NETWORK ANALYSIS

(PERT and CPM)

INTRODUCTION

PERT and CPM are two well-known network techniques or models **especially useful for planning, scheduling and executing large time-bound projects which involve careful co-ordination of a variety of complex and inter-related activities and resources**. **PERT** is the abbreviated form for Program Evaluation and Review Techniques and **CPM** for Critical Path Method. Both the techniques were developed in U.S.A. during the late 1950s. **PERT** was developed by US Navy Engineers to plan and control the huge Polaris Submarine Program**.** **CPM** was developed by E.I. DuPont Nemours & Co., U.S.A. and the Univac Division of Remington Rand Corporation in 1956 in connection with the periodic overhauling and maintenance of chemical plants. It resulted in reducing the shut-down period from 130 hours to 90 hours and saving hours and saving the company $1 million.

Both the techniques have been applied successfully to improve efficiency of execution of large projects within pre-determined time and cost limits. Any new venture may be regarded as a project, such as constructing a new plant, bridge, dam, shopping centre or residential complex, design of a new aircraft, manufacture of ships, R& D projects, introduction of a new product, installing pipeline, floating a new issue of shares, major repairs and overhaul of plant and machinery units, organizing a large conference/convention, handling an earthquake relief work and so on.

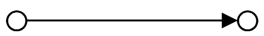
PERT and CPM converge on several aspects, and are almost treated as twins; there are, however, some points of difference between them which will be discussed later. The techniques recognize the systems or inter-related nature of activities on large work projects and translate the job proposed into a model by drawing a network of the activities involved. They are used in planning and controlling (monitoring) the projects. Planning in this context implies developing the overall layout of the project with estimates of time, the resources required and the detailed time scheduling and sequence of various jobs to be performed. The control, on the hand takes place during the work on the project. Gradually as resources get used and completion times are obtained, project management techniques can be used to reallocate, if necessary, the rescues, according to the revised criticality rankings of the jobs remaining to be done.

Constructing the Network

A project network is a directed graph that consists of finite collection of elements called events (or nodes) together with a subset of the ordered pairs (i, j,) of nodes called activities (or jobs or tasks or operations). In other words, a network is the graphical representation of logically and sequentially connected arrows and nodes representing activities and events of a project. (Also called arrow diagrams) diagrams show the operations/activities to be performed to complete a job, the sequence and inter-relationship of various activities involved.

In networks, an activity is a clearly identifiable and manageable operation or an element of work entailed in the project and it is represented by an arrow. An event (or node), is the and/or finish of an activity or group of activities. Others terms used are junction, milestone or stage. In general milestone is reserved for particularly significant events that require special monitoring. An activity arrow (i, j,) extends between two nodes, the tail node (or event), i, represents the start of an activity and the head node (event) j, represents the completion of an activity as shown below:

Activity

(j,) 

starting event completion event

Activities may also be termed jobs, tasks or operations. Activities which must be completed before a certain other activity starts are called the predecessor activity starts are called successors activities.

Predecessor activity: Activities that must be completed immediately prior to the start of another activity called predecessor activities.

Successor activities: Activities that cannot be started until one or more of the other activities are completed, but immediately succeed them are called successor activities.

Concurrent activity: Activities which can be accomplished at the same time are known as concurrent activities.

Path: An unbroken chain of activity arrows connecting the initial event to the final event via other events is called a path.

RULES OF NETWORK CONSTRUCTION.

1. Each defined activity is represented by one and only one arrow in the network. Therefore, no single activity can be represented more than once in the network. These arrows should be kept straight and not curved.
2. Before an activity can be undertaken all activities preceding it must be completed. Thus, a network should be developed on the basis of logical or technical dependencies between various activities of the project. The discipline of networking requires that the project be considered in a thorough and analytic manner and the predecessor-successor relationships between the various activities clearly laid.
3. The arrows depicting various activities are indicative of the local precedence only. The length and bearing of the arrows are of no significance, although arrows in network diagrams should be drawn to show time flow left to right i.e. in the forward direction.
4. The arrow direction indicates the general progression in time. Each activity must start and end in a node (or event). The tail of an activity represents the point in time at which the **"activity start"** occurs and the node marking this start is called the tail event for this event. The head of an activity represents the point in time at which the **"activity completion"** occurs and the node marking this termination is called the head event for that activity.

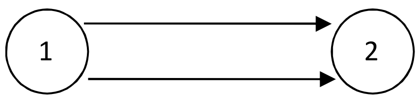
5. When a number of activities terminate at one event, it indicates that no activity emanating from that event may start unless all activities terminating there have been completed.

6. Events are identified by numbers. Each event identified by a number higher than that allotted to the event immediate preceding one. ie., events should be numbered such that for every arrow there is an event number before and after. In assigning numbers to the events, care should be taken that there is no duplication of event numbers in a network. The event numbered **1** denotes start of the project and is called initial node (or event) while the event carrying the highest number denotes the final event in the network. A network should have only one initial and one terminal node

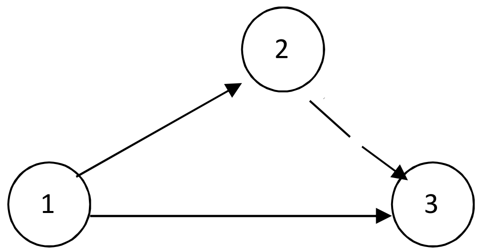
7. The activities are identified by the numbers of their starting and the ending events. An event which represents the joint completion of more than one activity is known as a merge event, while an event which portrays the initiation of more than one activity is called the burst event.

