SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
SCHOOL OF MECHANICAL ENGINEERING

Subject Title: Resource Management Techniques **Subject Code: SPR1307**

Course: B.E (Common to all Engineering Branches)

UNIT – III RESOURCE SCHEDULING AND NETWORK ANALYSIS

RESOURCE SCHEDULING - SEQUENCING

DEFINITION:

The selection of an appropriate order for a series of jobs to be done on a finite number of service facilities is called sequencing. The objective is to determine the optimal order of performing the jobs in such a way that the total elapsed time will be minimum. The total cost involved may be minimum if the total elapsed time is made minimum in the business situation.

Consider there are jobs 1,2,3,…..................n to be processed through m machines. (The machines may be A, B, C ....)There are actually (n!)^m combinations. The objective is to find the technologically feasible solution, such that the total elapsed time is minimum.

E.g.: Consider 5 jobs and 2 machines.

Possible sequences = $(5!)^2$ = 14400. From these (14400) sequences the best sequence(having minimum total elapsed time) has to be selected.

Consider a printing press. Each job is processed through two machines MI and M2. Documents arrive there for printing books, articles, magazines etc. Printing is done with desired number of copies on machine MI. Binding of the materials is done on machine M2.The press has at present, five jobs on hand. The time estimates for printing and binding for each job are worked out as follows:

	Time (hours) for	
Job No.	Printing	Binding
1	22	50
2	18	25
3	55	45
4	42	50
5	35	20

How do you sequence the jobs in order to minimize the finish time (the total time devoted by the press) of all the jobs?

IMPORTANT TERMS

- **No of machines** means the number of service facilities through which the jobs must be passed for processing.
- **Processing order** – is the order in which the machines are required for processing the job.
- **Processing time** – is the time taken by each job at each machine.
- **Total elapsed time** – is the time interval between starting the first job and completing the last job.
- **Idle time** – is the time during which the machine remains idle during the total elapsed time.
- **No passing rule** –refers to the rule of maintaining the same order of processing for all the jobs. Each job should be processed in the particular order.

ASSUMPTIONS OF SEQUENCING:

- Only one operation is carried out in a machine at a time.
- Processing times are known and they do not change.
- Each operation as well as the job once started must be completed.
- Only one machine of each type is available.
- The transportation time in moving jobs from one machine to another is negligible.

- No inventory aspect of the problem is considered.
- Only on completion of an operation, the next operation can start.
- Processing times are independent of the order in which the jobs are performed.
- Jobs are completely known and are ready for processing when the period under consideration starts.

SEQUENCING FOR PROCESSING OF 'n' JOBS THROUGH TWO MACHINES [JOHNSON'S ALGORITHM]

- Let the jobs be 1,2,3,…........................... n
- Let the two machines be A & B.
- Let the processing order be A-B.
- Let the processing time in A be A_1, A_2, A_3............................ A_n
- Let the processing time in B be B_1, B_2, B_3,............................ B_n

STEP 1:

Examine the available processing time on Machine A & Machine B and find the smallest Value.

STEP 2:

a) If the minimum value falls on A schedule it first. If it occurs in B schedule it last.

b) If there is a tie of equal minimum values, one in A and one in B for different jobs then schedule the job in A first and schedule the job in B last.

c) If there is a tie equal minimum values both in A, choose the job with the minimum value in B and schedule it first and the next job consequently.

d) If there is a tie of equal minimum values both in B, choose the job with the minimum value in A and schedule it last and the next job previously.

e) If there is a tie of equal min values both in A and B for the same job, choose the job and schedule it either first or last. (Preferably first)

STEP 3:

Cancel the scheduled job along with the processing times Repeat the same procedure from step 1 till all the jobs are scheduled, to get the optimum sequence.

SEQUENCING FOR PROCESSING OF 'n' JOBS THROUGH THREE MACHINES

- Let the 3 machines be A, B and C.
- Let the processing order be ABC
- Let the jobs be 1, 2, 3,…......................... n.
- Let the processing time in A be A_1, A_2, A_3.............................. A_n
- Let the processing time in B be B_1, B_2, B_3,…......................... B_n
- Let the processing time in C be C_1, C_2, C_3.............................. C_n

The three-machine problem can be converted in to a two-machine problem and Johnson's method can be applied for finding the optimum sequence if either of the following condition is satisfied:

[Min Processing time in A >= Max processing time in B]

OR

[Min Processing time in C >= Max processing time in B]

Convert the 3-machines in to 2 fictitious (imaginary) machines to apply Johnson's method for finding the optimum sequence. Let the two fictitious machines be X and Y.

$\mathbf{X_i = A_i + B_i}$

$\mathbf{Y_i = B_i + C_i}$

Follow the same procedure of Johnson's method as for 2 machines to find out the sequence.

Note : Consider all the three actual machines(A, B & C) to find out the total elapsed time & find idle time.

