

## **QUICK REVISION MATERIAL**

### **UNIT X: PROJECT MANAGEMENT AND ESTIMATION**

#### **Construction Management-**

Construction management is a managerial process involved in construction industries like management of labor, material and equipment to minimize the project cost and duration and also to optimize the quality of works. Time, cost and scope are the triple constraints in project management.

#### **Key Component Of Construction Management**

- a. Project planning
- b. Resource allocation
- c. Risk management
- d. Quality assurance
- e. Cost control and budget management

#### **The main objectives of construction management**

**are:**

- (i) Completing the work within estimated budget and specified time.
- (ii) Evolving a reputation for high quality workmanship.
- (iii) Providing safe and satisfactory working conditions for all personnel and workers.
- (iv) Taking sound decisions at the lowest practical management level through delegation of authority.
- (v) Motivating the people to give of their best within their capacities.
- (vi) Creating an organization that works as a team

#### **Functions-**

The functions of construction management are:

##### **(i) Planning and scheduling:**

Planning involves formulation of a number of alternative realistic work plans for achieving specified objectives and finally selecting plan which is best suited from the stand point of available resources and constraints imposed upon the project.

Scheduling is the fitting duration of the final work plan to a time scale. It shows the order of various construction activities. It deals with aspect of 'When to do it'.

##### **(ii) Organizing:**

Organizing is concerned with division of the total construction work into manageable departments/ sections and systematically arranging various operations by delegating specific task to the individuals.

##### **(iii) Staffing:**

Organizing involves the division of the project work into sections and staffing is the provision of people to fill the positions so created. Recruiting the right people, arranging staff training courses and carrying out proper staff assessment are all part of the staffing function.

##### **(iv) Directing:**

The directing function is concerned with training sub-ordinates to carry out assigned task, supervising their work and guiding their efforts. essence of directing lies in the ability to leadership, proper communication and motivate people individually and as groups to utilize their creative effort in achieving specified objectives.

##### **(v) Controlling:**

Controlling is necessary for ensuring effective and efficient working. It involves a constant review of the work plan to check on actual achievement and to discover and to rectify deviations through appropriate corrective measures.

##### **(vi) Co-ordination:**

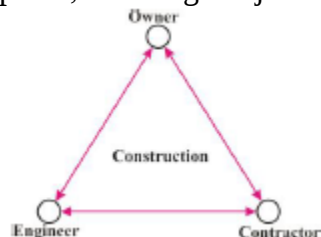
Since authority converges to the top of the organizational pyramid, it is necessary to bring together and co-ordinate the work of various departments and sections.

This requires an efficient system of communications that each department and section is aware of its role and the assistant to be expected from the others. Regular meetings of departmental/sections head with top management are fundamental to proper coordination, so that plans, problems

and remedies are discussed for determining the best solution.

### Construction Team Component:

For civil engineering project a construction team is composed of owner, engineer/architects and contractor. The owner forms the construction team to survey his interests through the services of both the contractor and the team of engineer. The object of the team is convert owners conceptual into a reality by making profit, finishing the job safely within budget.



### Classification of Construction-

**1. Light construction-** It includes general construction works.

**Ex.-**Residential office and school building, public and commercial building, water supply and sanitation engineering works and general industrial buildings etc.

**2. Heavy Construction Work-**

A large amount of construction material, equipment and labors are required under this construction.

**Ex.-**Dams, large road, bridges, railway stations, large building, tunnel, large thermal power plant etc.

**3. Industrial Construction-**

Large building comes under industrial construction. Special types of equipment required for their construction

### PROJECT MANAGEMENT

Project management as defined by PMBOK is the application of knowledge , skills, tools and techniques to a broad range of activities to meet the requirement of the particular project.

### Elements of Project Management

The elements included of project management starting from goals and ending with end product

### Stage of Project Managements

Construction project management involves the following given stage



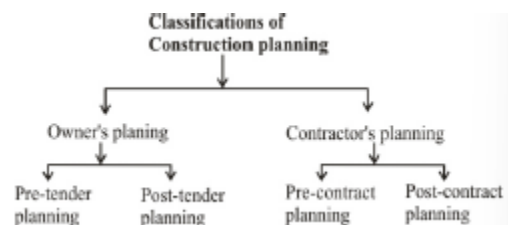
### 1. Planning -

It is the first and most important function that is defined as the process of selecting a particular method and the order of work to be adopted for a project from all the possible ways and sequences in which it could be done. It essentially covers the aspects of what to do and how to do it. Main objective of the planning is economical and on time completion of the project.

It is the most important phase of project management.

Planning stage consist of organizing the project Team

Following types of project planning steps are



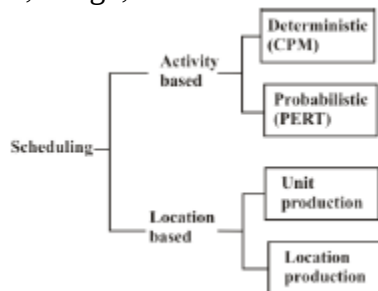
### Scheduling/Executing-

The process of determining how much time the total project will take, tracking labor

hours and how long each stage will take is known as scheduling.

It is all so the process of arranging the objective define during planning in sequence and allocation of resources to these activities.

Steps involves in project scheduling are give, assign, calculate and allocate.



### Advantages of scheduling-

(i) Construction scheduling gives information regarding the quantity of work, labor, machinery, equipment etc. required a particular period.

