CPM & CONSTRUCTION EQUIPMENT

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CONTENT

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CHAPTER-1
CPM & PERT

PROJECT:

- A project is made up of a group of interrelated work activities constrained by a specific scope, budget and schedule to achieve the specific goals of an agency.
- Projects are defined by their scope, budget and schedule.

Project cost:

- Project cost comprises of material cost and equipment cost.
- To reduce project cost, both material and construction cost are to be reduced.
- Material cost can be reduced by adopting different design philosophies.
- Construction cost is reduced with help of numerical techniques such as CPM and PERT

Note: A project has a specific purpose. It starts at a specific point and is finished when its objected is achieved/fulfilled.

Project Management:

Objective:

- To complete the project with minimum elapsed time.
- To minimize the project cost while satisfactorily completing the task.
- Optimum use of available resources.

Resources

Resources are of two types

(*i*) Physical Resources: *e.g.,* Manpower, Equipment, Space, Materials etc.

(*ii*) Non-Physical Resources: *e.g.,* Time.

Various Phases of a Project:

1. **Planning**:
   - Efficient use of machineries, material, men etc. along with minimizing resource cost is the basic aim of this phase.
   - It involves proper sequencing of events.

2. **Scheduling** :
   - Scheduling is basically the allocation of resources.
   - Process of sequencing various events of a project within a timeframe.
   - Required for continuous tracking of project, resource mobilization etc.
   - Useful in minimizing the cost and optimal use of resources.
   - Assigning dates for start and completion of each activity in logical sequence in systematic manner.
3. **Controlling & Monitoring** :

- Execution of the project is monitored for its timely completion.
- In controlling, actual activities that are to be performed are monitored and if there is any deviation from the original plan, it is rescheduled and re-planned in such a way that project is completed in time.

- To monitor project cost, progress of construction, etc.

Note: The first method that was developed for planning a project is called project planning & scheduling (PPS). Critical path method (CPM) came later and are generally used these days for similar type of project and it has a deterministic approach.

TECHNIQUE USED FOR PROJECT MANAGEMENT:

(I) Bart chart: [Characteristic] [Developed by Gantt in 1900 AD]

(i) It is simple & easy to understand.

(ii) It is graphical arrangement of the activities on the time scale.

(iii) A bar chart consist of two co – ordinate axes one representing the time elapsed and other represent the jobs or activities to be performed.

(iv) It is a pictorial representation.

(v) The activities are represented in the form of bars, whereas the beginning and the end point of the bar represents the starting and finish time of the activity. Hence the length of the bar signifies the duration of a particular activity.

(vi) Shaded width of bar represents the percentage completion of that particular activity.

(vii) It is used only for small scale project.

Short comings of bar chart:

(i) Can be used for small projects only

(ii) Can be used for the projects which are repetitive in nature.

(iii) Lack of details:

Only major actives are shown in a bar chart and sub activities cannot be separated out. It too many activities or tasks are shown separately it becomes clumsy.

(iv) Review of project progress:

It cannot be used as a control device as it does not shows the progress of work

(v) Activity inter relationship:

In a project there can be several activities which may start concurrently, bar char cannot differentiate such activities.

(vi) Time uncertainties:

Bar charts are not useful in the project where there are uncertainties in determination of estimation of time required for completion of various activities.

(vii) Bar chart cannot differentiate between critical and non – critical activities. Hence updating of individual activities of resources smoothing and resource leveling cannot be done.

