AN ANALYSIS OF NETWORK MODELS IN PROJECT MANAGEMENT

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Abstract

In the analysis of network models, **P**rogram **E**valuation and **R**eview **T**echnique (PERT) and **C**ritical **P**ath **M**ethod (CPM) are the methods which have been widely applied to industrial project planning and control in practice. PERT which is a large scale model, analyzes the project using a standard *forward-backward* analysis method. **PERT** and **CPM** are available to assist the project manager in carrying out these responsibilities. These techniques make heavy use of *networks* to help plan and display the coordination of all the activities. This paper illustrates how the application of ***network*** or ***precedence*** diagram can be used in project management. In this study, all the project activities will be able to construct Gantt chart using Excel spreadsheet and MS Project.

Keywords: Project management, Gantt chart, Network models, PERT, CPM

Introduction

Project management differs from management of more traditional activities mainly because of its limited time framework and the unique set of activities involved, which gives rise to a host of unique problems. The core technique available to Project Managers for planning and controlling their projects is **Network Analysis**.

Network analysis is one of the most wide spread methods in the planning and controlling of the project. Sources of complex projects can be managed more effectively by analyzing with networks that are modal illustrations of a series of events and activities. Network is a technique used for planning and scheduling of large projects in the fields of construction, maintenance, fabrication, purchasing, computer system instantiation, research and development planning etc.

Network Model

Networks model the interrelated flows of work that must be accomplished to complete a project. The two best-known techniques for network analysis are Program Evaluation and review Technique (PERT) and Critical Path Method (CPM).

Network analysis is a technique of planning, scheduling and controlling of a large and complex project comprising various activities. Network techniques provide a rational approach to the planning and controlling of construction works.

PERT/CPM are two of the most widely used techniques for ***planning and coordinating large-scale projects***. PERT and CPM are the two network-based project management techniques, which exhibit the flow and sequence of the activities and events. Although PERT and CPM were developed independently, Figure 1 is shown the relationship between PERT and CPM.

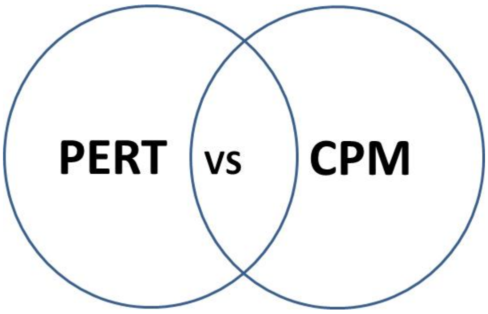

Figure 1 Relationship between PERT and CPM

For practical purposes, the two techniques now are the same; the comments and procedures described will apply to CPM analysis as well as to PERT analysis of projects. PERT and CPM are the two most widely applied techniques shown in Figure 2.

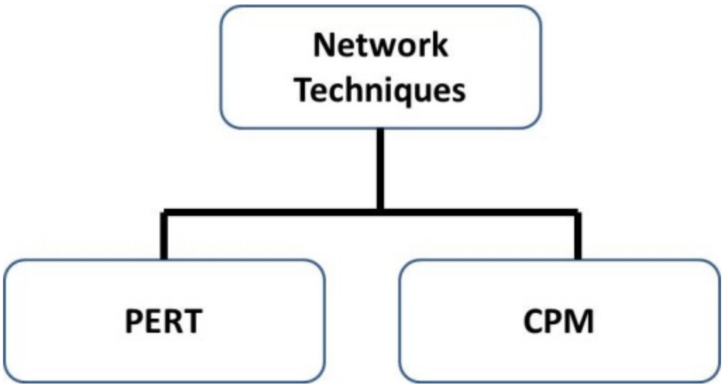

Figure 2 The two most widely applied techniques

In CPM method, fixed and defined processing times are accepted. **Critical path** is a path that has the ***longest total activity*** period that supplies project to be completed in the shortest time between starting and ending point on the project network. PERT method is established on probability estimation of operation times and completion duration of the project. The most important difference between CPM and PERT is estimation of operation time. PERT was designed for projects in which durations are unclear such as research and development projects. CPM and PERT are calculated with the same method.