(ii) The progress of the work and the expenditure can be checked and adjusted.

(iii) The project can be completed systematically and effectively.

(iv) The work progress can be well monitored and evaluated.

(v) It prevents undue delay and extension of time.

### Classification of Scheduling-

(i) Construction schedule

(ii) Material schedule

(iii) Labour schedule

(iv) Equipment schedule

### 3. Controlling -

Controlling is the process which consists of measuring and comparing results and taking suitable action to bring the project on track. It involves reviewing the difference between the schedule and the actual performance of the project.

Execution of planning and scheduling comes under the controlling. Project controlling starts when actual work starts.

### Objectives

Keeping a watch over the physical progress of each activity of the work.

ii. Controlling the expenditure one each item of work.

iii. Controlling the use of machines and materials

iv. Finding out the deviation if any.

v. Measurement of actual performance.

### Stages in construction project-

Every construction work has following distinct stages-

(i) Briefing stage

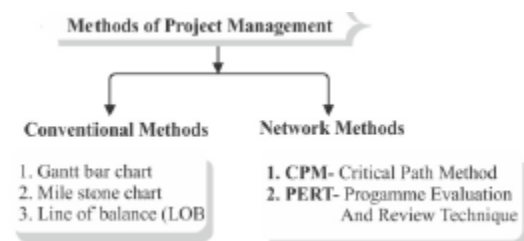
(ii) Designing stage

(iii) Tendering

(iv) Construction stage

(v) Commissioning stage

### Tools or Technique of Project Management



### Bar chart or Gantt Chart-

It is one of the oldest and simplest graphical representation of activity in planning and programming construction projects that is introduced by **Henery Gantt** around 1900 AD.

It is one of the most popular and useful ways of showing activities (task) displayed against time. A bar chart consists of two coordinate axis, one (xaxis) representing the time elapsed and other (Yaxis) represent one specific job or activity of the project. Each activity is represented by a bar where left or starting end of the bar represents the time of start while right end represents the time of finish of that activity. Length of the

bar represents the time required for the completion of that job or activity

Bar chart is used for production, scheduling or to display project schedule activity.

**Unit** - Hrs. , Day, week, month etc.

**Color of bar chart according to progress of task.**

| Progress of task         | Colour |
|--------------------------|--------|
| Actual progress          | Green  |
| Anticipated progress     | Black  |
| Progress behind Schedule | Red    |

### **Characteristics of Bar Chart.**

Bar chart is activity oriented.

ii. Provide idea about physical progress of the project i.e. comparison of actual progress with the schedule progress.

iii. The width of bar does not signify anything, it can be any size.

iv. It is adopted for small and medium type construction work.

### **Development of Bar Chart-**

#### **1. Breakdown-**

It is the process of breaking entire project into various activities or jobs or operations, each representing manageable unit for planning and control.

#### **2. Decide-**

Decide is the method to be employed in execution of the project as well as for each activity or operation or task.

#### **3. Assign-**

Assign is the duration of time for the completion of each activity.

#### **4. Represent-**

Represent is the information about the activities in the bar chart, indicating the relative position of each activity.

### **■ Advantage of Bar Chart-**

i. It is suitable for minor work

ii. Skill manpower is not required.

iii. It is simple to draw and easy to understand.

iv. Represents visual views of the projects.

v. Starting and finishing of project can be observed clearly.

vi. More convenient to construction schedule.

vii. Gantt chart has ability to show and clarify multiple task and timelines.

### **Disadvantages**

The length of the bar chart does not indicate the amount of work

ii. They all the time need to be updated

iii. Difficult to see on one sheet of paper.

iv. The Critical path can not be clearly indicated.

v. Job can be started one after other, so some bars can run parallel or overlap each other or may run serially.

vi. The schedule cannot be updated.

### **□ Limitation or weakness of Bar Chart-**

#### **1. Lack of degree of detail-**

On a bar chart, only major activities are shown while sub activities can't be separated out. Due to this, effective control over the activities can't be achieved.

#### **2. Review of project progress-**

A bar chart does not show the actual progress of work and hence it can not be used as a control device.

#### **3. Activity inter-relationship-**

The inter-relationship/Dependencies between various activities can not be clearly depicted.

#### **4. Time uncertainties-**

It is not useful in those projects where there are uncertainties in determination or estimation of time required for the completion of various activities.

5. Bar charts are useful for only small size conventional project.

6. Bar chart cannot distinguish between critical and non-critical activities and hence resource smoothening and resource leveling cannot so done.

### **■ LINE OF BALANCE METHOD (LOB)**

This technique is a linear scheduling method that allows the balancing of the operations such that each activity is continuously and efficiently performed in each consecutive unit some construction projects that involve

sets of tasks organized in repeating sequences are similar to continuous manufacturing process in their structure.

**Ex.** Multi-housing projects, and high-rise building construction, pavement construction.

It shows the repetitive construction activities of a project on a single line on a graph.

Better information for repetitive operation can be obtained by LOB.

LOB enables optimum employment of uninterrupted and efficient utilization of resources.

Production, objective & progress diagram are used in LOB.

#### **Advantage**

- i. It is relatively easier to modify, update and change the schedule.
- ii. Allow a clear understanding of the amount of work taking place at a certain time in a specific place.
- iii. Represents both a presentation format and a scheduling technique.
- iv. Very usual method of representing a particular type of project.
- v. Using a combination of sloping lines, both and blocks to sequence operation and then spall and resource conflicts are quickly identifies and addressed.