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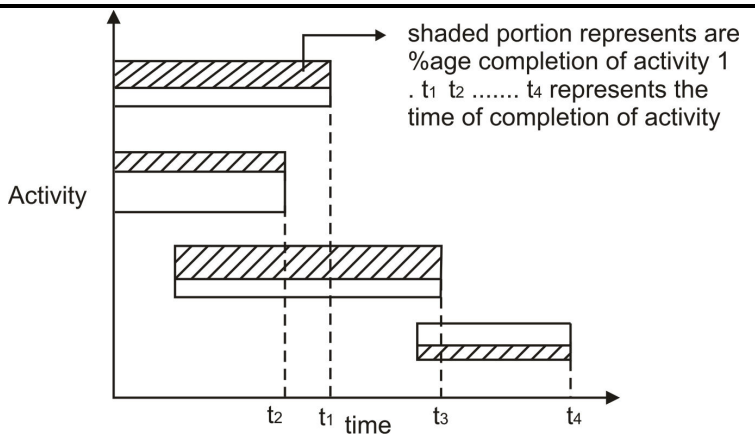


(II) Milestone chart:

i) It is an improvement over the original Gantt chart. Milestones are specific points in time which mark the completion of certain portions of the main activity.

ii) It gives idea about completion of sub activities.

iii) Controlling can be better achieved but still activity inters relationship and accountability of time uncertainly cannot be depicted.
This can be achieved by network method discussed further.

Network Methods

- CPM & PERT are two major network methods.
- Other network methods are like UNETICS, LESS, TOPS and SCANS. However PERT & CPM are major network method.

CPM: - Critical Path Method

- It involves deterministic approach.
- Used for repetitive project, e.g. construction of a building.

PERT: - Project / Programme Evaluation and Review Technique.

- It involves probabilistic approach.
- Used for research and development projects, e.g. Missile Programme.

Network Diagram

- It is a flow diagram consisting of activities and events connected logically and sequentially.
- In network diagram, all the limitations of bar chart and milestone chart are removed and they are generally used for big and complex projects.

Elements of a Network

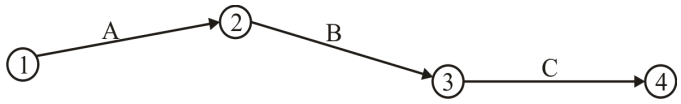
1. Activity :

- It represents execution of a specific job.
- It requires time and resources. For its completion.
- It is represented by an arrow.
  e.g. - Brickwork, Plastering etc.

Brickwork → Plastering →

- Activities which can be performed simultaneously and are independent of each other are called parallel activity.
- The activities which are performed one after the another are known as serial activities. These activities are dependent upon each other.
- Activities performed prior to an activity under consideration are called as predecessor activities to that activity.

- Activities performed after completion of an activity under consideration are called as successor activities to that activity.



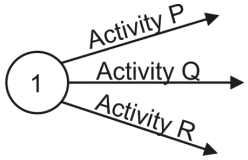
"A" is predecessor activity of "B".
"C" is successor activity of "B".
AoA system (Activity on arrow system) is represented by arrow between events.
AoN system (Activity on Node) system is represented by activity on nodes. Events have no place in such system.

2. Event :

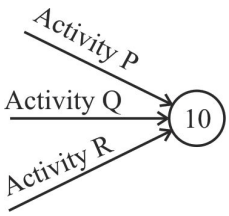
- It represents start or end of a task.
- It is generally represented by a circle.

Note: Circle is generally used but event can be represented by any shape.

- Beginning of an activity is called **tail event** and denoted by "i-node".



- Completion of an activity is called **head event** and denoted by "j-node". Add (8)

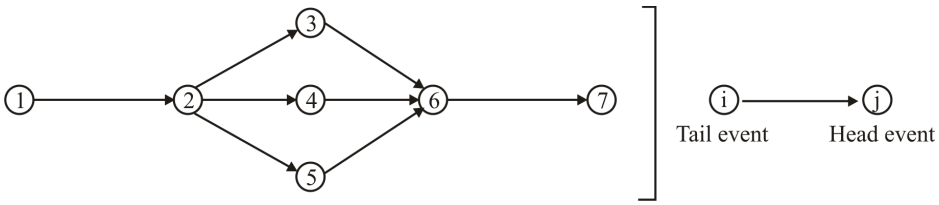


- Events which occurred prior to an event under consideration are called as **predecessor event** to that event.
- Events which occur after an event under consideration are called as **successor event** to that event.

