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Network Analysis in Project Planning (PERT and CPM)

14.1 PROJECT

The term project has been defined by many authors, and each one has defined it from his own point of view and in the perspective of his own field of activity. *Most often a project is defined as a combination of interrelated activities which must be executed in a certain order before the entire task is completed.* The salient characteristics of a project are

1. A project has identifiable beginning and end points; it is an entity by itself.
2. It is not a permanent entity, it is usually a non-repetitive task.
3. It can be broken down into identifiable activities which require time and resources for their execution.
4. It is scheduled to be completed by a target date.
5. The objectives are clear and output or end product definite.
6. It is usually large and complex with time horizon of 2 to 3 years. However, some projects have taken more than 10 years while others have lasted for less than 6 months.
7. It usually involves heavy investment.
8. Execution of project activities and hence completion of the project is always subject to some uncertainties and risks.

Each project, whether big or small, has three basic requirements:

(*i*) It should be completed without any delay.
(*ii*) It should use as small man power and other resources as possible.
(*iii*) It should involve as small investment as possible.

The project management helps to fulfill the above requirements.

The project management involves the following three phases:

(*i*) Project planning
(*ii*) Project scheduling
(*iii*) Project controlling

Out of these three phases, the first two are accomplished before the start of the actual project. The third phase comes into operation during the execution of the project. It highlights the bottlenecks during execution of the project and spells out measures to remove bottlenecks & complete the project in time. *The network techniques of PERT and CPM are valuable during all the three phases of project management.*

14.2 PROJECT PLANNING

Project planning is an important phase during which are set the plans and strategies of project execution, keeping in mind the policies, procedures and rules of the organisation. It has two important aspects—identification of the activities (jobs or tasks) to be performed and estimation of the required resources. Resources are of many kinds and are classified as:

1. Manpower resources
2. Equipment (machinery) resources

3. Financial resources
4. Material resources
5. Time & space resources

The manpower resources, say, in a construction project, consist of skilled workers (such as carpenters, turners, plumbers, fitters, etc.), unskilled labour, supervisory staff and top management. The equipment resources include plant and machinery such as dragline, power shovel, concrete mixing plant, etc. The financial resources comprise the money required for the project. The material resources include all the materials such as cement, sand, concrete, gravel, bricks, steel, etc. to be used. Space resources include the total space available for the project. It may be limited, thus causing constraints on the activities of the project. Time resources involve the total time available, which may also be limited in some projects.

Since resources are the starting points of projects, their proper planning and estimation helps to estimate the time and cost of the various activities and hence of the entire project.

Project planning involves the following steps:

1. Setting the objectives of the project and the assumptions to be made.
2. Developing the W.B.S. (*Work Breakdown Structure*). Depending upon the objectives of the management, the extent of control desired and the availability of computational aids, the project is broken down into clearly definable activities.
3. Determination of time estimates of these activities.
4. Estimation of resources–financial, managerial and operational.
5. Study of alternative ways of attaining the goals.
6. Establishment of inter-dependence relationship between the activities *i.e.*, the sequence of performing the activities.

14.3 PROJECT SCHEDULING

Scheduling is the laying out of the project activities along a time sequence in which they are to be performed so as to assign the starting and finishing dates to various activities and to allocate resources to them. In other words, scheduling is the preparation of time table of the implementation of the activities and computation of resources required at different stages of time. It also includes identifying the tasks that are critical & the resources that are limited so that the entire project proceeds in a logical, orderly and systematic manner. In short, the scheduling phase consists of determining:

1. Start and finish times of each activity and the earliest and latest times at which events can occur.
2. Critical activities that require special attention.
3. Allocating resources—men, machines, materials, etc. to each activity.
4. Slacks and floats for non-critical activities.
5. Various constraints due to limitation of resources.