#### **MILESTONE CHARTISROSE**

Milestone chart is a modification over the bar/Gantt chart. A graphical representation wherein long duration jobs are broken down to key segmental elements, where an events are shown in chronological order without attention to logical sequencing, and wherein interdependencies between the events is not highlighted is known as mile stone chart.

Milestones are 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 main activity. These points are identified over the main bar.

Beginning and end of the sub-divided activities or

task is known as the mile stone which is represented by arrow, circle or by a square.

Milestone chart is a event oriented chart that is used for project monitoring.

Controlling can be better achieved with the help of mile stone charts.

It is simplest scheduling method

It is suitable for small projects.

Lines represent duration of single activity with appropriate start and stop mile stone.

Open triangles indicate mile stones planned.

Closed triangle indicate mile stones completed.

Milestones is an important events located on the activities in a bar chart.

Milestone chart were invented in the year of 1940 AD

#### **Linked Bar Chart-**

It is the modification or advance form of bar chart and milestone chart in which inter-relationship between activities is shown with the help of link.

Arrow is used to connect the activity.

#### **■ Resource - Based Bar Chart-**

It is used for computation of resource histograms

| Bar Chart                | Adopted For                        |
|--------------------------|------------------------------------|
| Gantt Bar Chart          | Activity duration                  |
| Mile Stone bar chart     | Monitoring and interface           |
| Linked Bar Chart         | Activity relationship              |
| Resource Based bar chart | Computation of resource histograms |

#### **NETWORK ANALYSIS**

Network technique is a graphical and logical representation of different activities consisting of nodes and arrows. It is a modification of bar chart and mile stone chart. This techniques based on the basic characteristics of all projects, that all work must be done in well defined steps.

#### **Advantages**

Interrelationships between activities and events of a project are clearly shown.

ii The project can be treated as an integrated whole with all its sub-activities clearly related with each other. It helps in controlling the project.

iii. Network method is useful for very complicated project having large number of activities.

iv. It indicates the time required between two activities in which rescheduling of a project is possible

This technique is also known as PERT, CPM, UNETICS, LESS, TOPS, SCANS

Out of these there is two types of network system-

1. CPM 2. PERT

### **1. Critical Path Method(CPM)**

CPM is activity oriented method introduced by Morgan R. Walker and Remington K. James. Kelly in 1957. It is also known as critical path analysis (C.P.A.),critical path scheduling (C.P.S.) and network management technique (N.M.T.).

CPM is mainly used in project to determine critical as well as non-critical task that will help in preventing conflicts and reduce bottlenecks. In essence, CPM is about choosing the path in a project that will help in calculating the least amount of time that is required to complete a task with the least amount of wastage.

CPM network is generally used for repetitive type projects or for those projects for which fairly accurate estimate of time for completion of each activity can be made and for which cost estimation can be made with fair degree of accuracy.

CPM is very useful for construction projects not for research and development projects

It is also used for sequencing project activities in construction management.

### **Advantages And Disadvantages Of CPM**

#### **Advantages**

CPM identifies dependencies efficiently.

ii. It can identify critical activities that of priority.

iii.CPM takes into account the resources required for a project in the most effective way.

iv. Project managers can determine the precise cost and time required to complete a project.

v. CPM offers an efficient technique to assess the procedural and technical changes that might occur.

#### **Disadvantages.**

CPM can be extremely complicated to implement in case of large-scale project.

ii. Critical path identification consumes more time for projects on larger scales.

iii. Creating a CPM can be time-consuming at times.

### **2. PERT Method-**

Program Evaluation and Review Technique (PERT) is an activity to understand the planning, arranging, scheduling, coordinating and governing of a project and mainly used for uncertain research based projects.

This program helps to understand the technique of a study taken to complete a project, indentify the least and minimum time taken to complete the whole project.

PERT was developed in the 1950 with the aim of the cost and time of a project.

PERT is an event oriented technique which could be used when activities duration is uncertain.

This system is preferred for those projects which are of non-repetitive nature or where precise time determination for various activities cannot be made.

Beta probability distribution is taken to represent completion time.

It can be applied to designing a hyperloop.

### **PERTAdvantages**

PERT is beneficial for conducting a "what-if analysis". By analyzing the critical path, the likelihoods and different levels of uncertainties can be identified.

ii. It promotes coordination among various departments

of a project. This improves decision-making proficiencies and planning. Through coordination, Sample data is also available that makes it easier for project management.

iii. PERT networks allow an analysis of all activities, which tell whether the project will be completed within the budget.

iv. PERT displays the critical path, which identifies activities that cannot be stayed under any condition.

#### **Disadvantages**

PERT methodologies are entirely dependent on predictions, which can lead to going overboard on the estimated budget.

ii. It can be less accurate to implement as there is no data available to model a project since it is only used for non-repetitive jobs.

**PMBOK-** "Project management body of knowledge.

PMBOK identifies five process that are used to manage projects-

(i) Initiating (ii) Planning (iii) Executing (iv) Monitoring and controlling (v) Closing

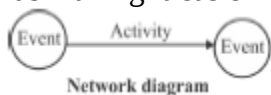
#### **ELEMENTS OF NETWORKS**

##### **NETWORK DIAGRAM OR**

**ARROW DIAGRAM** representation consisting of activities and events, connected logically and sequentially. Activity is represented by arrows while elements are represented by circle in a network diagram.