Building the Network Diagram

One of the main features of PERT and related techniques is their use of a network or precedence diagram to depict major project activities and their sequential relationships. There are two slightly different conventions for constructing these network diagrams. Under one convention, the *arrows* designate activities; under the other convention, the *nodes* designate activities.

These conventions are referred to as activity-on-arrow (AOA) and activity-on-node (AON). Activities consume resources and/or *time*. The nodes in the AOA approach represent the activities' starting and finishing points, which are called *events*. Events are points in time. Unlike activities, they consume neither resources nor time. The *nodes* in an AON diagram represent *activities*. This gives an *activity-on-arrow* (AOA) network, usually associated with PERT. The *activity-on-node* (AON) is often associated with CPM. This describes a small project represented by the activities and precedence shown in Table 1.

Table 1 A sample set of Project Activities and Precedence

Activity No	Activity Name	Predecessor
1	Locate facilities	-
2	Order furniture	1
3	Interview	-
4	Hire and train	3
5	Remodel	1
6	Furniture setup	2
7	Move in	5,4

The AOA network is generally more difficult to draw, but depicts the technical relationships of the activities quite well. Beginning the same way, it creates a Start node from which flow all activities that have no predecessors, in this case 1. The completion of these activities results in Figure 3. Because it is easiest to draw, it starts with the AON network. Because activity 1 has no predecessor, it follows the Start node. They are connected to the starting node with arrows as in Figure 4. A simple project network diagram which is PERT and CPM with AOA and AON is shown in the following figure 3 and figure 4.

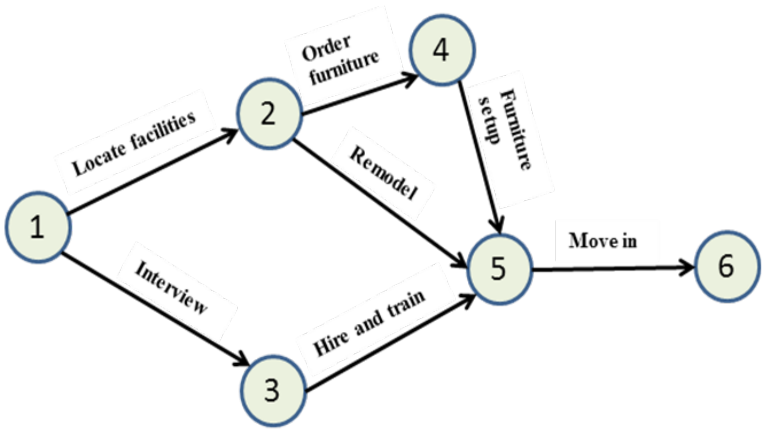

Figure 3 Activity-on-arrow (AOA) diagram

In the AOA diagram, the arrows represent activities and they show the sequence in which certain activities must be performed (e.g., Local facilities precedes Order furniture, Interview precedes Hire and train) from Table 1. Activities in AOA networks can be referred to in either of two ways. One is by their end points (e.g., activity 2-4) and the other is by a letter assigned to an arrow (e.g., activity *c*).

