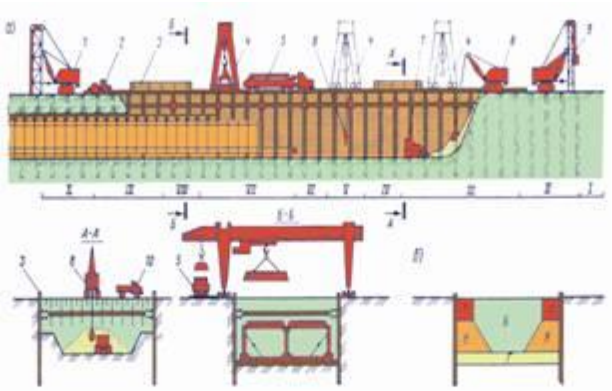
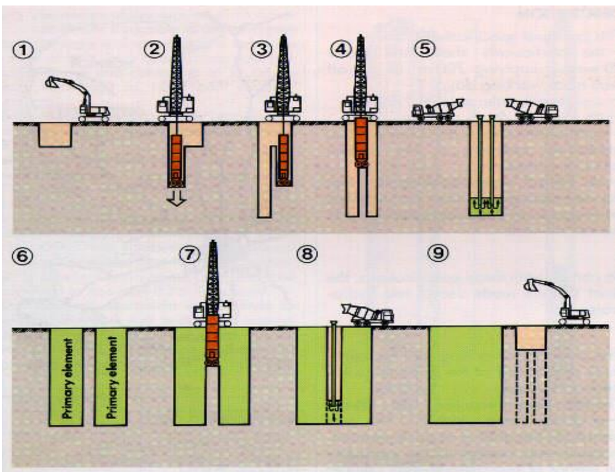
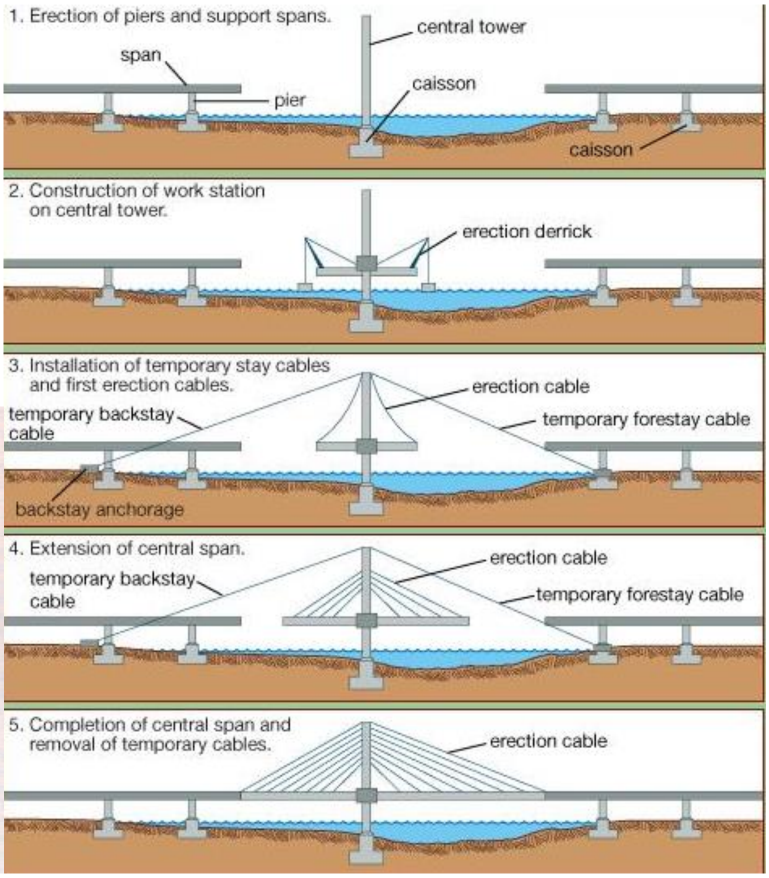
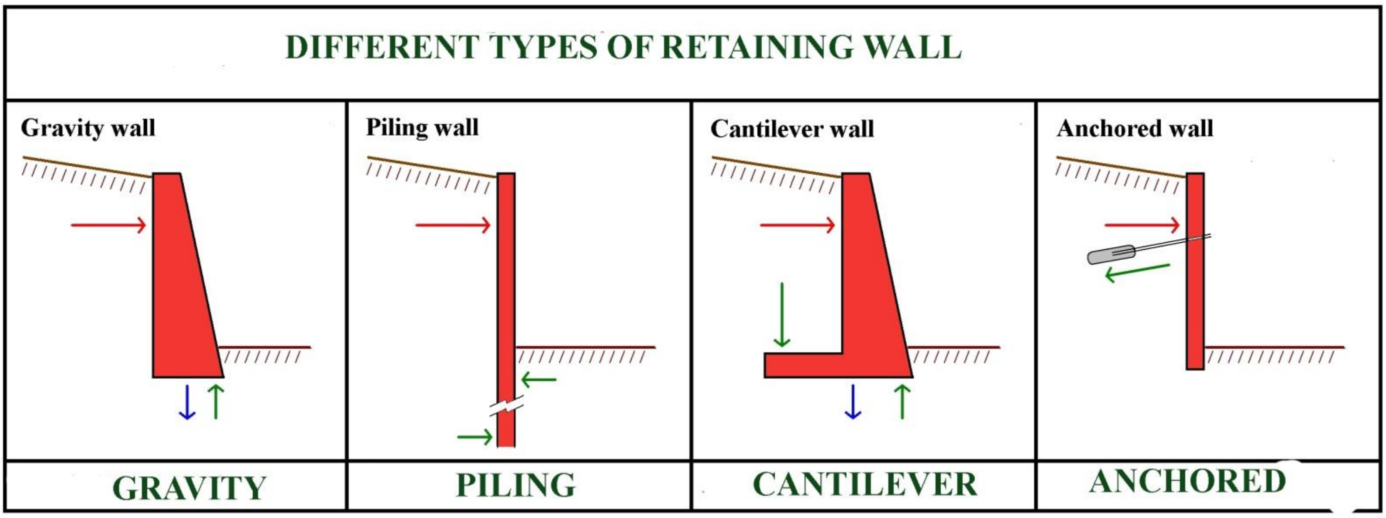
Method of Construction & Estimation