Advantage-

- It clearly shows the inter-relationship between events.
- The project is seen as integrated whole, thus making it easier for control.



#### **ELEMENT OF NETWORK DIAGRAM**

##### **A. ACTIVITY**

Actual performance of a specific task or any individual operation which utilizes time and

resources and has an end and a beginning is called activity. An activity required time and resources for its completion. An arrow is commonly used to represent the direction of progress where arrows tail represents start of activity and head represents the end of activity.

- Length of arrow does neither represent the magnitude of work involved nor the time required for its completion.

#### **Classification of Activity-**

**(i) Serial Activity-** Serial activity are those which are to be performed after the completion of another activity.

##### **(ii) Parallel Activity-**

An activity which can be carried out/performed simultaneously and independently to each other is known as parallel activity.

##### **Predecessor Activity-**

Activity that must be completed immediately prior to the start of another activity is known as predecessor activity.

##### **Successor Activity-**

Activity that can be performed after the performance of other activity is known as successor activity. An activity that immediately follows another activity, without any intervening activity are known as immediate successor activity.

##### **Overlapping Activity-**

When activity can be started before completion of predecessor activity, such activity is known as overlapping activity. Overlapping usually result in faster project finish.

##### **Dummy Activity-**

An artificial activity which does not consume any kinds of resources nor any time but merely depict the technological dependence among operations is called dummy activity. It is represented by dashed arrow.

A dummy activity is identified by the number of terminal node.

- It is connecting links for control purpose and for maintaining uniqueness of activity.

#### **Use of Dummies-**

Dummies serve two purposes in a network-

##### **1. Grammatical Purpose-**

A dummy is used to prevent two arrows having common beginning and end points.

##### **2. Logical Purpose-**

Dummy is also used to give logical clear representation in a network having an activity common to two sets of operations running parallel to each other.

#### **B. EVENT**

The commencement and completion of an activity is called event. or

An event represents a point in time signifying the completion of some activities and the beginning of new ones.

- Event is usually represented by a circular, square, Rectangular or oval shape in a network that is also called node or connector.

- An event has 3 basic properties.

An event is either the start or completion of an activity.

ii. An event represents a noteworthy, significant and recognizable point in the project. Event act as control points in a project.

iii. An event is an accomplishment occurring at an instantaneous point in time, but requiring no time or resources itself.

#### **Specifying the Events**

**1. Tail Event** - It is the beginning of an activity. If a particular tail event represents the commencement of the project then it is called initial event.

##### **2. Head Event-**

Completion of an activity is called head event. Head event is connected to the head or barbed end of an arrow. If a particular head event marks the completion of the project then it is called final or end event.

##### **Dual Role Even-**

All events except initial and final events are dualrole events.

Here even 5 is the head event for activity P and tail event for activity Q

#### **CLASSIFICATION OF EVENTS-**

##### **(i) Merge Event-**

When more than one activity comes and joins an event is known as merge events

##### **(ii) Burst Event-**

An event which has only one preceding activity and more than one succeeding activity is known as burst.

- More than one activity leaves an event.

##### **(iii) Merge and Burst Event-**

An activity may be merge and burst event at the same time as with respect to some activities it can be merge event and with respect to some other activity it may be a burst event.

#### **Inter-relationship b/w events**

**a. Successor Event-** The events that follow another events are called successor events to that event.

**b. Predecessor Events-** The event that occur before another events is called predecessor events to that event.

#### **■ Rules for Network Construction-**

1. A complete network should have only one point of entry (a start event) and only one point of exit (a finish event).
2. Each activity is represented by one and only one arrow in the network.
3. An event can not occur twice hence there should be no looping error in the network
4. There must be no dead end left except the final node.
5. No activity can start until its tail event occurs.
6. Any arrow should represent singular situation.
7. Representation of the network should be such that every activity is completed to reach the end objective.
8. Logic of network should always be maintained.

9. It is usual practice to show the time flow from left to right.

10. As far as possible curved arrow must be avoided.

11. As far as possible crossing of arrows must be avoided and if it can not be avoided bridging of activity must be done.

### **NUMBERING OF EVENT**

Numbering of event is done by Fulkerson's rule

#### **Fulkerson's Rule-**

In a network, the events or nodes at the tail and head

of an activity have to be numbered for proper identification. The numbering of the various events should progress from left to right reflecting the logical sequence of activities.

#### **Procedure of Fulkerson's rule.**

In every network there is one 'initial' event. This 'initial' event has arrows coming out of it and no arrows entering it. Number this event as 1.

ii. Neglect all arrows coming out of the 'initial' event.

This will give rise to one or more new 'initial' events.

iii. Number the new 'initial' events generated in step (ii) (iii) etc.

iv. Neglect all arrows coming out of the new 'initial' events, which will give rise to further initial events.

Number these initial events sequentially.

v. Repeat step (iv) till the last event, which has no arrows coming out of it, is numbered.

#### **Skip Numbering-**

In networks for large and complex projects, skip numbering may be adopted for the events or nodes. In skip numbering the events are numbered as 10, 20, 30, 40, 50 etc. This system permits additional/more detailed activities.

### **WORK BREAKDOWN STRUCTURE (WBS)-**

WBS is a method of breaking down a project into individual elements

components, subcomponents, activities and tasks in a hierarchical structure.

