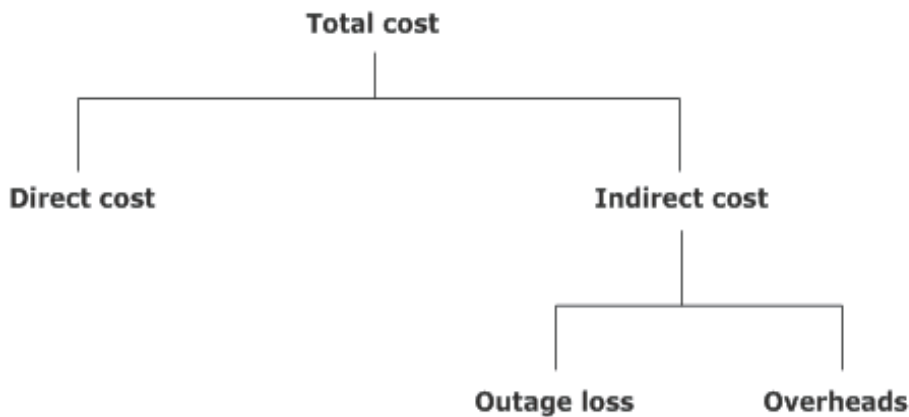
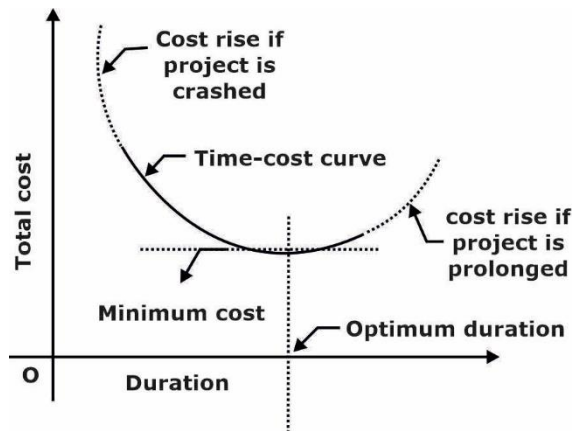
Project Cost

Total project cost is the sum of two separate costs:

- (a) The direct cost for accomplishing the work, and

(b) The indirect cost related to the control or direction of that work, financial overhead, lost production, and the hike etc.

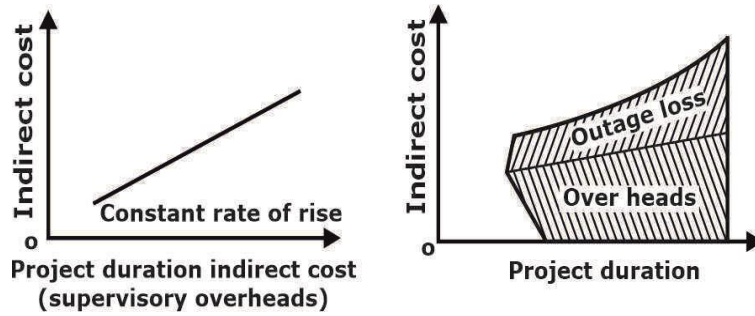
The components of the total cost are shown in figure below.



Components of Project Cost

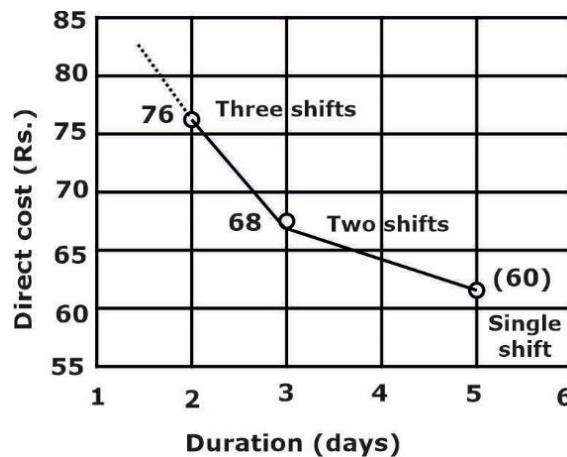
Indirect Project Cost

- Indirect costs on a project are the 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 expenditures related to administrative and establishment charges, overhead, supervision, expenditure on a central store organization, loss of revenue, lost profit, penalty etc.
- Indirect cost rises with increased duration, considering only overhead and supervision. It is represented by a straight line, with a slope equal to daily overhead.
- But when there is a loss in profits, due to inability to meet demand or due to some penalty due to delay, a corresponding cost increase must be added to the cost of overheads producing the curve. Such a loss is called the outage loss.
- The total indirect cost curve will thus be curved.



Direct Project Cost

- It is a cost which is directly dependent on the amount of resources involved for completion of activities.
- It includes labour materials, plants and machining etc.
- To get the same work done in less time, we have to increase the amount of labour, equipment and time saving materials, plants and machining etc.
- To get the same work done in less time, we have to increase the amount of labour, equipment and time saving material that takes extra charges which simply means increases in direct cost.
- The project has the highest cost corresponding to the crash duration, and has normal cost corresponding to the normal duration.
- **Normal time (t_n):** Normal time is the standard time that an estimator would usually allow for an activity.