Dr. Danar Hassan Talabani

Content

Introduction

CHAPTER 1	Planning and scheduling
CHAPTER 2	Earth moving materials and operations
CHAPTER 3	Excavating and Lifting
CHAPTER 4	Loading and Hauling
CHAPTER 5	Compacting and Finishing
CHAPTER 6	Rock Excavation
CHAPTER 7	Culvert Use, Installation, and Sizing
CHAPTER 8	Dams
CHAPTER 9	Canals
CHAPTER 10	Foundations
CHAPTER 11	Irrigation Structures
CHAPTER 12	Concrete Construction
CHAPTER 13	Concrete Form Design
CHAPTER 14	Masonry Construction
CHAPTER 15	Retaining Walls
CHAPTER 16	Estimation
CHAPTER 17	Construction Economics
CHAPTER 18	Factors Affecting the Selection of Construction Equipment

Appendix 1	CONSTRUCTION SITE LAYOUT PLANNING
Appendix 2	CONSTRUCTION and OFF ROAD EQUIPMENT
Appendix 3	Construction Equipment Earthwork & Soil Compaction
Appendix 4	Concrete, plaster & mortar mixes for builders

Introduction

The working drawings usually contain information relative to the design, location, dimensions, and construction of the project, while the project manual is a written supplement to the drawings and includes information pertaining to materials and workmanship, as well as information about the bidding process. The working drawings and the project manual constitute the majority of the contract documents, define the scope of work, and *must* be considered together when preparing an estimate. The two complement each other, and they often overlap in the information they convey. The bid submitted must be based on the scope work provided by the owner or the architect.
The estimator is responsible for including everything contained in the drawings and the project manual in the submitted bid. Because of the complexity of the drawings and the project manual, coupled with the potential cost of an error, the estimator must read everything thoroughly and recheck all items. Initially, the plans and the project manual must be checked to ensure that they are complete. Then the estimator can begin the process of quantifying all of the materials presented. Every item included in the estimate must contain as much information as possible. The quantities determined for the estimate will ultimately be used to order and purchase the needed materials. The estimated quantities and their associated projected costs will become the basis of project controls in the field.