- WBS is a hierarchical listing of what must be done during a project.

- WBS facilitates resource allocation, assignment of responsibilities and measurement and control of the project.

The WBS is the basis for developing time and cost estimates.

- It follows top to bottom/down approach.

- It decomposes the project scope into manageable component/sub-division.

#### **\_ Forms of Network Diagram-**

Methods to draw network is following types-

#### **(i) Activity On Arrow (A.O.A.) network diagram-**

Activities are marked on arrows while event marked on the node. The first circle represents the start of the activity and second circle represents the finish of the activity. In this network zero float is associated with a critical activity.

#### **(ii) Activity on Node (A.O.N.) network or precedence diagram-**

It refers precedence diagramming method which uses boxes to denote schedule activities. These various boxes or "nodes" are "connected from beginning to end with arrows to depict a logical progression of the dependencies between the schedule activities.

This system completely eliminates the dummy activities.

- Completely eliminates the use of dummy activities.

- There is no place for event.

- Arrows indicate the relationship between activities,

so it is also known as precedence or interdependence diagram.

### **ERRORS IN NETWORK DIAGRAM**

#### **DIAGRAM**

Three types of common errors occur in network diagramming.

#### **(i) Dangling Error-**

To disconnect an activity before the completion of all activities in a network diagram is known as dangling error. At an event other than the final event, no activity emerges.

If the activity has a duration, it does not influence the total project duration.

### (ii) Looping or Cyclic Error-

Looping error is also known as cycle error in the network drawing and endless loop in a network diagram is known as error of looping.

### (iii) Redundancy Error-

Unnecessarily inserting the dummy activity in a network diagram is known as error of redundancy.

This error occurs in AON network. This error is related to dummy activity.

## PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT)

### PERT

It is a technique which is used for planning, scheduling and controlling the project time is the most essential and basic variable for the completion of project which is depend upon the estimate of different activities.

PERT was developed and has been used most frequently in the research and development type project, such as space industry, aerospace industry, defense products industry etc.

### Method of Time Estimate for the Activity-

#### (i) Optimistic Time Estimate-

It is the shortest/ least possible time in which an activity can be completed under ideal conditions. It represents the time of completion of an activity, if everything goes perfectly well. It is denoted by 'to'.

#### (ii) Pessimistic Time Estimate

The longest estimated time period within which a task is likely to be completed. It is used in project management activities. It does not include possible effects of

earthquakes, floods and fires. It is denoted by 'tp'.

### (iii) Most likely time/Most probable time-

It is the time in which the activity is normally expected to complete under normal contingencies. It lies between optimistic and pessimistic time estimates. It is denoted by 'tm'.

### \_ Expected/Weighted Time (te)-

The expected time in PERT analysis is a weighted average of optimistic, pessimistic and most likely time estimate for an activity. When the time required for an activity is uncertain then expected time is used.

- The probability of completing the activity is 50 %

Probabilistic (expected completion) time (te) for completion of an activity

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

## FREQUENCY DISTRIBUTION CURVE (F.D.C.)

If a curve is plotted between 'time' of completion and the number of activities complete in that 'time',

is called frequency distribution curve.

In a PERT frequency distribution curve represents the probability distribution of a activity completion time. PERT uses a beta distribution for individual activity duration while normal distribution is used for overall project duration.

The curve shown above the fig. is symmetrical on either side of apex is known as **symmetrical** curve.

If the curve is not symmetrical about apex then it is known as **skew** curve.

| Condition of (F.D.C.) | Types of Curve       |
|-----------------------|----------------------|
| Having a single hump  | Unimodal Curve       |
| Symmetrical           | Normal or Bell Curve |
| Unsymmetrical         | Skew Curve           |

### Variance-

It is the mean of the standard deviations. Variance is always +ve and can not be zero.

it is used as measure of variability of the distribution.

$$\sigma^2 = \frac{\sum \delta^2}{n} = \frac{\sum (t - t_m)^2}{n}$$

Variance is the measure of uncertainty. Greater the variance, greater will be uncertainty. It is commonly used in statistics.

### Standard Deviation-

It is the square root of the variance.

$$\sigma = \sqrt{\frac{\sum (t - t_m)^2}{n}}$$

### Probability Factor (Z)

$$Z = \frac{t_s - t_e}{\sigma}$$

Where,

$t_s$  = Scheduled completion time

$t_e$  = Expected completion time

### Normal Probability Distribution -

If the probability distribution curve is symmetrical about the apex then it is referred as normal or Gaussian probability distribution. In a PERT normal distribution is used for the completion time of project.

- Whole project duration follows normal distribution.

### ♦ Beta Distribution Curve-

If probability distribution curve is non-symmetric about the apex then it is termed as  $\beta$ -distribution curve. Activity in PERT network follow  $\beta$ - distribution curve.

Standard deviation for  $\beta$ -distribution is

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

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

### EVENT TIME-

#### (i) Earliest Expected Time (TE)-

Minimum time taken to reach at any event is known as earliest event time. It appear above or below the node in a network. It is computed by adding the expected time  $t_E$  for all the activities along an activities path leading to the event.

- It is calculated by forward pass method.

#### (ii) Latest allowable Time (TL)-

The max. Time in which an event can possible begin without delaying the schedule of the project. It is written at near of event in triangular section.

- It is calculated by backward pass method.