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

(a) Circular
(b) Rectangular
(c) Square
(d) Oval

- If a tail event marks the beginning of a project then it is known as initial event.
- If a head event marks the ending of a project, it is known as finish event.
- The events which acts as both head and tail events are known as dual role events.
- There can only be one initial event and one finish event in a project.

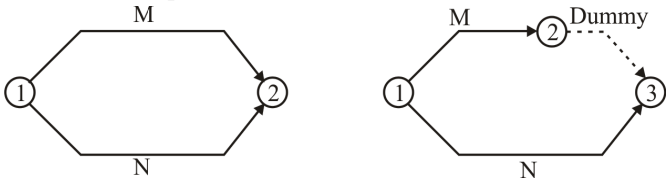


(1) Is initial event (7) Is finish event

(1), (2) are predecessors event to (3).
(6), (7) are successor events to (3).
Event (2), (3), (4), (5) & (6) are dual role events.

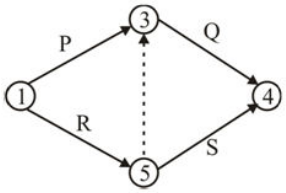
3. **Dummy :**
   - It denotes an artificial activity.
   - It is represented by a dotted arrow.
   - It indicates that an activity following the dummy cannot be started until the activities preceding the dummy are not completed.
   - It does not require time or resources.
   - It denotes depending among the activities

Objective:
(*a*) To avoid geometrical/grammatical mistakes.
(*b*) To establish logical relationship between activities.



Type (a)

Use of "Dummy" here gives both activities a unique identification.
M → ①-②
N → ①-②

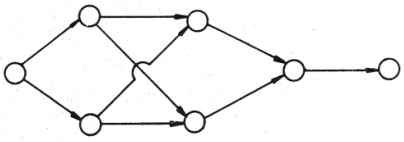


Type (b)

- Dummies are used to show predecessor relationship but if that relation is perfectly established inside the network, then such dummy is a redundant & should be removed.
- It dummy is only incoming arrow to a node then it can be removed provided there is no logical or grammatical error.

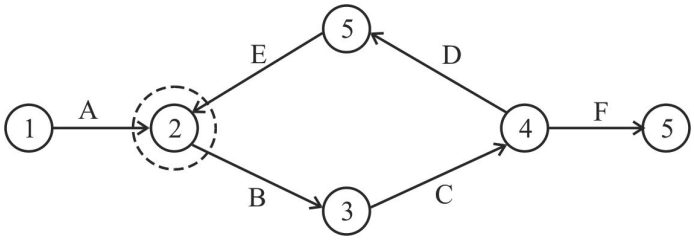
Rule of Network:

- In every project network, there should be only one initial and final event.
- Events occur in a particular order and any event cannot occur until all the predecessor events are not completed.
- Time flow is preferably assumed from left to right.
- Normally, arrows should not cross each other. If it is necessary to cross each other, the arrow should make a bridge over the other.



- Every activity should have its own "i-j" node, such that value of "j-node" should always be greater than "i-node".

- Number of arrows should be equal to the number of activities.
- An event cannot occur twice.



i.e., Error occurs at event (2) due to looping
Note: An arrow used to represent the activity in the network is not a vector.

Fulkerson's rule for numbering the node of events:

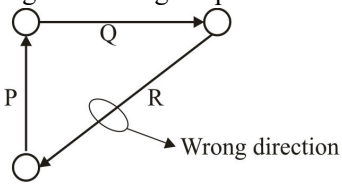
- 1. The initial event is numbered as (1, 10 etc.)
- 2. Now all arrows coming out of initial event (1, 10 etc.) are removed. Thus one or more initial events are created which is numbered as (2, 3,4 etc…….or 20,30,40 etc…)
- 3. Step 2 is repeated until the final event of the network is not numbered.