Estimating the ultimate cost of a project requires the integration of many variables. These variables fall into either direct field costs or indirect field costs. The indirect field costs are also referred to as general conditions or project overhead costs in building construction. The direct field costs are the material, labor, equipment, or subcontracted items that are permanently and physically integrated into the building. For example, the labor and materials for the foundation of the building would be a direct field cost. The indirect field costs are the cost for the items that are required to support the field construction efforts. For example, the project site office would be a general conditions cost. In addition, factors such as weather, transportation, soil conditions, labor strikes, material availability, and subcontractor availability need to be integrated into the estimate. Regardless of the variables involved, the estimator must strive to prepare as accurate an estimate as possible. Since subcontractors or specialty contractors may perform much of the work in the field, the estimator must be able to articulate the scope of work in order for these companies to furnish a price quote.

The complexity of an estimate requires organization, estimator’s best judgment, complete specialty contractors’ (subcontractors’) bids, accurate quantity takeoffs, and accurate records of completed projects.

PART ONE

Construction Method

1

Planning and Scheduling

1–1 INTRODUCTION

Planning and Scheduling

As you already know, some planning must be done in order to perform any function with a minimum of wasted time and effort. This is true whether the function is getting to work on time or constructing a multimillion dollar building. A schedule is nothing more than a time phased plan. Schedules are used as guides during the performance of an operation in order to control the pace of activities and to permit completion of the operation at the desired or required time.

Scheduling is utilized for many different phases of the construction process, from master planning through facility construction to facility operation and maintenance. In the construction phase itself, schedules are useful for a number of purposes before starting a project and after completion of the project as well as during the actual conduct of construction work. Some of the principal uses for schedules during each of these phases of construction are listed below.

Before Starting

1. Provides an estimate of the time required for each portion of the project as well as for the total project.
2. Establishes the planned rate of progress.
3. Forms the basis for managers to issue instructions to subordinates.
4. Establishes the planned sequence for the use of personnel, materials, machines, and money.

During Construction

1. Enables the manager to prepare a checklist of key dates, activities, resources, and so on.
2. Provides a means for evaluating the effect of changes and delays
3. Serves as the basis for evaluating progress.
4. Aids in the coordination of resources.

After Completion of Construction

1. Permits a review and analysis of the project as actually carried out.
2. Provides historical data for improving future planning and estimating.

1–3 CPM—THE CRITICAL PATH METHOD

Both CPM and PERT use a network diagram to graphically represent the major activities of a project and to show the relationships between activities. The major difference between CPM and PERT is that PERT utilizes probability concepts to deal with the uncertainty associated with activity-time estimates, whereas CPM assigns each activity a single fixed duration.

The Network Diagram

Act no.	Description	Duration	Early start	Early finish	Late start	Late finish	Total float
1-2	Drill well	4	0	4	6	10	6
1-3	Deliver material	2	0	2	3	5	3
* 1-4	Excavate	5	0	5	0	5	0
1-5	Power line	3	0	3	10	13	10
2-5	Pump house	3	4	7	10	13	6
3-6	Assemble tank	4	2	6	5	9	3
* 4-6	Foundation	4	5	9	5	9	0
4-7	Install pipe	6	5	11	9	15	4
5-7	Install pump	2	7	9	13	15	6
* 6-7	Erect tower and tk	6	9	15	9	15	0

* = critical activity

Figure 1–1 Activity-time data for example network.

As indicated, a network graphically portrays major project activities and their relationships. There are basically two methods of drawing such networks: the *activity-on-arrow diagram* and the *activity-on-node diagram.* Special forms of activity-on-node diagram, such as *precedence diagrams,* will be discussed later in the chapter. While activity-on-node diagrams have certain advantages, activity-on-arrow format will be utilized to illustrate network construction and time calculations.