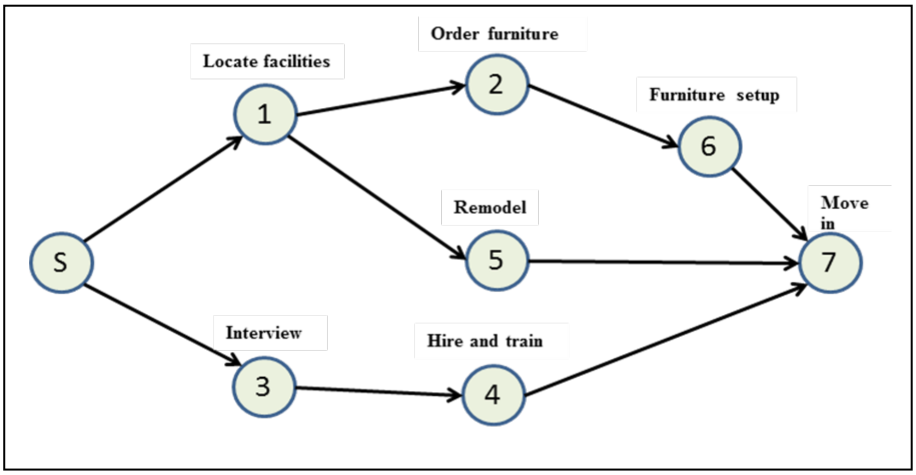

Figure 4 Activity-on-node (AON) Diagram

In the AON diagram, the arrows show only the sequence in which certain activities must be performed while the nodes represent the activities. Activities in AON networks are referred to by a letter (or number) assigned to a node (e.g. Local facilities assigned to number 1, Order furniture assigned to number 2, and so on.) from Table 1. The AON diagram has a starting node, S, which is actually not an activity but is added in order to have a single starting node.

Finding the Critical Path and Critical Time

A sample problem for finding the critical path and critical time is given in Table 2. Firstly, a project table will be created by using the given data in MS Excel sheet.

Table 2 A sample problem for finding the critical path and critical time

Activity	**Predecessor**	**Duration(**days)
A	-	5
B	-	4
C	A	3
D	A	4
E	A	6
F	B, C	4
G	D	5
H	D, E	6
I	F	6
J	G, H	4

To find the critical path and critical time using the data from Table 2, it can start drawing the associated **AON network** as in Figure 5. The activity names and durations are shown in the appropriate node.

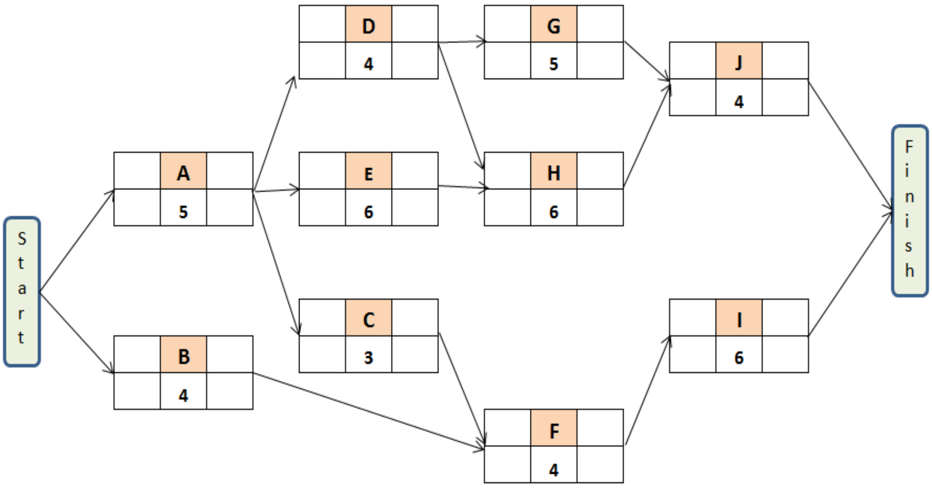

Figure 5 A complete network for Table 2

After using the data from Table 2, information contents can be added to the nodes in the network. Just above each node it is common practice to show what is called the earliest start time (ES) and earliest finish time (EF) for associated activity. Just below each node is shown the latest start time (LS) and latest finish time (LF) for the activity. The information contents in an AON node can be shown in Figure 6. Activity name is J and expected duration is 4 days. Earliest start is 17 days and earliest finish is 21 days. Then Latest start is 17 and latest finish is 21 days.