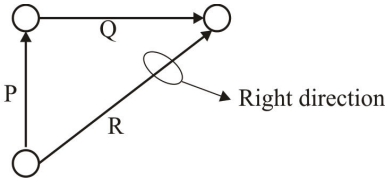
Note: During the controlling phase, new events may be added in the network or existing events may be removed from the network requiring the re-numbering of the network.
In such cases, skip numbering of events is done to avoid the renumbering in network.

Errors in Network:

1. **Looping Error:**

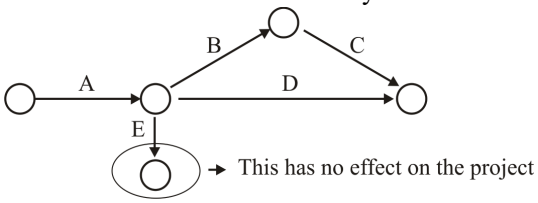
- It generates logical problem in the network.





2. **Dangling Error:**

- Each network should contain only one initial event and one final event.



3. **Wagon Wheel Error:**

- It generates logical error in network.

CPM NETWORK:

- In CPM, only one time estimate is done for each activity since it is based upon deterministic approach.

Critical Path:

- It is defined as the path of longest project duration.
- The activities lying in critical path are called critical activities.
- Hence critical activities signify that any delay in critical activities will ultimately delay the overall project.
- All other activities which are not on critical path will not affect total duration of project.
- Alternatively, it can be stated that critical path is the shortest possible duration to complete the job/project.

Computation of project time:

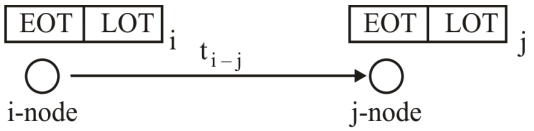
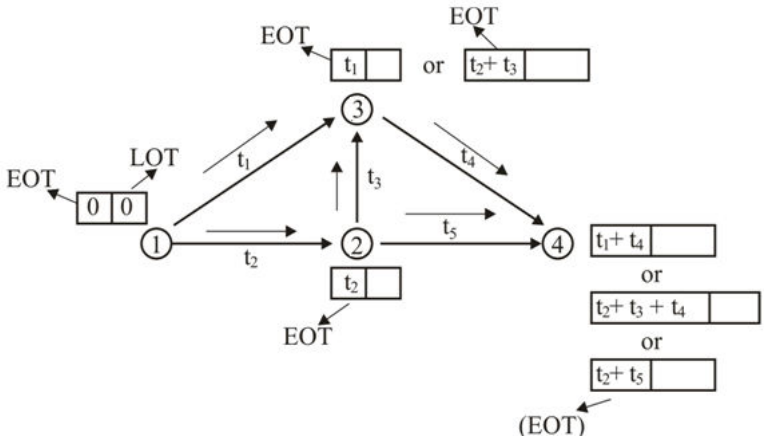


Figure (a)

- The box at the "i-node" contains two terms:
  - (i) EOT- Earliest occurrence time at i-node.
  - (ii) LOT- Latest occurrence time at i-node.
- "t_{i-j}" → Duration of Activity.

EOT & LOT:



- It is the earliest time when an event can occur.
- In general ,it can be written as:

$$\boxed{(EOT)_j = (EOT)_i + t_{i-j}} \quad \text{.....(i)}$$

- To compute the (EOT)at all the nodes:

i. Assume the value of | EOT | LOT | at first node i.e. at 1 equal to | O | O |

ii. Now, calculate the value at the other nodes using above equation

$\therefore \boxed{(EOT)_2 \quad 0 \quad t_2 + \quad t_2}$ (at node only one activity merges)

$$\left.\begin{array}{l}(EOT)_2 = 0 \quad t_1 \quad t_1 = \\ \qquad OR \\ \qquad = t_2 \quad t_3 \quad (t_2 \quad t_3)\end{array}\right\} \therefore \quad (EOT)_3 \quad \text{Maximum of}\,(t_1, (t_2 \quad t_3))$$