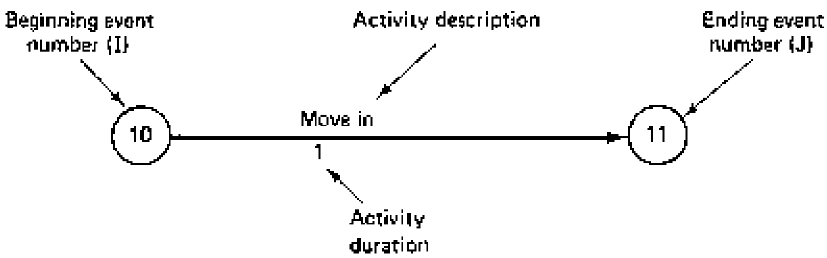


Figure 1–5 Activity-on-arrow notation.

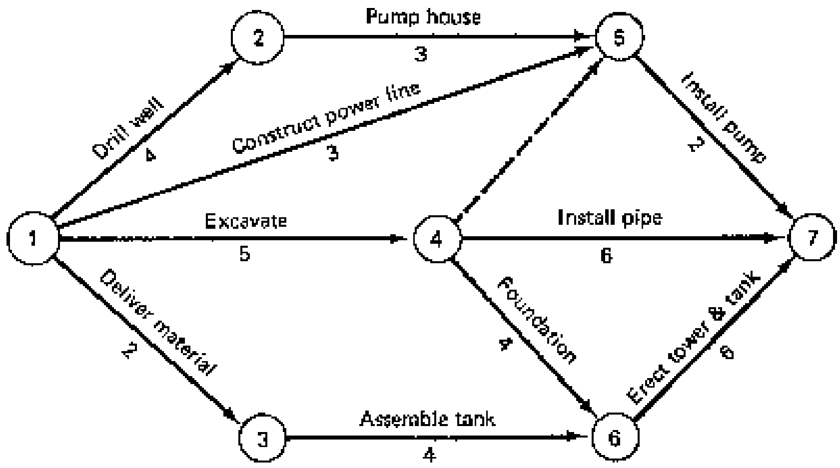


Figure 1–6 Example network diagram.

Notice the dashed arrow in Figure 1–6. This is called a *dummy activity* or simply a *dummy.* Dummies are used to impose logic constraints and prevent duplication of activity I–J numbers. They do not represent any work and, hence, always have a duration of zero.

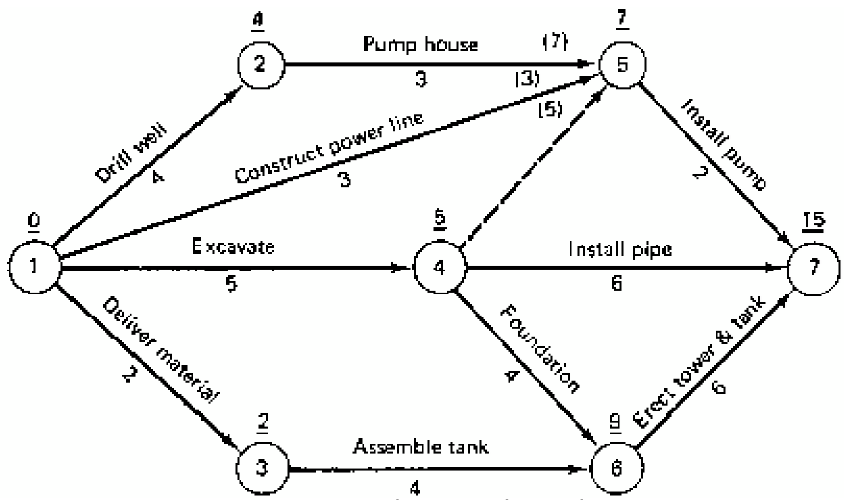


Figure 1–7 Example network—early event times.