SEQUENCING FOR PROCESSING OF 'n' JOBS THROUGH 'm' MACHINES

- Let the machines be A,B ,C .... m
- Let the processing order be ABC..m
- Let the jobs be 1,2,3,…........................... n.
- Let the processing time in A be A_1, A_2, A_3.............................. A_n
- Let the processing time in B be B_1, B_2, B_3,…........................... B_n
- Let the processing time in C be C_1, C_2, C_3.............................. C_n
- Let the processing time in m be m_1, m_2, m_3.............................. m_n

The m machine problem can be converted in to a two-machine problem and Johnson's method can be applied for finding the optimum sequence if either of the following condition is satisfied:

[Min Processing time in A >= Max processing time in B,C,D….m-1]

OR

[Min Processing time in m >= Max processing time in B,C,D….m-1]

Convert the m machines in to 2 fictitious (imaginary) machines to apply Johnson's method for finding the optimum sequence. Let the two fictitious machines be X and Y.

$\mathbf{X_i = A_i + B_{i \ldots\ldots} (m-1)_i}$

$\mathbf{Y_i = B_i + C_i \ldots . m_i}$

Follow the same procedure of Johnson's method as for 2 machines to find out the sequence.

Note : Consider all the actual machines(A, B,C,D,E, …) to find out the total elapsed time & find idle time.

Project Management

Project management is concerned with the overall planning and co-ordination of a project from conception to completion aimed at meeting the stated requirements and ensuring completion on time, within cost and to required quality standards.

Project management is normally reserved for focused, non-repetitive, time-limited activities with some degree of risk and that are beyond the usual scope of operational activities for which the organization is responsible.

What is a Project?

"A project is a one-shot, time-limited, goal-directed, major undertaking, requiring the commitment of varied skills and resources".

- A project is a temporary endeavor undertaken to create a unique product or service.
- A project is temporary in that there is a defined start (the decision to proceed) and a defined end (the achievement of the goals and objectives).
- Ongoing business or maintenance operations are not projects. Energy conservation projects and process improvement efforts that result in better business processes or more efficient operations can be defined as projects.
- Projects usually include constraints and risks regarding cost, schedule or performance outcome.

Steps in Project Management

A successful Project Manager must simultaneously manage the four basic elements of a project: resources, time, cost, and scope. Each element must be managed effectively. All these elements are interrelated and must be managed together if the project is to be a success.

The various elements of project management process are

a) Need identification

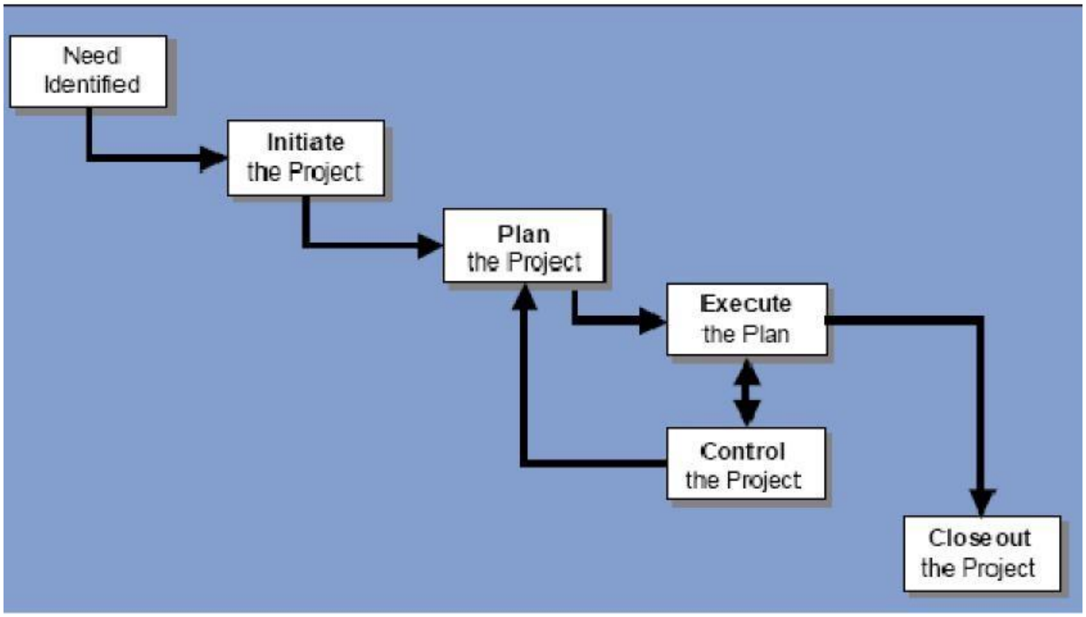
b) Initiation

c) Planning

d) Executing

e) Controlling

f) Closing out



The first step in the project development cycle is to identify components of the project. Projects may be identified both internally and externally. The project could be undertaken for a specific objective or need like Cost-effectiveness of energy savings or Sustainability of the savings over the life of the equipment. Or Availability of technology, and ease of adaptability of the technology to Indian conditions or Other environmental and social cost benefits (such as reduction in local pollutants)

b) Initiation

Initiating is the basic processes that should be performed to get the project started. The success of the project team depends upon starting with complete and accurate information, management support, and the authorization necessary to manage the project.

c) Planning

The planning phase is considered the most important phase in project management. Project planning defines project activities that will be performed; the products that will be produced, and describes how these activities will be accomplished and managed. Project planning defines each major task, estimates the time, resources and cost required, and provides a framework for management review and control.

d) Executing

Once a project moves into the execution phase, the project team and all necessary resources to carry out the project should be in place and ready to perform project activities.

e) Controlling

Project Control function that involves comparing actual performance with planned performance and taking corrective action to get the desired outcome when there are significant differences. By monitoring and measuring progress regularly, identifying variances from plan, and taking corrective action if required, project control ensures that project objectives are met.

f) Closing out

Project closeout is performed after all defined project objectives have been met and the customer has formally accepted the project's deliverables and end product or, in some instances, when a project has been cancelled or terminated early.