- **Crash Time (t_c):** Crash times is the minimum possible time in which activity can be completed, by employing extra resources. Crash time is that time, beyond which the activity cannot be shortened by any amount of increase in the resources.
- **Normal Cost (C_n):** This is the direct cost required to complete the activity in normal time duration.

- **Crash Cost (C_c):** This is a direct cost corresponding to the completion of the activity within crash time.
- **Crash Slope:** $\text{Cost Slope} = \frac{\text{Crash Cost} - \text{Normal Cost}}{\text{Normal Time} - \text{Crash Time}}$

Note- Activities having minimum cost slope are crashed first.

CHAPTER-6-COST ESTIMATION

Unit of MEASUREMENT:

S No.	Particulars of Item	Unit of measurement
1.	Earthwork	
	(i) Earthwork in excavation	Cum
	(ii) Earthwork in filling in foundation trenches	Cum
	(iii) Earthwork in filling in plinth	cum
2.	Concrete	
	(i) Concrete in foundation	Cum
	(ii) Cement concrete in beam, slab	Cum
	(iii) Lime concrete in roof terracing (Thickness specified)	Sqm
3.	(iv) Cement concrete in Lintels	cum
	Damp proof course (Thickness specified)	sqm
4.	Brick work	
	(i) Brickwork in foundation	Cum
	(ii) Brickwork in superstructure	Cum
	(iii) Thin partition walls	Cum
	(iv) reinforced brick work	Cum
5.	(v) One brick thick wall (Thickness specified)	sqm
	Stone work	cum
6.	Wood work	Cum

	(i) doors and windows frames and chowkhats (ii) Shutters of doors and windows (thickness specified) (iii) doors and windows fitting (Hinges, handles etc.)	Sqm Number
7.	Steel work (i) Steel reinforcement bars (ii) rivet, bolt and nuts (iii) Binding of steel reinforcement (iv) Iron hold fast (v) Iron railing (vi) iron grills, iron gate and shutters	Quintal Quintal Quintal Quintal Quintal sqm
8.	Roofing (i) RCC slab roof (ii) LC roofs over bricks or stone slab (Thickness specified) (iii) Centering and shuttering form work (iv) AC sheet roofing	Cum Sqm Sqm sqm
9.	Plastering, pointing and finishing (i) Plastering, cement or lime mortar (Thickness specified) (ii) Pointing (iii) White washing, colour washing (Number of coats specified) (iv) Distempering, painting and varnishing (Number of coats specified)	Sqm Sqm Sqm sqm
10.	Flooring (i) 25 mm or 40 mm CC floor (ii) Doors and window sills (iii) 25 mm CC over 75 mm LC floor	Sqm Sqm Sqm

11.	Steel wooden trusses	No
12.	Glass panels	sqm
13.	Fixing of Glass panels	No.

Sinking Fund: A fund which is kept aside annually to reconstruct the property after the expiry of the period of utility is known as sinking Fund.

The sinking fund is calculated using the following formula:

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

Where,

I = Amount of Sinking fund

N = Life of the property

i = Rate of interest expressed in decimal

S = Money required to buy the property

Depreciation: The loss in the value of a property due to constant wear and tear is termed as depreciation.

The depreciation can be calculated using the following methods:

(a) Straight Line Method: In this method, it is assumed that the property loses its value by the same amount every year. A fixed amount of the original cost is deducted every year, so that at the end of the utility period, only the scrap value is left.

$$\text{Annual Depreciation} = \frac{C - S}{n}$$

(b) Constant Percentage Method: In this method, it is assumed that the property will lose its value by a constant percentage of its value at the beginning of every year.

$$\text{Annual Depreciation} = 1 - \left(\frac{S}{C}\right)^{1/n}$$

Where,

S = Scrap value

C = Original cost

n = life of property in years

The value of the property at the end of first year = C - DC.

(c) Sinking Fund Method: In this method the depreciation of a property is assumed to be equal to annual sinking fund plus interest on the fund for that year.

If A is the annual sinking fund and b, c, d etc. represent interest on the sinking fund for subsequent years, then the depreciation at the end of various years can be calculated as:

year	Depreciation	Total Depreciation	Book Value
1 st year	A	A	C - A
2 nd year	A + b	2A + b	C - (2A + b)
3 rd year	A + c	3A + b + c	C - (3A + b + c)

(d) Sum of Year Digit Method: In this method, the digits corresponding to the number of each year of life are listed in reverse order. The general expression for the annual depreciation for any year (q) when the life is p years is expressed as:

$$D_q = (C - S) \left[\frac{(p - q + 1)}{\frac{p(p + 1)}{2}} \right]$$

Where,

q= number of years in which depreciation is to be calculated

p= life of property in years