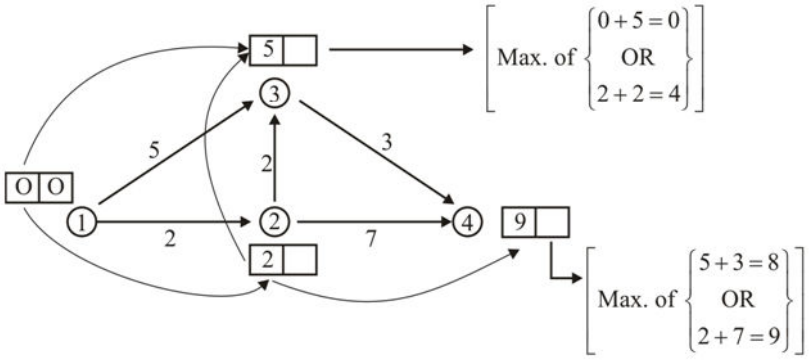
- Then, proceed with maximum value of $(EOT)_2$
  (for illustration both values is taken here for calculation at $(EOT)_4$)

$$(EOT)_4 = \text{Maximum of} \begin{cases} (t_1) + (t_4) = t_1 + t_4 \\ (t_2 + t_3) + (t_4) = t_2 + t_3 + t_4 \\ (t_2) + (t_5) = t_2 + t_5 \end{cases}$$

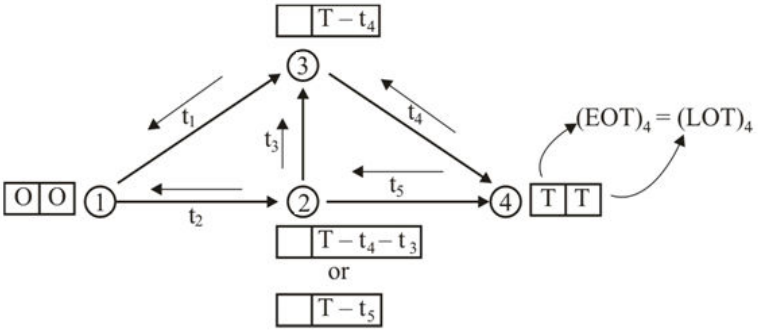
- Hence, in general it can be stated that

$$\boxed{(EOT)_j = \left[(EOT)_i + t_{i-j}\right]_{\max.}}$$ if more than one activities merge at an event.

- Total project time is given by $(EOT)_4$ or EOT of last event.
- Thus, it is calculated by forward method.
  e.g.



- Proceed with previous figure



- It is defined as the latest possible time at which event may take place without affecting the total project duration which is calculated by forward pass method.
- Hence,(LOT) of last event is taken equal to (EOT) of last event.

Hence, $\boxed{(EOT)_4 = (LOT)_4 = T}$

- In general, $\boxed{(LOT)_i = (LOT)_j - t_{i-j}}$ ……..(ii)
- It is also known as backward pass method.
- Now calculate values at other nodes using above equation (ii)

$(LOT)_3 = T - t_4$ [only one activity meets at this event while tracing in backward direction]

$$(LOT)_2 = \text{Minimum of } \begin{cases} T - t_5 = T - t_5 \\ (T - t_4) - t_3 = T - t_4 - t_3 \end{cases}$$

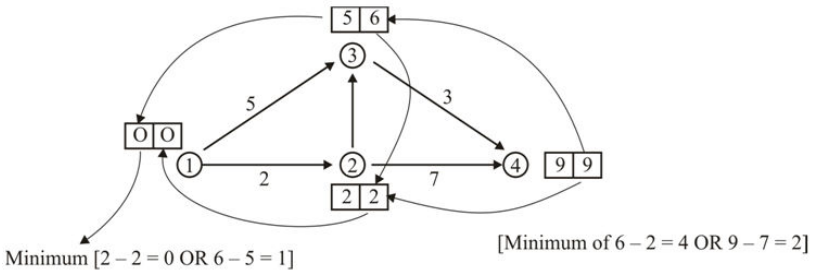
Similarly, $(LOT)_1$=Minimum of values calculated at 1