Project Planning Techniques

The three basic project planning techniques are Gantt chart, CPM and PERT. All monitor progress and costs against resource budgets.

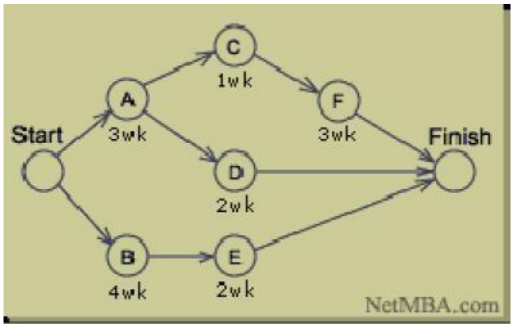
Gantt Chart

Gantt charts are also called Bar charts. Gantt chart is now commonly used for scheduling the tasks and tracking the progress of energy management projects.

CPM - Critical Path Method

DuPont developed a **Critical Path Method** (CPM) designed to address the challenge of shutting down chemical plants for maintenance and then restarting the plants once the maintenance had been completed.

CPM models the activities and events of a project as a network. Activities are shown as nodes on the network and events that signify the beginning or ending of activities are shown as arcs or lines between the nodes.



Steps in CPM Project Planning

1. **Specify the individual activities.**
2. **Determine the sequence of those activities.**
3. **Draw a network diagram.**
4. **Estimate the completion time for each activity.**
5. **Identify the critical path (longest path through the network)**
6. **Update the CPM diagram as the project progresses.**

1. Specify the individual activities

All the activities in the project are listed. This list can be used as the basis for adding sequence and duration information in later steps.

2. Determine the sequence of the activities

Some activities are dependent on the completion of other activities. A list of the immediate predecessors of each activity is useful for constructing the CPM network diagram.

3. Draw the Network Diagram

Once the activities and their sequences have been defined, the CPM diagram can be drawn. CPM originally was developed as an *activity on node* network.

4. Estimate activity completion time

The time required to complete each activity can be estimated using past experience. CPM does not take into account variation in the completion time.

5. Identify the Critical Path

The critical path is the longest-duration path through the network. The significance of the critical path is that the activities that lie on it cannot be delayed without delaying the project. Because of its impact on the entire project, critical path analysis is an important aspect of project planning.

The critical path can be identified by determining the following four parameters for each activity:

- ES - earliest start time: the earliest time at which the activity can start given that its precedent activities must be completed first.

- EF - earliest finish time, equal to the earliest start time for the activity plus the time required completing the activity.
- LF - latest finish time: the latest time at which the activity can be completed without delaying the project.
- LS - Latest start time, equal to the latest finish time minus the time required to complete the activity.

The *slack time* for an activity is the time between its earliest and latest start time, or between its earliest and latest finish time. Slack is the amount of time that an activity can be delayed past its earliest start or earliest finish without delaying the project.

The critical path is the path through the project network in which none of the activities have slack, that is, the path for which ES=LS and EF=LF for all activities in the path. A delay in the critical path delays the project. Similarly, to accelerate the project it is necessary to reduce the total time required for the activities in the critical path.

6. Update CPM diagram

As the project progresses, the actual task completion times will be known and the network diagram can be updated to include this information. A new critical path may emerge, and structural changes may be made in the network if project requirements change.

CPM Benefits

- Provides a graphical view of the project.
- Predicts the time required to complete the project.
- Shows which activities are critical to maintaining the schedule and which are not.

CPM Limitations

While CPM is easy to understand and use, it does not consider the time variations that can have a great impact on the completion time of a complex project. CPM was developed for complex but fairly routine projects with minimum uncertainty in the project completion times. For less routine projects there is more uncertainty in the completion times, and this uncertainty limits its usefulness.

PERT

The *Program Evaluation and Review Technique* (PERT) is a network model that allows for randomness in activity completion times.

A distinguishing feature of PERT is its ability to deal with uncertainty in activity completion times. For each activity, the model usually includes three time estimates:

- *Optimistic time (OT)* - generally the shortest time in which the activity can be completed. (This is what an inexperienced manager believes!)

- *Most likely time (MT)* - the completion time having the highest probability. This is different from expected time. Seasoned managers have an amazing way of estimating very close to actual data from prior estimation errors.

- *Pessimistic time* (PT) - the longest time that an activity might require.

Benefits of PERT

PERT is useful because it provides the following information:

• Expected project completion time.

• Probability of completion before a specified date.

• The critical path activities that directly impact the completion time.

• The activities that have slack time and that can lend resources to critical path activities.

• Activities start and end dates.

Limitations of PERT

The following are some of PERT's limitations:

- The activity time estimates are somewhat subjective and depend on judgment. In cases where there is little experience in performing an activity, the numbers may be only a guess. In other cases, if the person or group performing the activity estimates the time there may be bias in the estimate.
- The underestimation of the project completion time due to alternate paths becoming critical is perhaps the most serious.