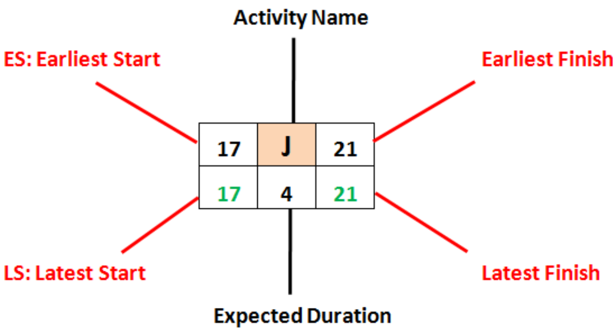

Figure 6 Information contents in an AON node

All activities and thus all paths must be completed to finish the project. The shortest time for completion of the network is equal to the ***longest path*** through the network, in this case A-E-H-J. If any activity on the A-E-H-J path is even slightly delayed, the project will be delayed and that identifies A-E-H-J as the critical path and 21 days as the critical time. In Figure 8, the critical path is depicted by thick lines – a common practice with PERT/CPM networks. It can be found that the critical path is A→E→H→J.

The ES and EF begin for each activity quite easily at the start node and move from left to right through the network, calculate from node to node. This is called a ***forward pass*** (left to right pass) and makes it simple to find the critical path and time for PERT/CPM networks as shown in Figure 7.

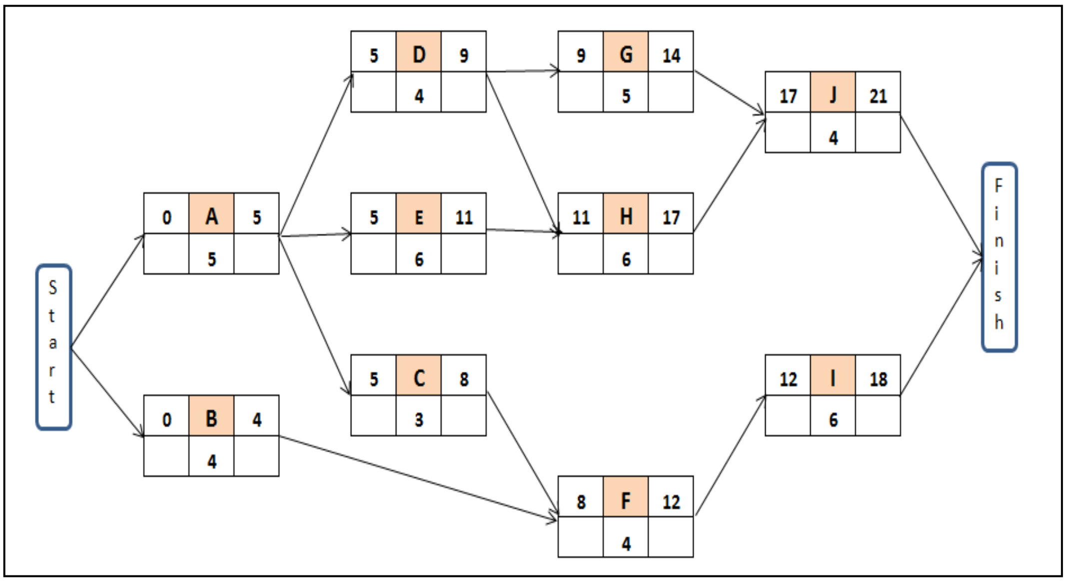

Figure 7 Forward pass calculation for the critical path and time

In a similar fashion, this can perform a **backward pass** (right-to-left pass) to calculate the LS and LF values for each activity. The thin arrows are represented for a backward pass of each activity. The thickest arrow- lines are represented for a critical path of all activities. After completing the backward pass calculation, the critical path can be easily determined in Figure 8. This can be easily seen that the critical time is 21 days.