[since, it is initial event, hence it should be equal to $(EOT)_1=0$]

- Hence ,it can be stated as :

$\boxed{(LOT)_i = [\ (LOT)_j - t_{i-j}\ ]_{\text{min.}}}$ - Minimum of all the values, if more than one activity merges at an event.

e.g. using the previous example:

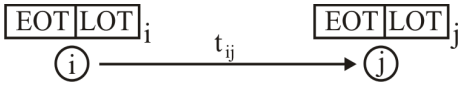


Notes:

I. Nodes having some values of EOT and LOT are called as critical nodes. And the paths connecting the critical nodes are called as critical path.

II. A project may have more than one critical paths, but the time taken by each critical paths will be same.

Activity time in CPM:



1. **EST: Earliest Start Time:**

- It is the earliest possible time at which an activity may start.

$$(EST)_{i-j} = (EOT)_i$$

2. **EFT: Earliest Finish Time:**

- It is the earliest possible time at which an activity may finish

$$(EFT)_{i-j} = (EOT)_i + t_{ij}$$

3. **LST : Latest Start Time:**

- It is the latest possible time at which an activity may start without any delay in project duration.

$$(LST)_{i-j} = (LOT)_j - t_{ij}$$

4. **LFT : Latest Finish Time:**

- It is the latest possible time at which an activity may finish without any delay in project duration.

$$(LFT)_{i-j} = (LOT)_j$$

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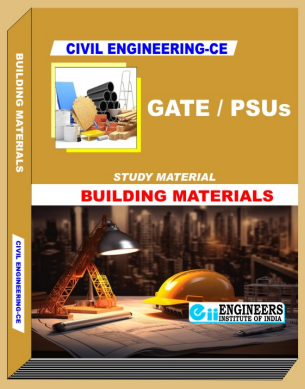

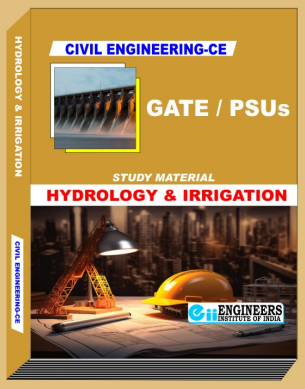

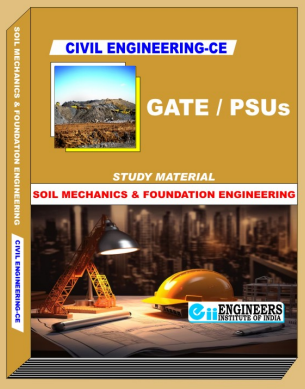

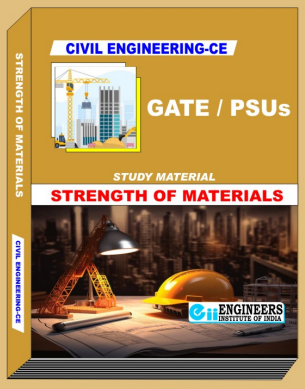

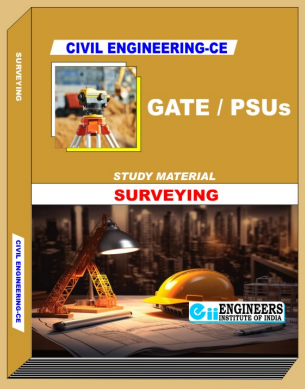

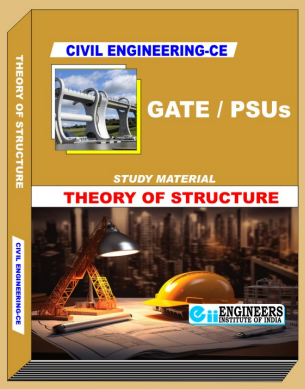

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