NETWORK ANALYSIS

Introduction

Planning is as vital for the survival and growth of an organization as it is for any individual. This is so because planning is intimately and inseparably linked with the very existence of human being. Every non-routine task, whether major or minor, demands planning for its completion in definite time and at a definite cost .For example. you may think of your tasks as going out for a picnic with your friends. Similarly, organizations may be interested in the tasks like developing a new product, construction of a new building or highway, expansion or relocation of a factory; we refer to these tasks as projects.

With growing sophistication of technology, the projects at organizational level have tended to become more and more complex, demanding efficient method of planning. Considering the inherent adequacies for planning big and complex projects, some efforts were made in USA and other western countries during 1950s to develop certain more efficient techniques. The outcome was the development of **CPM** (Critical Path Method) and **PERT** (Project Evaluation and Report

Technique), which are two important techniques for planning and scheduling of large projects. These techniques are most widely used in industry and services around the globe.

CPM was first developed by E. I. du Pontde Bemours & Company as an application to construction projects and was later extended to a more advanced status by Mauchly Associates. However, PERT was developed for the U.S. Navy by a consulting firm for scheduling the research and Project Scheduling development activities for the Polaris missile program.

Although these two methods were developed independently, they are similar. The most important difference is that the time estimates for the activities are assumed to be deterministic in CPM and probabilistic in PERT. But, the underlying basis of both the techniques is the Network diagram.

Project

A **project** defines a combination of interrelated **activities** that must be executed in a certain order before the entire task can be completed. The activities are interrelated in a logical sequence in the sense that some activities cannot start until others are completed. An activity in a project is usually viewed as a job requiring time and possibly resources (like manpower, money, material, machinery etc.) for its completion.

PHASES OF PROJECT

Any type of project scheduling consists of three basic phases namely:

PLANNING

The planning phase is initiated by breaking down the project into distinct activities with their associated logical sequence. The time estimates for each of the activities are then determined.

SCHEDULING

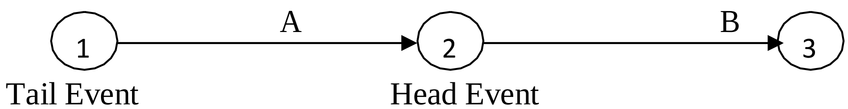
The scheduling phase constructs a time table giving the start and finish times of each activity as well as its relationship to the other activities in the project.

CONTROLLING

The final phase is project control where periodic progress is reviewed and, depending upon the situation revised time-table for the remaining part of the project is worked out.

Network Diagram

A network (or arrow) diagram is a graphic representation of the project, describing the logical sequence and the interdependence of the activities. Moreover, construction of network diagram helps studying all the activities more critically. The basic elements of a network diagram are Arrow and Node



So, in a network diagram, an arrow is used to represent an activity, with its head indicating the direction of progress of the concerned project. The length of an arrow is arbitrary; it has no relation with the duration of the concerned activity. And, a node indicates an event that signifies the star and/or completion of an activity.

A node is the beginning and end of activity. It represents a specific point in network time and does not consume time money and resources.

Activity

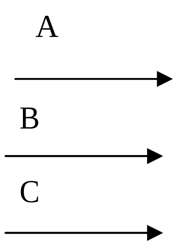
An activity represents a job or an individual operation for a project. It consumes time, money, or resources in doing the work.

Every activity has a head event and tail event. Event 1(tail event) indicates start and event 2 (head event) indicates completion of activity A. Activity B can start only after completion of activity A. Activity A is the predecessor activity and Activity B is the successor activity.

Dummy activity

An activity is one which does not consume time, money and resources but merely deceipts the technological dependence. It is an imaginary activity represented by a dotted line. Purpose for having a dummy activity is to create logic and avoid ambiguity.

Ex. Sending invitation cards for a function:

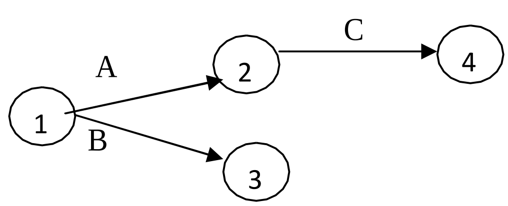


Printing of cards

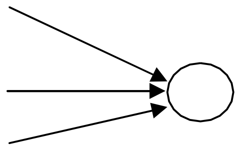
Collection of address

Dispatching

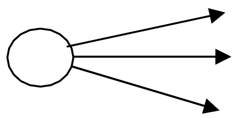
A & B can be done simultaneously but C can be done only after A & B hence to get the network logic we draw dummy activity.



Two or more activities ending in a single node is **merging**



Two or more activities starting in a single node is **burst**



The important aspect of the CPM is that it classifies every activity of the project into two categories - critical and non-critical activity.

An activity is critical if a delay in its start results in a delay in the completion of the entire project, otherwise it will be called a non-critical activity. Every critical activity is directly related to the duration of the project. Obviously, the activities that are critical call for close monitoring if the project is to be completed in due time. Non-critical activity will have some spare time, which is referred to as slack or float.

Critical Path

A path in a network diagram is a continuous chain of activities that connects the initial event to the terminal event. The length of a path is the sum of the durations of all the activities those lie on it. Critical Path defines the path consisting of critical activities only. It is the longest duration taken to complete the project. After preparing the network diagram and indicating the activity times on it, we can enumerate all the possible paths for the identification of critical path.