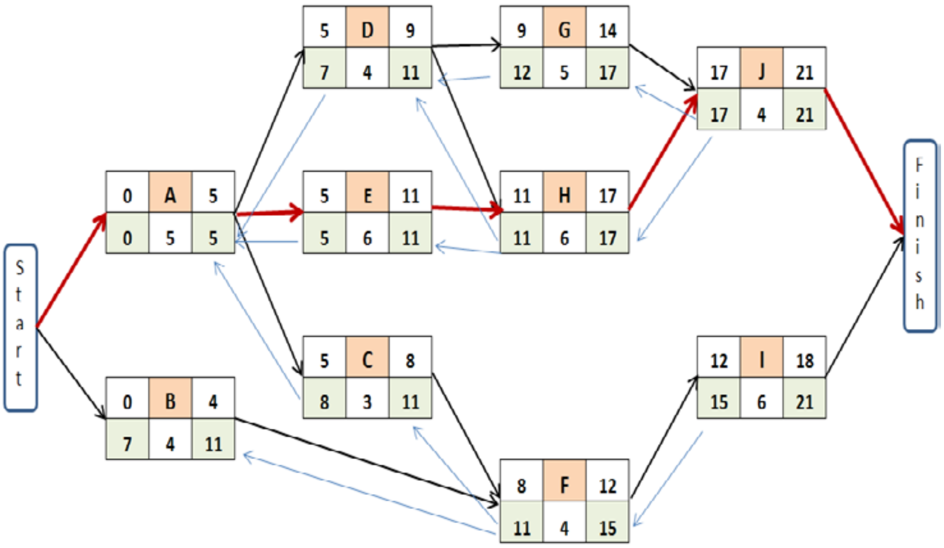

Figure 8 Backward pass calculation for the critical path and time

Calculating Activity Slack

The allowable slippage for any path is called **slack,** and it reflects the difference between the length of a given path and the length of the critical path. ***The critical path, then, has zero slack time.*** The amount of time a non-critical task can be delayed without delaying the project is called slack or float. The slack for any activity is easily calculated as LS-ES = LF-EF = slack. By using the data from Table 2, this will be calculated firstly earliest finish (EF) and latest finish

(LF). The result of them is shown in Table 3-1. After resulting EF and LF, it will be calculating slack time and critical path (CP). Then it can be seen zero slack time and 'YES' in CP column in Table 3-2.

Table 3-1 Calculating earliest finish and latest finish

Activity	Duration (Days)	Preceding Activity	ES	EF =ES+ Duration	LS= LF Duration	LF
A	5	**-**	0	5	0	5
B	4	**-**	0	4	4	8
C	3	**A**	5	8	8	11
D	4	**A**	5	9	7	11
E	6	**A**	5	11	5	11
F	4	**B,C**	8	12	11	15
G	5	**D**	9	14	12	17
H	6	**D,E**	11	17	11	17
I	6	**F**	12	18	15	21
J	4	**G,H**	17	21	17	21

Table 3-2 Calculating activity slack for the critical path

Activity	Duration (Days)	Preceding Activity	ES	EF = ES + Duration	LS= LF - Duration	LF	Slack = LF-EF	CP
A	5	**-**	0	5	0	5	**0**	YES
B	4	**-**	0	4	4	8	4	NO
C	3	**A**	5	8	8	11	3	NO
D	4	**A**	5	9	7	11	2	NO
E	6	**A**	5	11	5	11	**0**	YES
F	4	**B,C**	8	12	11	15	3	NO
G	5	**D**	9	14	12	17	3	NO
H	6	**D,E**	11	17	11	17	**0**	YES
I	6	**F**	12	18	15	21	3	NO
J	4	**G,H**	17	21	17	21	**0**	YES

By calculating activity slack in MS E**xcel**, the critical path has zero slack time shown in Table 3-2. In this case, the project can be identified **A-E-H-J** as the critical path.

Furthermore, once the project plan data are entered, **MS Project** will automatically draw an AON PERT/CPM network and Gantt chart as shown in Figure 8 and Figure 9. A Gantt chart displays project activities as bars measured against a horizontal time scale. It is the most popular way of exhibiting sets of related activities in the form of schedules.

Figure 9 shows a Gantt chart of the sample project for given data from Table 2. Any activity that has no predecessors starts at the beginning of Day 1 and extends to its duration. Any activity with predecessors begins when its latest predecessor has been completed. Figure 9 shows a PERT/CPM Network Diagram of the sample project for given data from Table 2.