14.4 PROJECT CONTROLLING

Controlling phase is the follow up of the planning and scheduling phases. While planning and scheduling are undertaken before the actual project starts, the controlling phase is undertaken during the actual execution of the project. The project is monitored to find deviations in actual progress from the scheduled plan and to apply the corrective measure, so as to achieve the targets. Project controlling usually involves the following steps:

1. Setting standards and targets with regard to time and cost of the project.
2. Reviewing the progress by comparing the work accomplished to the work scheduled at different stages of time and finding the deviations.
3. Evaluating the effect of deviations on the project plan.
4. Updating the project schedule.

5. The corrective measures to rectify the deviations from the plan should be suggested. This requires decision-making with regard to scheduling of resources, scheduling of jobs, crashing of projects, etc.

14.5 WORK BREAKDOWN STRUCTURE (W.B.S.)

A Project is a combination of interrelated activities which must be performed in a certain order for its completion. The process of dividing the project into these activities is called Work Breakdown Structure (W.B.S.). The *activity* or *unit of work* or *work content* is a clearly identifiable and manageable work unit. The number of activities or the size of each activity will depend upon the level of detail desired.

14.6 BASIC TOOLS AND TECHNIQUES OF PROJECT MANAGEMENT

The various tools and techniques of project management are grouped into the following two heads:

1. Bar charts, milestone charts and velocity diagrams.
2. Network techniques.

14.6-1 Bar charts, Milestone charts and Velocity diagrams

Bar charts are the two-dimensional pictorial representation of a project. In a bar chart, the activities of the project are shown on one axis and their durations are represented on the other axis. A bar chart helps to review the project progress, allows for rescheduling the project and highlights the critical activities and other bottlenecks in the completion of the project. A bar chart, however, is normally suited to small projects. It cannot take into account the uncertainties in activity duration nor represent the interrelationships between the various activities of the project.

Milestone charts are the modified and improved versions of bar charts. However, whereas bar charts represent activities, milestone charts represent the events which mark either the beginning or the end of an activity. Though milestone charts are more detailed and offer better control than bar charts, they possess most of the drawbacks inhert in bar charts.

Velocity diagrams are useful for representing the activities which require a series of crews working in a given sequence.

14.6-2 Network Techniques

A *network* (also called *network diagram or network technique*) is a symbolic representation of the essential characteristics of a project. PERT and CPM are the two most widely applied techniques.

(a) Programme Evaluation and Review Technique (PERT)

It uses event oriented network in which successive events are joined by arrows. It is preferred for projects that are non-repetitive and in which time for various activities cannot be precisely pre-determined. There is no significant past experience to guide; they are once-through projects. Launching a new product in the market by a company, research and development of a new war weapon, launching of satellite, sending space craft to Mars are PERT projects. Three time estimates — the optimistic time estimate, pessimistic time estimate and the most likely time estimate are associated with each and every activity to take into account the uncertainty in their times.

(b) Critical Path Method (CPM)

It uses activity oriented network which consists of a number of well recognised jobs, tasks or activities. Each activity is represented by arrow and the activities are joined together by events. CPM is generally used for simple, repetitive types of projects for which the activity times and costs are certainly and precisely known. Projects like construction of a building, road, bridge, physical verification of store, yearly closing of accounts by a company can be handled by CPM. Thus it is deterministic rather than probabilistic model.

14.7 ROLE OF NETWORK TECHNIQUES IN PROJECT MANAGEMENT

The complexities of the present-day management problems and the business competitions have added to the pressure on the brains of decision-makers. In a large and complex project involving a number of interrelated activities, requiring a number of men, machines and materials, it is not possible for the management to make and execute an optimum schedule just by intuition based on the organisational capabilities and work experience. Managements are, thus, always on the look out for some methods and techniques which may help in planning, scheduling and controlling the project. The aim of planning is to develop a sequence of activities of the project, so that the project completion time and cost are properly balanced and the excessive demand of key resources is avoided. To meet the object of systematic planning, the managements have evolved a number of techniques applying network strategy. As already explained, PERT and CPM are two such widely applied techniques used for planning, scheduling and controlling of large and complex projects. With slight modifications both have given rise to several other network techniques, such as PEP (Programme Evaluation Procedure), RAMPS (Resource Allocation for Multi-Project Scheduling), LESS (Least Cost Estimating and Scheduling) and SCANS (Scheduling and Control by Automated Network System), etc.