The length of the critical path gives the duration of the project. So, to shorten the time for completion of the project, we must reduce the duration of the activities lying on the critical path.

In order to complete the project in specified time, no delay is allowed in execution of the critical activities. It may be achieved by diverting allocated resources of non-critical activities to critical activities. However, this calls for information on the slack of each non-critical activity and Critical Path Method finds the same. They are extremely useful to a project-manager.

The important points with regard to network diagram construction:

- **(a)** In network diagram, an arrow represents an activity a d each node signifies either of the two events - start time or completion time. The length of an arrow is arbitrary. It has no relationship with the duration of the activity. The orientation of an arrow indicates the direction of its completion.

(b) The tail-event and head-event of an arrow represent the start and completion of the concerned activity respectively.

(c) Only one activity can span across any given pair of events.

(d) Event numbers should not get repeated.

(e) A dummy activity follows the same logic of precedence relationship as any other normal activity, but consumes no resource (including time).

(f) No unnecessary dummies.

(g) The start-time as well as the completion time of the project must be represented by unique events.

(h) No dangling of arrows. There should not be more than one terminal node.

(i) The logic of inter-dependencies between the activities is governed by the following rules.

(i) An event can occur only when all activities leading into it, have been completed.

(ii) No activity can commence until its tail event has occurred.

Earliest Occurrence Time

The earliest time for an event is the time at which the event will occur if the preceding activities are started as early as possible. The earliest times are obtained by making a forward pass through the network diagram, starting with the initial event and ending with the terminal event.

The following are the rules followed while carrying out forward pass:

(i) The e earliest time of the initial event is assumed to be zero.

(ii) An event occurs if (a) each immediately preceding event occurs at its earliest time, and (b) each intervening activity consumes exactly its specified duration.

(iii) The earliest time of an event is the sum of (a) the earliest time of the immediately preceding event, and (b) the intervening activity time. In case two or more activities lead to an event, its earliest time is the **maximum** of these sums involving each immediately preceding event and intervening activity.

Latest Occurrence Time

A backward pass, through the network diagram starting with the terminal event, gives the latest times for the events. The latest occurrence time of an event is the last time at which the event can occur without delaying the completion of the project beyond its earliest completion time. The following are the rules followed while carrying out backward pass:

1. The latest time for the terminal event is set equal to its earliest time, which is computed during forward pass.
2. An event occurs if (a) each immediately following event occurs at its latest tirne, and (b) each intervening activity consumes exactly its specified duration.
3. The latest time of an event is the difference of (a) the latest time of the immediately following event, and (b) the duration of intervening Activity. In case, two or more activities lead out of an event, its latest time is the **minimum** of these differences involving each immediately following event and the intervening activity.

Earliest Start is the Earliest occurrence time.

Earliest Finish = Earliest Start + Duration of an activity

Latest Start = Latest Finish – Duration of an activity

Latest Finish is the Latest occurrence time

Total Float

1. Total float is the time by which a particular activity can be delayed for non-critical activity.
2. It is a difference between latest finish & earliest finish or latest start & earliest start.
3. If the total float is positive, it indicates resources are more than adequate.
4. If the total float is negative, it indicates resources are inadequate.
5. If the total float is zero, it indicates resources are thus adequate.

Free Float:

It is the portion of Total Float. It is that amount of time where the activity can be rescheduled without affecting succeeding activity.

Free Float = Total Float – Slack of Head event

Where Slack = Latest Occurrence time – Earliest occurrence time

Individual Float

It is that amount of time where activity can be rescheduled without affecting both preceding & succeeding activity. It is a portion of Free Float

To Summarise

Arrow: An arrow is used to represent an activity, with its head indicating the direction of progress of the concerned project. The length of an arrow is arbitrary; it has no relation with the duration of the concerned activity.

Node: It indicates an event that signifies the start and/or completion of an activity.

Dummy Activity: It is a hypothetical (not real) activity that consumes no resources including time. It is used in the network diagrams to show the correct logical sequence between the activities, or to ensure that activities are uniquely defined. A dummy activity is represented by a dotted arrow and obeys the same logicof precedence relationships **as** the normal activities.

Path: It is a continuous chain of activities through the arrow diagram that connects the initial event to the terminal event.

Earliest Occurrence Time of an Event: This is the time at which the event will occur if the preceding activities are started as early as possible.

Latest Occurrence Time of an Event: This is the last time at which the event can occur without delaying the completion of the project beyond its earliest completion time.

Slack of an Event: The slack for an event is the difference between its Latest Occurrence Time and Earliest Occurrence Time.

Slack for an Activity: Slack for an Activity = Latest Occurrence Time of its head-event - Earliest Occurrence Time of its tail-event- Duration of the activity.

Critical Activity: An activity having zero slack is called critical.

Critical Path: It is a path consisting of only the critical activities. Every network diagram has a critical path. The length of a critical path gives the duration of the project.