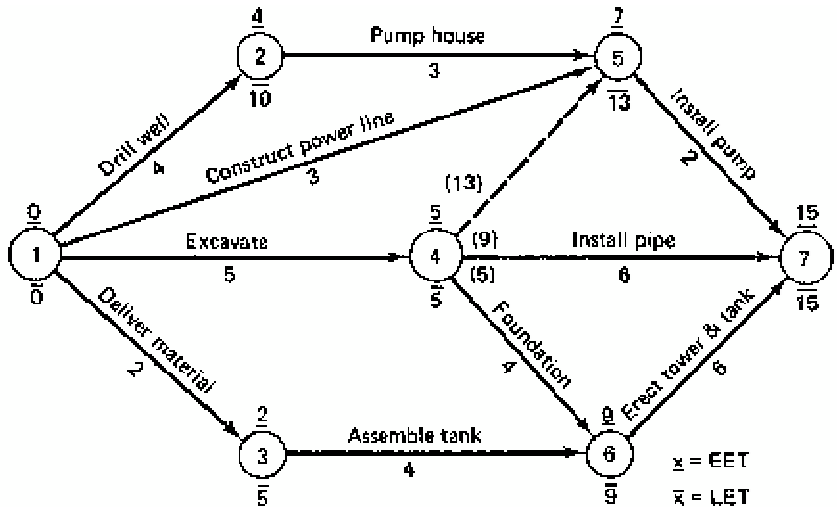


Figure 1–8 Example network—late event times.

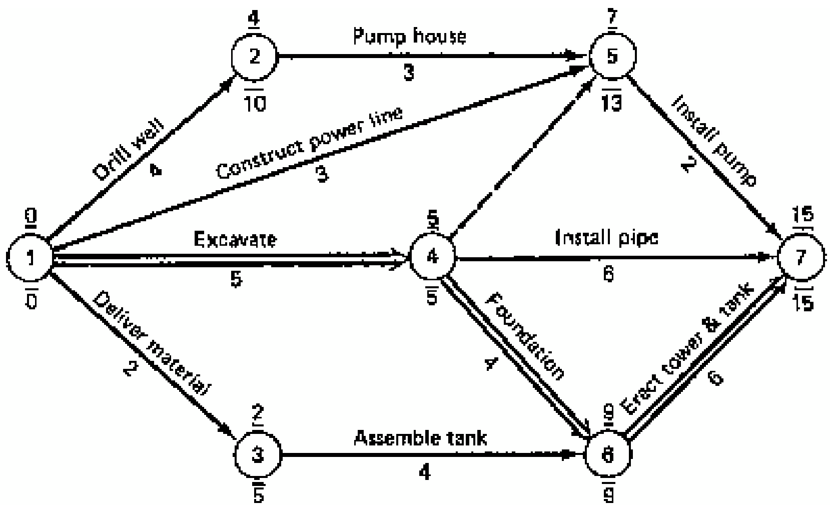


Figure 1–9 Example network—critical path.

Activity Times

Early start (ES) = Early event time of preceding (I) event	**(16–2)**
Early finish (EF) = Early start + Activity duration	**(16–3)**
Late finish (LF) = Late event time of following (J) event	**(16–4)**
Late start (LS) = Late finish – Activity duration	**(16–5)**
Total float (TF) = Late finish – Early finish	**(16–6)**
or	
Total float (TF) = Late start – Early start	**(16–7)**

Definitions

Float (slack) - amount of time that a task can be delayed without causing a delay to:

Subsequent tasks (free float)

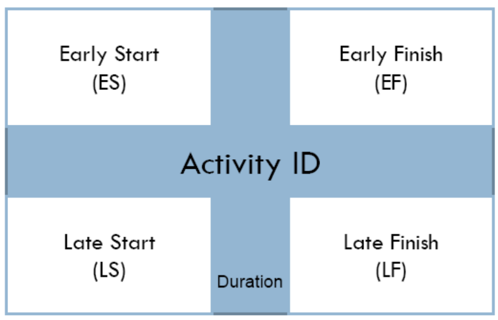
Project completion date (total float)

Critical path is the sequence of activities which add up to the longest overall duration. It is the shortest time possible to complete the project. Any delay of an activity on the critical path directly impacts the planned project completion date (there is no float on the critical path). A project can have several, parallel, near critical paths. An additional parallel path through the network with the total durations shorter than the critical path is called a sub-critical or non-critical path.