14.8 NETWORK LOGIC (NETWORK OR ARROW DIAGRAM)

Some of the terms commonly used in networks are defined below.

Activity

It is physically identifiable part of a project which requires time and resources for its execution. An activity is represented by an arrow, the tail of which represents the start and the head, the finish of the activity. The length, shape and direction of the arrow has no relation to the size of the activity.

Event

The beginning and end points of an activity are called events or nodes. Event is a point in time and does not consume any resources. It is represented by a circle. The head event, called the jth event, has always a number higher than the tail event, called the ith event $i.e.$, $j > i$. For example
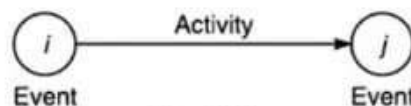

Fig. 14.1

'Making the pattern of impeller' is an activity.

'Start making the pattern of impeller' is an event.

'Pattern making completed' is an event.

Path

An unbroken chain of activity arrows connecting the initial event to some other event is called a path.

Network

It is the graphical representation of logically and sequentially connected arrows and nodes representing activities and events of a project. Networks are also called *arrow diagrams*.

Network Construction

Firstly the project is split into activities. Start and finish events of the project are then decided. After deciding the precedence order, the activities are put in a logical sequence by using the graphical notations. While constructing the network, in order to ensure that the activities fall in a logical sequence, following questions are checked:

(*i*) What activities must be completed before a particular activity starts ?

(*ii*) What activities follow this ?

(*iii*) What activities must be performed concurrently with this ?

Activities which must be completed before a particular activity starts are called the *predecessor activities* and those which must follow a particular activity are called *successor activities*.

While drawing the network following points should be kept in mind:

1. Each activity is represented by one and only one arrow. But in some situations where an activity is further subdivided into segments, each segment will be represented by a separate arrow.
2. Time flows from left to right. Arrows pointing in opposite direction are to be avoided.
3. Arrows should be kept straight and not curved.
4. Angles between the arrows should be as large as possible.
5. Arrows should not cross each other. Where crossing cannot be avoided, bridging should be done as shown in Fig. 14.6.
6. Each activity must have a tail and a head event. No two or more activities can have the same tail and head events.
7. An event is not complete until all the activities flowing into it are completed.
8. No subsequent activity can begin until its tail event is completed.
9. In a network diagram there should be only one initial event and one end event.

Dummy

An activity which only determines the dependency of one activity on the other, but does not consume any time is called a dummy activity. Dummies are usually represented by dotted line arrows.

To illustrate the use of dummy, refer to Fig. 14.2 (*a*) and assume that the start of activity C depends upon the completion of activities A and B and that the start of activity E depends only on the completion of activity B. For this situation, figure 14.2 (*a*) is a faulty representation. This is corrected by introducing a dummy activity D as shown in Fig. 14.2 (*b*).
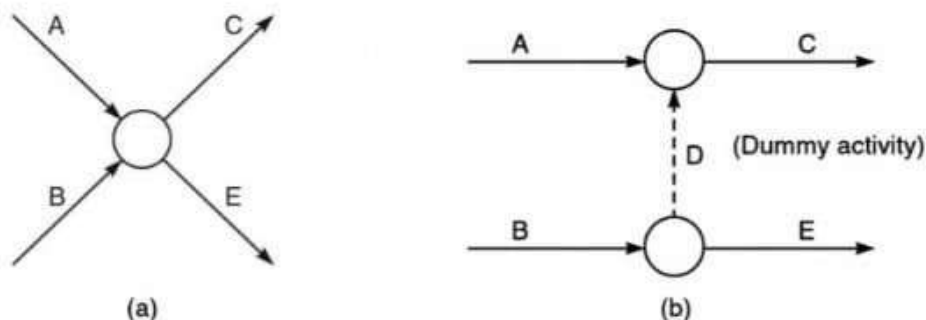

Fig. 14.2. (a), (b)