PROJECT EVALUATION &REVIEW TECHNIQUE

In the CPM method, we have assumed that the estimate for the duration of every activity is accurate or exact. However, in real-life situations, it cannot be determined certainly. CPM could be helpful in cases of projects of repetitive nature which has sufficient prior information on activities involved and their duration like construction of buildings, bridges etc., whereas the activities and their duration for an entirely new project cannot be estimated certainly. In such a case PERT technique is used. It takes into consideration the concept of probabilities.

PERT calculations depend on three time estimates:

1. **Optimistic estimate** (t_o) is**a** minimum time duration of any activity when everything goes on well about the project. It can be also written as '**a**'.
2. **Pessimistic estimate** (t_p) is **maximum** time duration of any activity when everything goes against our will and lot of difficulties is faced in the project. It can be also written as '**b**'.
3. **Most likely estimate** (t_m,) means the time required in normal course when something goes on very well and something goes on bad during the project. It can be also written as '**m**'.

Then, given any activity, we compute its expected duration and variance induration are given by the following relations.

(a) **Expected duration (t_e)** = $\dfrac{t_o + 4t_m + t_p}{6}$

(b) **Standard deviation** = $\dfrac{t_p - t_o}{6}$

(c) **Variance** = $\left[\dfrac{t_p - t_o}{6}\right]^2$

Basic difference between PERT AND CPM

PERT

- PERT was developed in a brand new R and D project it had to consider and deal with the uncertainties associated with such projects. Thus the project duration is regarded as a random variable and therefore probabilities are calculated so as to characterize.
- Emphasis is given to important stages of completion of task rather than the activities required to be performed to reach a particular event or task in the analysis of network .i.e., PERT network is essentially an event-oriented network.
- PERT is usually used for projects in which time estimates are uncertain. Example :R&D activities which are usually non-repetitive.
- PERT helps in identifying critical areas in a project so that suitable necessary adjustments may be made to meet the schedule completion date of the project.

CPM

- CPM was developed for conventional projects like construction project which consists of well known routine tasks whose resources requirement and duration were known with certainty.
- CPM is suited to establish a trade off for optimum balancing between schedule time and cost of the project.
- CPM is used for projects involving well known activities of repetitive in nature.

Cost considerations in PERT

In PERT calculations, the cost involved in completing the project is also considered. There are two kinds of costs, direct cost and Indirect cost. Direct costs are the costs associated with each activity such as machine cost, labour cost, etc. Direct cost varies inversely as the duration of the activity. It increases when the time of completion of the job is to be reduced (crashed) since more machines and more labour, become necessary to complete the job in less time. Indirect costs are the costs due to management services, rentals, cost of security, establishment charges and similar overhead expenditures. When the duration of the project is shortened, indirect cost decreases. Therefore there is some optimum project duration which is a balance between the direct costs increasing with reducing of project duration and the indirect costs increasing with the lengthening of the duration. This method of finding the optimum duration is called Least Cost Schedule.

For each activity a normal time and normal cost is known. Also the crash time and the corresponding crash cost are also given. In order to reduce the duration, we crash the critical activities one by one and obtain the optimum duration.

Step-by-step Procedure

- Draw the network diagram.
- Determine the critical path, normal duration and total normal cost of the project.
- Find the cost slope of each activity using the formula

  $$\text{Cost slope} = \frac{\text{Crash cost - Normal Cost}}{\text{Normal time – Crash time}}$$

- Crash the critical activity having the least slope.
- Calculate the revised total cost [revised direct cost + new indirect cost] for the reduced duration.

- Determine the new critical path and repeat the process of crashing systematically till an optimum duration is obtained.

PROJECT SCHEDULING WITH LIMITED RESOURCES

Problems of resource scheduling vary in kind and complexity depending upon the nature of the project and its organization set up. Activities are scheduled so that no two of them requiring the same facility occurs at the same time, wherever possible. The problem of scheduling activities so that none of the precedence relations are violated is an extremely difficult task even for projects of modest size. The problem of scheduling project with the limited resources is usually large, combinatorial. Even the powerful techniques aided by the fastest, sophisticated computer can solve only small projects having not more than about 100 activities. Analytical techniques are impractical for real world problems of this type usually. One turns to Resource leveling Programs for such cases.

RESOURCE LEVELING PROGRAM:

Resource leveling helps an organization to make use of the available resources to the maximum. The idea behind resource leveling is to reduce wastage of resources i.e. to stop over allocation of resources. These programs attempt to reduce peak resource requirements and smooth out period to period assignments without changing the constraint on project duration.

Using the resource requirements data of the early start schedule, the program attempts to reduce peak resource requirements by shifting jobs with slack to non peak periods. Resource limits are not specified but peak requirements are leveled as much as possible without delaying the specified due date.

STEPS:

- Draw the early start schedule graph.
- Draw the corresponding manpower chart.
- Identify the activities with slack.
- Adjust the activities identified in step (3) and adjust them to level the peak resource requirements.

QUESTIONS

SEQUENCING

1. Find out the optimum sequence for the jobs which are to be processed through two machines. Machines A and B.

	Jobs			
	1	2	3	4
Machine A	1	6	6	5
Machine B	2	8	10	3

2.

	Jobs			
	1	2	3	4
Machine A	1	6	8	5
Machine B	2	10	6	3

3.

	Jobs					
	1	2	3	4	5	6
Machine A	2	4	6	3	3	10
Machine B	4	4	8	4	9	12

4. Find out the appropriate sequence total elapse time and total idle time for jobs to be processed through 2 machines.

	Jobs					
	A	B	C	D	E	F
Machine X	11	7	12	4	6	7
Machine Y	11	11	11	11	11	15

5.