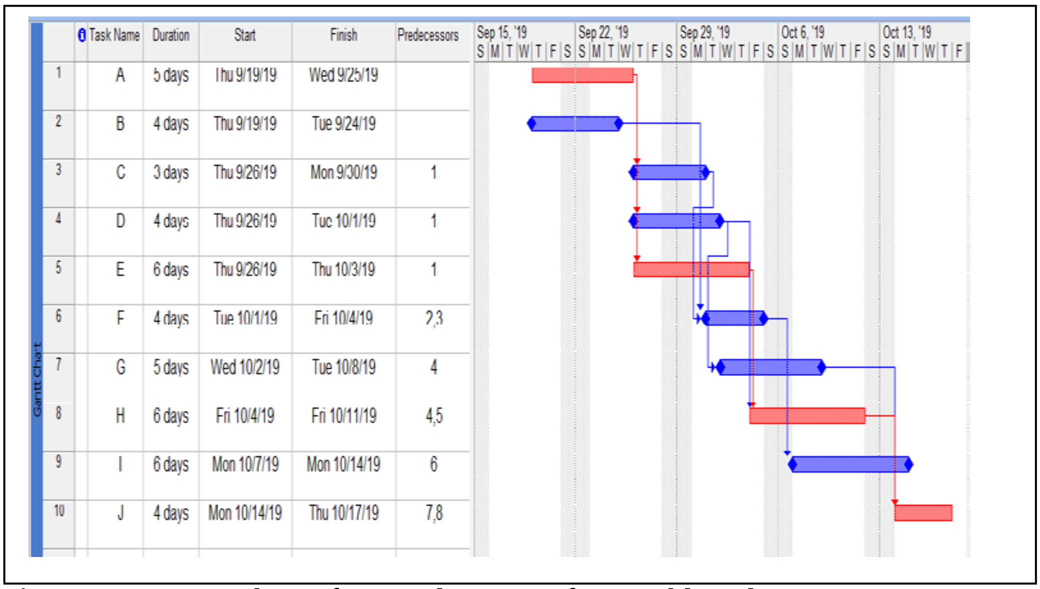

Figure 9 A Gantt chart of a sample project from Table 2 data in MS Project

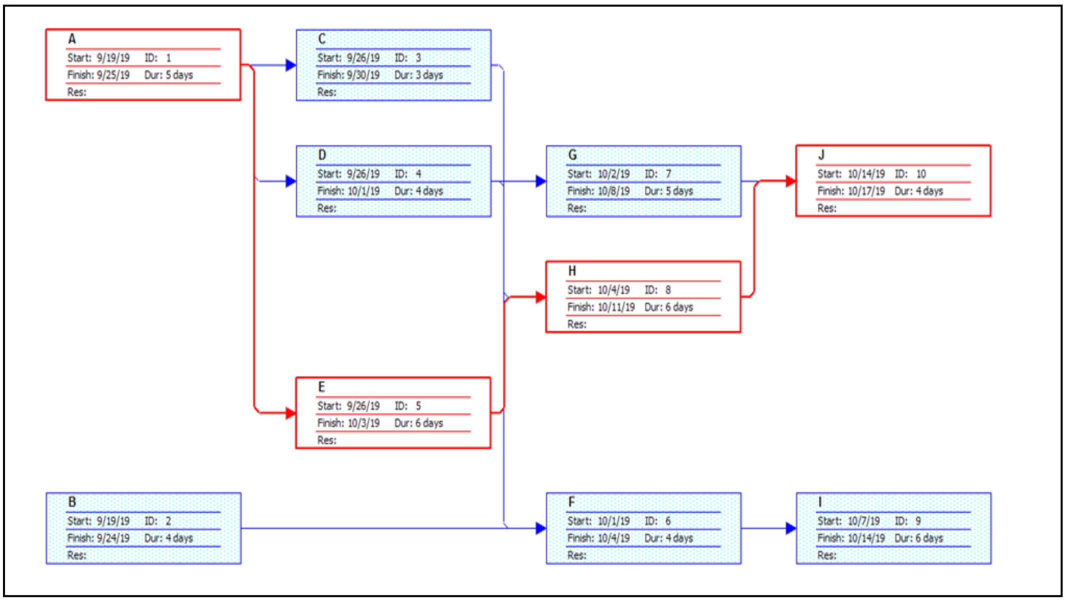

Figure 10 A PERT/CPM network from Table 2 data in MS Project

In order to Figure 9 and Figure 10, the result can be found that the critical path is **A-E-H-J.** Furthermore, Figure 11 shows a Gantt chart of Milestone and Critical in MS Project.