A dummy activity is introduced in the network for two basic reasons:

1. To maintain the precise logic of the precedence of activities. Such a dummy is called '*logical dummy*'. It is shown in Fig. 14.2 (*b*).
2. To comply with the rule that no two or more activities can have the same pair of tail and head events. Such a dummy is called '*grammatical dummy*'. In Fig. 14.2 (*c*), both activities A and B have the same tail event 10 and same head event 20, which is incorrect since no two activities can have the same pair of tail and head events. Such activities are called duplicate activities. This difficulty is resolved by the introduction of a dummy activity in any of the four ways represented in Fig. 14.2 (*d*), (*e*), (*f*) or (*g*).
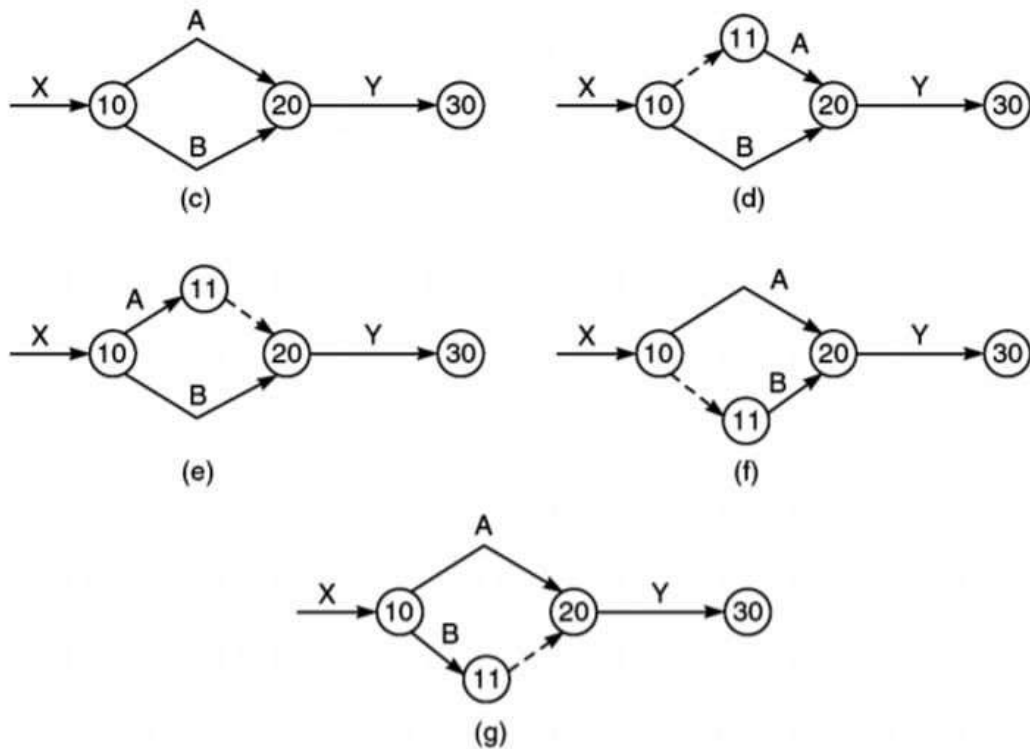
Fig. 14.2. (c) to (g)

Looping (Cycling)

Sometimes due to faulty network sequence a condition illustrated in figure 14.3, arises. Here the activities D, E and F form a loop (cycle). Activity D cannot start until F is completed, which, in turn, depends upon the completion of E. But E is dependent upon the completion of D. Thus the network cannot proceed. This situation can be avoided by checking the precedence relationship of the activities and by numbering them in a logical sequence.
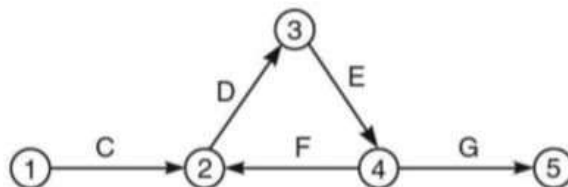

Fig. 14.3