### SLACK/PS

Slack is defined as the difference between latest allowable time and the earliest expected time of an event.

or

The time by which occurrence of an event can be delayed without affecting the schedule completion time of project is called slack.

$$S = TL - TE$$

Slack value may be +ve, -ve or 0.

### TYPES OF SLACK-

#### (i) Zero Slack (S = 0)-

Then event is called critical event. It indicates that event is on schedule we can not allowed the delayed in the occurrence of this events.

$$\text{If, } S = TL - TE = 0 \text{ or } TL = TE$$

#### (ii) Positive Slack

It means the event running ahead of the schedule time. This event is called sub critical event. It also indicates condition of excess resources deployed.

$$\text{If, } S = TL - TE > 0 \text{ or } TL > TE$$

#### (iii) Negative Slack

It indicates that this event is running behind the scheduled time. This types of event is called as super critical event it also indicates that resources deployed are not adequate enough.

$$\text{If slack, } S = TL - TE < 0 \text{ or } TL < TE$$

### CRITICAL PATH

In PERT it is the longest path from initial to final event in terms of time in which project can be completed on time. A critical path consumes maximum resources and gives the minimum time required to complete the entire project.

- Event oriented slack relates to the determination of critical path

- Critical path is that path which joins critical event (for critical event slack = 0)
- Critical path can be easily determined with the help of total float calculation. A critical path is the one which connect the events having zero or minimum slack times. All the events along the critical path are considered to be critical in the sense that any delay in their occurrence will result in the delay of the scheduled completion of the project.
- Critical path requires single time estimate  
Critical path can be easily determined with the help of total float.
- The activities on the critical path are those activities that have total float equal to zero.

#### **Critical path network involves-**

- A series of interconnected network
- A logical sequence of activities
- Uncertainties is not considered in time estimate
- Node number at arrow head is numerically greater than that at tail end because the time in chart move from left to right.

#### **■ Steps to Find Critical Path.**

- Identify all tasks/activities required to complete the project.
- Determine the sequence of tasks.
- Estimate the completion time of each tasks.
- Draw a network diagram.
- Identify the critical path and calculate the float.
- Monitor the critical path.

### **CRITICAL PATH METHOD (CPM)**

#### **CPM : NETWORKS**

The Critical Path Method or CPM is a network analysis technique concerned with planning and controlling of complex, but routine projects. Simply, Critical path method is generally used for the projects whose time duration is known with certainty and also the amount of resources required for the completion of the project is assumed to be known.

Once the critical activities are identified, the network is drawn connecting all the crucial activities and depicting which activity to be carried first, so that successor activities could be performed effectively. For each activity the following parameters need to be determined.

In CPM method primary focus is on the sequence of task that determines the project duration.

#### **Start and Finish Time of Activity-**

Following activity time are useful for network computations.

##### **1. Earliest Start Time (TE)-**

It is defined as the earliest possible time at which an activity can start. It is calculated by moving from first to last event in a network diagram. It is naturally equal to or less than the earliest event time of the following node.

EST latest even time of preceding nodes.

##### **2. Earliest Finish Time (EFT)-**

It is the earliest possible time at which an activity can be finished. It is always less than or equal to latest event time of preceding node.

$$E.F.T = TE + D \text{ or } t_{ij}$$

$T_{ij}$  = activity duration

E.F.T. of an activity is not equal to head event.

EFT latest event time of preceding nodes.

##### **3. Latest Start Time (L.S.T.)-**

It is the latest possible time by which an activity can start without affecting/delaying the completion time

of project. LFT for an activity will be equal to the latest allowable occurrence time for the event at the head of arrow. i.e. LFT = Latest event time (TLJ)

It is always greater than or equal to latest event time of preceding node.

$$LST = LFT - t_{ij}$$

##### **4. Latest Finish Time (LFT or TL)-**

It is the time by which a specific activity must be completed. It is indicated by

triangle and calculated by moving from last event to the first event of the network diagram.

$L.F.T. = L.S.T + \text{duration of that activity}$

For any critical operation,

$E.F.T = L.F.T$

### **FLOAT**

Float indicates the range within which the start and finish time of an activity may vary without affecting the scheduled completion time of project.

Float is the total time available for an activity delaying the project.

### **TYPES OF FLOAT**

#### **1. Total Float (FT)-**

Total float of an activity is the excess of maximum time available over the activity time.

Succeeding and preceding both activities are affected by total float. Total float for activities on critical path is zero.

Total float,

$T.F = L.S.T - E.S.T$

or,  $L.F.T - E.F.T$

It affects both succeeding and preceding activities.

#### **2. Free Float (FF)-**

Free float of an activity is the excess of available time over the activity time when all jobs start as clearly as possible. The term "free" indicates that the use of this float does not affect the succeeding activities.

The concept of free float is based on the possibility that all the events occur at their earliest times.

Only proceeding activity is affected in free float.

Only preceding activity is affected in this float.

#### **3. Independent Float (FI)-**

Independent float of an activity is the excess of minimum available time over activity time. In some cases the absorption of this float neither predecessor nor successor activity that's why, it is called independent.

Independent float is less than or equal to total float

This float affects only particular activity.

It affects only particular activity involved

#### **4. Interfering Float (FIF)-**

Interfering float of an activity is the difference between total float and free float. It is thus equal to the head event slack. It is also known as head event slack.