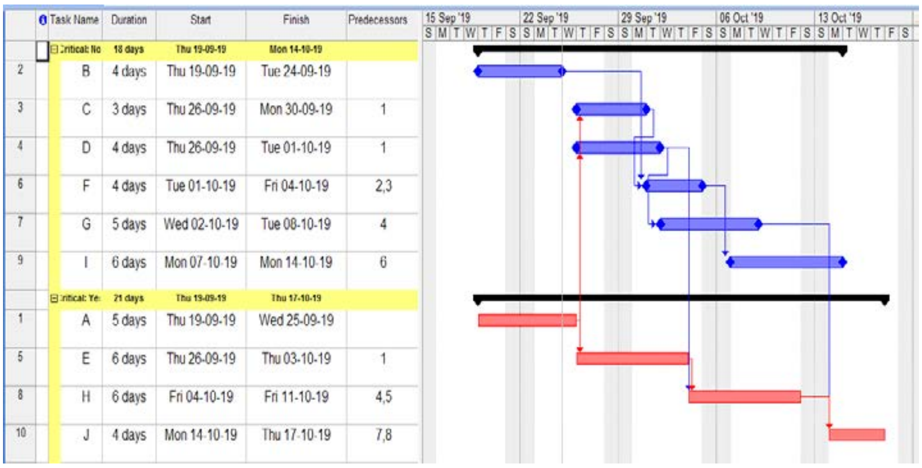

Figure 11 A Gantt chart of Milestone and Critical in MS Project

Difference between PERT and CPM

PERT is appropriate for the projects where the time needed to complete different activities are not known. **The Critical Path Method (CPM)** is appropriate for the projects which are recurring in nature. The primary difference between PERT and CPM is shown in Table 4.

Table 4 Differences between PERT and CPM

CPM	PERT
• CPM is **activity** oriented	• PERT is **event** oriented
• Single time estimates are used for the various activities i.e. the time estimates are **deterministic**.	• The time estimates for activities are **probabilistic**.
• Appropriate for Reasonable time estimate	• Appropriate for High precision time estimate
• Model under certainty	• Model under uncertainty
• Project management that manages well defined activities of a project	• Technique, used to manage uncertain activities of a project
• A method to control cost and time	• A technique of planning and control of time
• Suitable for Non-research projects like civil construction, ship building etc.	• Suitable for Research and Development Project

Conclusion

The two scheduling methods use a common approach for designing the network and for ascertaining its critical path. They are used in the successful completion of a project and hence used in conjunction with each other. Nevertheless, PERT is focuses on time and CPM is focuses on the time-cost trade-off. PERT and CPM are available to assist the **project manager** in carrying out these responsibilities. These techniques make heavy use of *networks* to help plan and display the coordination of all the activities. These techniques are widely used for *planning and coordinating large-scale projects*. By using PERT or CPM, managers are able to obtain (1) a graphical display of project activities (2) an estimate of how long the project will take (3) an indication of which activities are the most critical to timely project completion (4) an indication of how long any activity can be delayed without delaying the project.

This paper illustrates how the application of network or precedence diagram can be used in project management. All the project activities are constructed project network and Gantt chart for a sample project using MS Excel spreadsheet and MS Project.

The difference between these two project management tools PERT and CPM is getting blurred as the techniques are merged with the passage of time. That is why, in most projects, they are being used as a single project. The primary distinguishes PERT from CPM is that the former gives the extreme importance of time, i.e. if the time is minimized, consequently the cost will also be reduced. It is illustrated the critical path and time for PERT/CPM by performing forward pass and backward pass. Furthermore, it is found easily the length of the critical path by calculating the slack time for any activity.

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