8. Parallel activities between two events, without intervening events, are prohibited. Thus two or more activities cannot be identified by the same beginning and ending events. By implication, any two events should not be connected with more than one arrow. When two or more activities in a project have the same head and tail events, dummy activities are needed in constructing the network. The figure on the left is the wrong way to represent the two activities while the figure on the right shows the correct representation of the two activities using a dummy.

9. WRONG



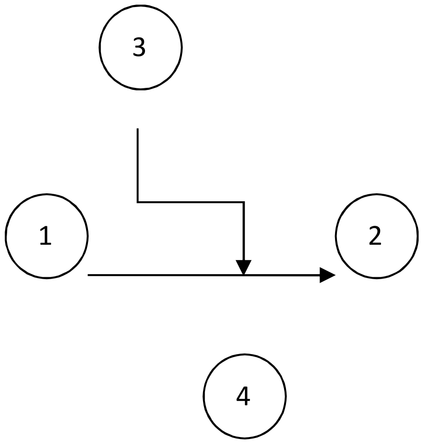
RIGHT



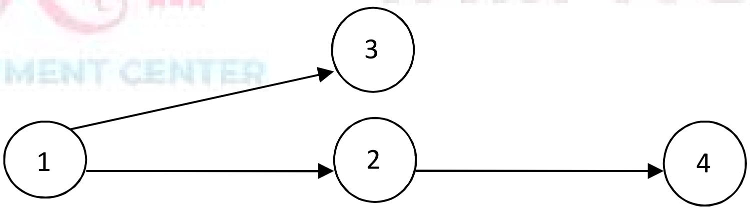
10. DUMMY ACTIVITY: Dummy activities are usually shown by arrows with dashed lines. Dummy activities are also very useful in establishing

proper logical relationships in the networks which cannot, otherwise, be adequately represented.

11. Looping is not permitted.



12. Dangling is not permitted.



<u>Numbering the events (Fulkerson's Rule)</u>

After the network is drawn in a logical sequence, every event is assigned a number which is placed inside the node circle. The number sequence should be such so as to reflect the flow of the network. The rule devised D R Fulkerson is used for the purpose of numbering and involves the following steps.

1. The initial event has all outgoing arrows with no incoming arrow is numbered 1.

2. Delete all the arrows coming out of node 1. This will convert some more nodes (at least one) into initial events. Number these events 2,3 …
3. Delete all the arrows going out from these numbered events to create more initial events. Assign the next numbers to these events.
4. Continue until the final or terminal node, which has all arrows coming in with no arrow going out, is numbered.

CRITICAL PATH : The critical path in a network diagram is the longest continuous chain of activities (i.e. a path along which it takes the longest duration) through the network starting from first to the last event and is shown by thick line or double lines. All activities lying on this critical part are called **critical activities,** as any delay in their execution will lead to a delay in the completion of the entire project.

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NETWORK CRASHING

Project Time & Cost in Networking

Introduction: For completing a project various activities have to be completed which requires lot of money. Hence, the project manager always remains conscious of time as well as costs involved. CPM assumes direct relationship between time and cost and uses time-cost trade-off concept, which is its unique feature. This concept relates to the fact that on a crash basis, it will cost a little more but even this increase in cost may prove economical in various ways. As such the project manager will keep in mind the time-cost consideration before taking decisions regarding the project and its different activities.

CRASHING: is employed when project manager want to shorten the project completion time by spending extra resources (more money). In real life, it is always possible to employ more resources. For example, the activity of laying tiles which requires team of mason assisted by a labourers. By increasing the number of mason and labourers the activity duration can be shortened or crashed. But this to has limitation by increasing the mason and labourers would not reduce the duration any more since they are liable to jam up. Concerned specialists would have to estimate the crashing limit for each activity as also the extra money for crashing each activity.Crash time is the minimum activity duration to which an activity can be compressed by increasing the resources and hence by increasing the direct costs.

Time-cost optimisation algorithm

The process of shortening a project duration is called crashing and is usually achieved by adding extra resources to an activity.

Project crashing involves the following steps:

NETWORK CRASHING

Step I: Find the critical path and identify the critical activities. List all possible paths starting and duration of each path.

Step II: Calculate the cost slope for the different activities by using the formula.

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

The crash slope indicates the extra cost required to expedite an activity per unit time.

Identify the activities on critical path which have cost slope less than the indirect cost.

Step III: Crashing the activity having minimum cost slope i.e. Less than the indirect cost. Redraw the network diagram with the crashing time. And find out the critical path if there is no change. This means that the network cannot be further crashed. This is the optimum network.

Step IV: Calculate the total cost of the project before and after crashing. Check whether crashing reduces the cost of project. By calculating the difference of before and after crashing

Total cost without crashing

Direct cost + indirect cost

Total cost after crashing

Direct cost + indirect cost