### **COST MODEL ANALYSIS**

Project cost management is one of the main and undeniable components in the project management processes, which becomes more important, costly and long term projects such as major construction projects. Cost time balancing is one of the important issue in the transactional analysis of a variety of project costs and project execution time.

#### **Total Cost-**

Total project cost is the sum of direct cost for accomplishing the work and the indirect cost related to the control or direction of that work, financial overhead, lost production. It is very necessary to maintain the project cost is minimum at the optimum project duration. From the diagram given below it is clear that-If a project goes on indefinitely, the cost will increase and also if project is expedited. Total cost gives a curvilinear relationship with time.

Cost is minimum at a some optimum project duration.

#### **(i) Indirect Cost-**

It is that cost or expenses which can not be computed individually for an activity, but can be found for the entire project.

Total indirect cost = Overhead - Outage loss

Indirect cost increase linearly with time/duration.

**Ex.-**Cost at inspection staff, workshop, staff, workshop establishment or storage shed.

#### **(ii) Direct Cost-**

It is those expenses which are directly chargeable and can be identified by activities.

**Ex.-** Cost of material, Machinery, Labors wages etc.

Direct cost of a project is minimum w.r.t normal Time

Direct cost decrease with project duration reduced while indirect cost increases.

#### ■ Normal time (tn)-

It is time taken by the project without any delay in any activity of the project. Normal time of the project does not contain crashing of any activities.

#### ■ Normal Cost (Cn)-

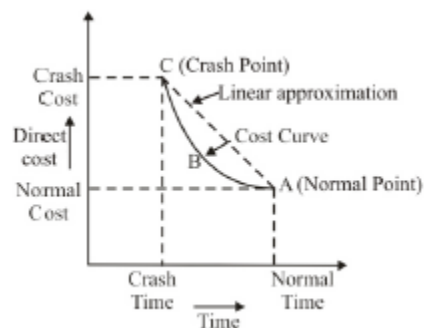
It is the direct cost of an activity required to complete in normal time duration.

#### ■ Crash Cost(Cc)-

Crash cost is the cost corresponding to the completion of the activity within crash time.

#### ■ Crash time (tc)-

Crash time is the minimum possible time associated with crash cost by which the project may be completed by assigning/using extra resources and overtime.



#### Cost Slope-

The cost slope of an activity is an indication of the

rate at which the cost of the activity increases per

unit reduction in time when the activity is crashed.

$$\text{Cost slope} = \frac{\text{Crash cost} - \text{Normal cost}}{\text{Normal time} - \text{Crash time}} = \frac{C_c - C_n}{t_n - t_c}$$

It is also the indication of extra cost needed.

It is additional cost incurred to crash down the activity per unit time period

It show how much extra cost is incurred to reduce the activity duration by one time unit.

A steeper cost slope means crashing the activity is expensive.

#### ■ Optimum Cost-

Optimum cost is defined as that cost which is lower as compared to that of the normal project cost at optimum lower project duration.

#### ■ Optimum Duration-

Optimum project duration is the time corresponding to minimum project cost for completion of the project. The corresponding cost is known as the minimum cost

#### ■ Total project cost and optimum duration-

The total project cost is the sum of direct cost and indirect cost. If the project duration is increased, the total cost will increase, while is project duration is decreased to the crash value, the project cost will be highest.

### CRASHING, UPDATING AND RESOURCES ALLOCATION

#### CRASHING

The process of reduction of total project duration along the longest path of the network i.e. along the critical path to obtain the optimum project cost and optimum duration is known as crashing.

Crashing is done on original activity and those that become critical at any stage of crashing in order to ascending cost slope.

#### UPDATING

The process of replanning and rescheduling based on the results which serve a guidance for decision by performing calculation made by taking into consideration the new knowledge and latest information at an intermediate stage of the project thus modifying the original network, is known as updating.

Critical path, critical activities and project duration may change during updating.

For critical activities, updating is mandatory. Any activity is neither added nor deleted.

#### **Data Required For Updating-**

- i Original network
- ii. Original network calculation chart
- iii. Stage/point at which updating is being done
- iv. Execution position of the project at that stage
- v. New information and knowledge which will affect the duration time of the activities to be performed.

#### **Updating need:**

- (i) Change in plan.
- (ii) Change in activity and its duration.
- (iii) Change due to major reason: Climatic condition or natural calamities, man made disaster, etc.

#### **Updating Process-**

During the process of implementing the plan according to the network, we may come across one or more of the following possibilities.

- i. That some or all activities are progressing according to schedule.
- ii. That some or all activities are ahead of schedule.
- iii. That some or all activities are behind schedule

### **RESOURCE ALLOCATION**

Resource allocation is process of assigning resources to different tasks, projects, or activities based on their importance, priority, and availability. By allocating resources effectively, organizations can ensure that they are maximizing their productivity by using their resources in the most productive way possible, leading to greater efficiency and profitability.

A resource is a physical variable, as men, money, material, machines, space that is required for completing various activities/job of a project.

Supervisory, technical and skilled manpower, space and equipment are usually the most important resources that need allocated carefully.

Resource allocation has effect on inventory management as well as resource optimizations because availability of resource will also decide project completion time.

#### **Approaches to Solve Resource Allocation Problem**

##### **1. Resources smoothing-**

A technique that adjust the activities of a schedule model such that requirements of resources on the project do not exceed certain predefined limit. In this case demand of the resources is made more or less uniform throughout the duration of project that is achieved by delaying starting or finishing of the activities by their available float, critical activity, critical path, project duration.