Critical activity – activity with zero float

Resource leveling – iterative process of assigning crews to activities in order to calculate their duration

Activity Identity box



Network Diagram Representation

In a network representation of a project certain definitions are used

1. Activity

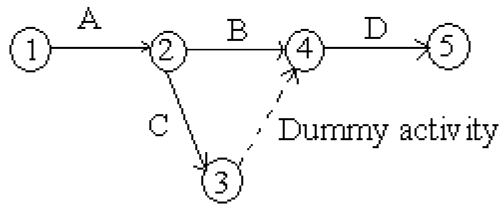
Any individual operation which utilizes resources and has an end and a beginning is called activity. An arrow is commonly used to represent an activity with its head indicating the direction of progress in the project. These are classified into four categories

1. **Predecessor activity** – Activities that must be completed immediately prior to the start of another activity are called predecessor activities.
2. **Successor activity** – Activities that cannot be started until one or more of other activities are completed but immediately succeed them are called successor activities.
3. **Concurrent activity** – Activities which can be accomplished concurrently are known as concurrent activities. It may be noted that an activity can be a predecessor or a successor to an event or it may be concurrent with one or more of other activities.
4. **Dummy activity** – An activity which does not consume any kind of resource but merely depicts the technological dependence is called a dummy activity.

The dummy activity is inserted in the network to clarify the activity pattern in the following two situations

- To make activities with common starting and finishing points distinguishable
- To identify and maintain the proper precedence relationship between activities that is not connected by events.

For example, consider a situation where A and B are concurrent activities. C is dependent on A and D is dependent on A and B both. Such a situation can be handled by using a dummy activity as shown in the figure.

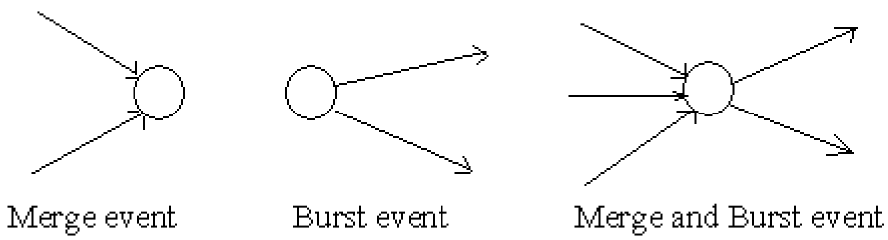


2. Event

An event represents a point in time signifying the completion of some activities and the beginning of new ones. This is usually represented by a circle in a network which is also called a node or connector.

The events are classified in to three categories

- **Merge event** – When more than one activity comes and joins an event such an event is known as merge event.
- **Burst event** – When more than one activity leaves an event such an event is known as burst event.
- **Merge and Burst event** – An activity may be merge and burst event at the same time as with respect to some activities it can be a merge event and with respect to some other activities it may be a burst event.



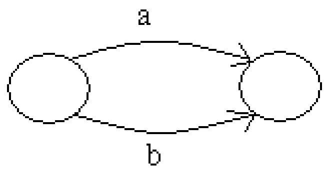
3. Sequencing

The first prerequisite in the development of network is to maintain the precedence relationships. In order to make a network, the following points should be taken into considerations

- What job or jobs precede it?
- What job or jobs could run concurrently?
- What job or jobs follow it?
- What controls the start and finish of a job?

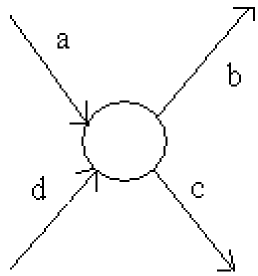
Since all further calculations are based on the network, it is necessary that a network be drawn with full care.

Rules for Drawing Network Diagram



Rule 1

Each activity is represented by one and only one arrow in the network



Rule 2

No two activities can be identified by the same end events

Rule 3

In order to ensure the correct precedence relationship in the arrow diagram, following questions must be checked whenever any activity is added to the network

- What activity must be completed immediately before this activity can start?
- What activities must follow this activity?
- What activities must occur simultaneously with this activity?