	Jobs				
	1	2	3	4	5
Machine A	4	8	6	8	1
Machine B	3	4	7	8	5

6. Find out the appropriate sequence, idle time, and total elapsed time for processing through 3 machines.

	Jobs				
	1	2	3	4	5
Machine A	4	8	6	4	6
Machine B	2	3	1	1	4
Machine C	6	8	2	4	3

7. Find out the appropriate sequence, idle time, and total elapsed time for processing through 3 machines.

	Jobs					
	A	B	C	D	E	F
Machine 1	8	7	3	2	5	1
Machine 2	3	4	5	2	1	6
Machine 3	8	7	6	9	10	9

8. Find out the optimum sequence, idle time and total elapsed time for the jobs to be processed through 4 machines.

	Jobs			
	A	B	C	D
Machine 1	8	8	4	3
Machine 2	4	2	1	6
Machine 3	6	8	10	12
Machine 4	14	18	20	22

9.

	Machines			
	M1	M2	M3	M4
JOB1	11	8	7	14
JOB 2	10	6	8	19
JOB 3	9	7	5	18
JOB 4	8	5	5	18

NETWORK ANALYSIS

NETWORK CONSTRUCTION AND SCHEDULING

1. Draw the network for the project given :

Activities	**Predecessor**
A	-
B	-
C	-
D	A
E	B
F	B
G	C
H	D
I	E
J	H, I
K	F, G

2. Draw the network for the project given :

Activities	**Predecessor**
P	-
Q	-
R	-
S	P, Q
T	R, Q

3. Draw the network for the project given :

Activities	**Predecessor**
A	-
B	A
C	A
D	-
E	D
F	B, C, E
G	F
H	E
I	G, H

4. Draw the network for the project given :

Activities	**Predecessor**
A	-
B	-
C	A, B
D	B
E	B
F	A, B
G	F, D
H	F, D
I	C, G

5. Draw the network for the project given :

Activities: A, D, and E can start simultaneously. Activities B, C is greater than A; G,F greater than D, C; H> E, F.

Hint:

Activities	**Predecessor**
A	-
B	A
C	A
D	-
E	-
F	D, C
G	D, C
H	E, F

6. A< C, D; B< E; C, E < F, G; D < H; G < I; H, I, < J.

Hint:

Activities	**Predecessor**
A	-
B	-
C	A
D	A
E	B

F	C, E
G	C, E
H	D
I	G
J	H, I

CRITICAL PATH METHOD

7. Draw the network and also find the critical path. Duration of each activity is given below

A < C, D, I; B < G, F; D < G, F; F < H, K; G, H, < J; I, J, K < E.

Activities	**Predecessor**	**Duration**
A	-	5 days
B	-	3
C	A	10
D	A	2
E	I, J, K	8
F	B, D	4
G	B, D	5
H	F	6
I	A	12
J	G & H	8
K	F	9

8. Draw the network and find the critical path. Also find earliest start, earliest finish, latest start and latest finish of each activity.

Activity	Duration
1-2	8 days
1-3	4
2-4	10
2-5	2
3-4	5
4-5	3

9. Draw the network and find the critical path, and also calculate floats

Activity	Duration
1-2	8 days
1-3	7
1-5	12
2-3	4
2-4	10
3-4	3
3-5	5
3-6	10
4-6	7
5-6	4

PROGRAM EVALUATION AND REVIEW TECHNIQUE

10. Draw the network; find the expected duration and the variance of the project. Also find the standard deviation of the project.

Activity	Optimistic time	Moderate time	Pessimistic time
1-2	3	5	8
1-3	3	4	9
1-4	8	10	12
2-4	14	15	16
3-4	3	4	6
2-5	1	3	5
3-5	2	4	6
4-5	3	4	6

11. Draw the network; find the expected duration and the variance of the project. Also find the standard deviation of the project

Activity	a	m	b
1-2	3	6	15
1-3	2	5	14
1-4	6	12	30
2-5	2	5	8
2-6	5	11	17
3-6	3	6	15
4-7	3	9	27
5-7	1	4	7
6-7	2	5	8

What is the probability that project will be completed within 27 days.

- What is the probability that project will be completed within 33 days.
- What is the probability that project will take above 33 days.
- What is the probability that project will be completed within 25 days or probability that the project is just completed on the expected duration.
- What is the probability that project will be completed between 20-25 days.