Total project duration, critical activity, critical path are not changed in this system but some of the activity start times are shifted by their available float so that more or less uniform demand is generated.

It focus on moving the activities. It is an adjustment of resource without affecting project duration.

If resources are limited then it is adopted.

##### **2. Resource Leveling-**

It is a technique used to examine unbalanced use of resources over time, and for resolving over allocation of conflicts resulting from scheduling certain tasks simultaneously. Total duration of project is increased in this approach. There are activities rescheduled in such a way that the maximum demand of the resources becomes less than availability of resources.

In the resource leveling process, the activities are so rescheduled that the maximum or peak resources requirement does not cross the limit of available resources.

It is used to balance the workload of primary resources over the course of the project, usually at the expense of one of the traditional triple constraints (time, cost, scope).

It assigns resources to project activities in a manner that will improve productivity and efficiency.

It focuses on moving the resources.

**Resource management-** It refers to the judicious (effective) allocation of physical resources and the utilization of various resources, including human resources, equipment, material, and finances, to meet project or operational objectives.

**Manpower leveling-** It is a specific aspect of resources management that focuses on the effective allocation of human resources to ensure a balanced and steady workflow throughout a project.

**Supply chain management** - It is defined as the planning, implementation and controlling of the flow of materials (getting the correct materials to surface when needed), information and finances across the entire supply chain, from the initial supplier to the end customer.

## **ORGANIZATION**

The project organization is the structure of the project. Created separately with specialists and workers from various departments.

### **Types of Organizations-**

#### **1. Line/Military Organization-**

It is the oldest and simplest method of administrative organization. According to this type of organization, the authority flows from top to bottom in concern. Responsibilities in all levels are definite and fixed in this organization.

- It is suitable for small construction works.

#### **Advantage of line organization–**

- i. It is simple to work and easy to understand by the employees.
- ii. It permits quick decisions.
- iii. It is most effective and economical.

iv. It provides strong discipline.

v. Responsibility is fixed and every body knows to whom he is responsible and who is responsible to him.

vi. These are easier to establish

vii. There is unity of control

viii. Decisions can be taken quickly

ix. There is a strong sense of discipline.

#### **Disadvantages of line organization–**

i. Lack of specification

ii. Lack of co-ordination

#### **2. Functional Organization**

This type of organization was introduced by F.W.

Taylor.

- Under the functional organization, the quality of work is better, wastage of material is minimum and specialized knowledge and guidance to individual member is provided.

- This type of organization is suitable for large/heavy construction works.

#### **3. Line and Staff Organization-**

It is also known as specialist organization. This type of organization has practically all the advantages of both the line and functional organizations. In the line and staff organization, the quality of work is improved and there is less wastage of material, man and machine.

- It is a most popular type of organization which is preferred for medium size construction work.

## **QUALITY CONTROL**

Function of the management to ensure the project work is carried out in accordance, with the specification and drawing and the delivery of durable, safe and reliable structures, effective quality control practices not only enhance the durability and safety of structures but also contribute to client satisfaction, regulatory compliance and overall project success. QC is carried out through proper inspection at various stages of project.

#### **Importance of quality control-**

(i) Ensuring structural integrity

- (ii) Enhancing client satisfaction
- (iii) Cost and time saving
- (iv) Meeting regulatory standards.
- (v) Enhance safety and regulation
- (vi) Improved efficiency and reduced liability

### **Elements of Quality**

#### **a. Quality Characteristics-**

Material quality like compressive strength, slump, size of aggregate, water cement ratio, surface finish etc, are the important characteristics to be checked frequently for structural purpose.

#### **b. Quality of Design**

The desired standards for the characteristics that define a product such as dimension or strength and other standards are specified. If very high standards

of quality and stiff tolerance limits are set, then this will increase the cost of the project.

#### **c. Quality of Conformance**

Whatever design quality has been specified, then the degree to which it is achieved in the actual construction work is the quality of conformance.

#### **■ Organization for Quality Control-**

The responsibility for quality control is taken by the resident engineer and his inspectors. The specifications stipulated in the design are enforced

by the resident engineer and his inspection team during the construction. The resident engineer also interacts with the project engineer and his team who are carrying out the construction for complying with the standards.

#### **Quality Assurance-**

It is the independent function that monitors the quality control programs and assures that the desired results within specified limits and tolerances are obtained. PMBOK refers to QA as the "management section of quality managements."

#### **Quality Assurance Techniques-**

The major quality control methods are:

##### **i. Inspection**

This consists of receiving inspection, in-process inspection and the final inspection before accepting the constructed structure. First of all, inspection is to be carried out for the materials of construction about their quality and acceptability. Then comes the inspection during the process of construction. For doing this, a check list has to be prepared.

##### **ii. Testing**

This means the examination of a material or product to check its conformance to the specified performance standards. Testing can be destructive or non-destructive. It may take place on the site or in the special laboratories. In destructive testing, the elements is tested intentionally to failure as in the case of concrete cube testing.

##### **iii. Sampling**

This is the process of determining the quality of a large group by examining a part of the group that will be statistically representative of the whole group. The reliability of the information obtained increases with the size of sample used. IF the size of the sample is recued, then the cost of inspection is reduced, but this will also reduce the reliability. This will result in acceptance of substandard work.