12. Draw the network; find the expected duration and the variance of the project. Also find the standard deviation of the project

Activity	to	tp	tm
1-2	0.8	1.2	1
2-3	3.7	9.9	5.6
2-4	6.2	15.4	6.6
3-4	2.1	6.1	2.7
4-5	0.8	3.6	3.4
5-6	0.9	1.1	1

CRASHING- COST TRADE OFF

1. For the project represented by the following network and the table showing time and cost, find the optimum duration and cost:

Activity	Normal Time (days)	Normal Cost (₹)	Crash Time (days)	Crash Cost (₹)	Δ T	Δ C	Δ C/Δ T (Slope)
1-2	8	100	6	200	2	100	50
1-3	4	150	2	350	2	200	100
2-4	2	50	1	90	1	40	40
2-5	10	100	5	400	5	300	60
3-4	5	100	1	200	4	100	25
4-5	3	80	1	100	2	20	10

Indirect cost = ₹ 70

2. The following table gives the cost particulars of a project, find the optimum duration and cost:

Activity	Normal Time (days)	Normal Cost (₹)	Crash Time (days)	Crash Cost (₹)
1-2	2	800	1	1400
1-3	5	1000	2	2000
1-4	5	1000	3	1800
2-4	1	500	1	500
2-5	5	1500	3	2100
3-4	4	2000	3	3000
3-5	6	1200	4	1600
4-5	3	900	2	1600

RESOURCES LEVELLING

1. The manpower required for each activity of a project is given in the following table:

Activity	Normal Time (days)	Manpower required per day
A 1-2	10	2
B 1-3	11	3
C 2-4	13	4
D 2-6	14	3
E 3-4	10	1
G 4-5	7	3
F 4-6	17	5
I 5-7	13	3
H 6-7	9	8
J 7-8	1	11

The contractor stipulates that the first 26days, only 4 to 5 men and during the remaining days 8 to 11 men only are available. Find whether it is possible to rearrange the activity suitably for levelling the manpower resources satisfying the above condition.

UNIT – III RESOURCE SCHEDULING AND NETWORK ANALYSIS

MODEL QUESTION PAPER

PART - A

1. What do you mean by sequencing? State the objectives of sequencing.
2. List out the assumptions of sequencing.
3. What is meant by a) Total elapsed time b) Idle time.
4. Write the conditions to convert 3 machines problem into 2 machines problem.
5. Write the conditions for the conversion of 4 machines problem into 2 machines problem in sequencing.
6. Write short notes on i) Total float ii) Free float iii) Independent float
7. What do you mean by critical path?
8. What is meant by a) Project b) Earliest Start and Earliest Finish b) Latest start and Latest finish?
9. Find the optimum Sequence for the following tasks:

Tasks

Machines		A	B	C	D	E	F	G	H	I
	M1	2	5	4	9	6	8	7	5	4
	M2	6	8	7	4	3	9	3	8	11

10. Construct the network for the project whose activities and their precedence relationships are as given below.

    A, B, C can start simultaneously

    A<F, E: B<D; C, E, D<G.

PART - B

1. Write Johnson's algorithm.

OR

2. The time in hours to process six known batches J1 – J6 through the washer and cooker is given below:

Batches

	J1	J2	J3	J4	J5	J6
Washer (M1)	4	7	3	12	11	9
Cooker (M2)	11	7	10	8	10	13

Find out the optimum sequence and also find out total elapsed time and idle time.

3. Find out the optimum sequence, idle time, and total elapsed time for the given 3 machines problem.

Jobs

Machines		1	2	3	4	5
Machine A	4	8	6	4	6	
Machine B	2	3	1	1	4	
Machine C	6	8	2	4	3	

OR

4. Find out the optimum sequence, idle time and total elapsed time for the jobs to be processed through 4 machines.

Jobs

	A	B	C	D
Machine 1	8	8	4	3
Machine 2	4	2	1	6
Machine 3	6	8	10	12
Machine 4	14	18	20	22

5. Draw the network and find the critical path. Find earliest start, earliest finish, latest start, and latest finish of each activity.

Activity	Duration	Preceding Activity
A	6	-
B	8	A
C	4	A
D	9	B
E	2	C
F	7	D

OR

6. Draw the network and find the critical path, and also calculate floats

Activity	Duration
1-2	8 days
1-3	7
1-5	12
2-3	4
2-4	10
3-4	3
3-5	5
3-6	10
4-6	7
5-6	4

7. Draw the network; find the expected duration and the variance of the project. Also find the standard deviation of the project

Activity	a	m	b
1-2	3	6	15
1-3	2	5	14
1-4	6	12	30
2-5	2	5	8
2-6	5	11	17
3-6	3	6	15
4-7	3	9	27
5-7	1	4	7
6-7	2	5	8

What is the probability that project will be completed within 27 days.

- What is the probability that project will be completed within 33 days.
- What is the probability that project will take above 33 days.
- What is the probability that project will be completed within 25 days or probability that the project is just completed on the expected duration.
- What is the probability that project will be completed between 20-25 days.

OR

8. Draw the network and find the critical path. Find earliest start, earliest finish, latest start, latest finish, total float, free float and independent float for each activity.

Activity	Preceding Activity	Duration
A	-	2
B	A	6
C	A	6
D	B	5
E	C,D	3
F	-	3
G	E,F	1

9. Draw the network and find the critical path. Find earliest start, earliest finish, latest start, latest finish A< C, D; B< E; C, E < F, G; D < H; G < I; H, I, < J.

Hint:

Activities	**Predecessor**
A	-
B	-
C	A
D	A
E	B
F	C, E
G	C, E
H	D
I	G
J	H, I

OR

10. Draw the network; find the expected duration and the variance of the project. Also find the standard deviation of the project

Activity	to	tp	tm
1-2	0.8	1.2	1
2-3	3.7	9.9	5.6
2-4	6.2	15.4	6.6
3-4	2.1	6.1	2.7
4-5	0.8	3.6	3.4
5-6	0.9	1.1	1