In case of large network, it is essential that certain good habits be practiced to draw an easy to follow network

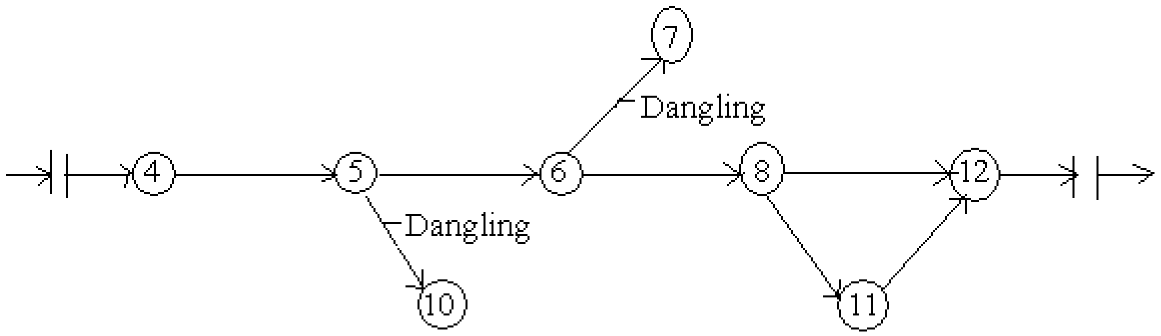
- Try to avoid arrows which cross each other
- Use straight arrows
- Do not attempt to represent duration of activity by its arrow length
- Use arrows from left to right. Avoid mixing two directions, vertical and standing arrows may be used if necessary.
- Use dummies freely in rough draft but final network should not have any redundant dummies.
- The network has only one entry point called start event and one point of emergence called the end event.

Common Errors in Drawing Networks

The three types of errors are most commonly observed in drawing network diagrams.

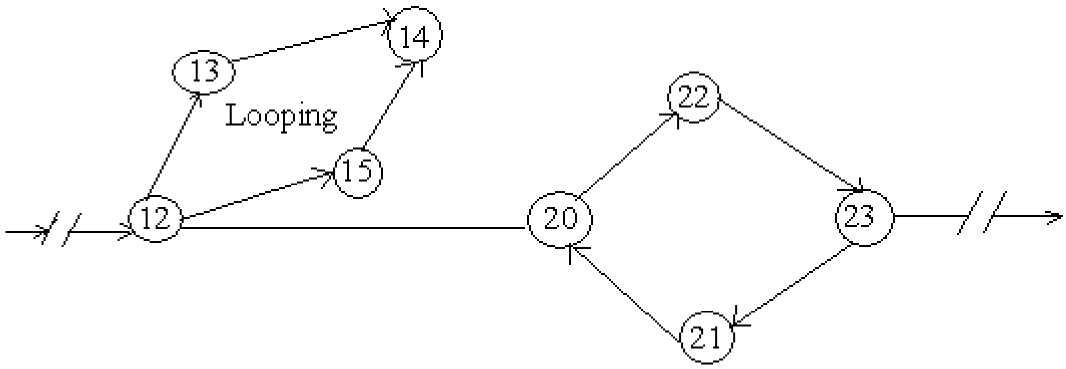
1. Dangling

To disconnect an activity before the completion of all activities in a network diagram is known as dangling. As shown in the figure activities (5 – 10) and (6 – 7) are not the last activities in the network. So the diagram is wrong and indicates the error of dangling



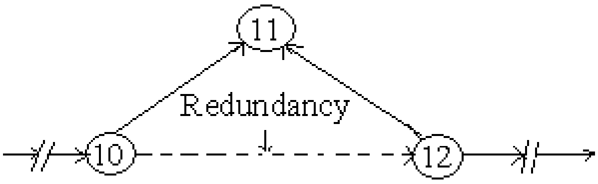
2. Looping or Cycling

Looping error is also known as cycling error in a network diagram. Drawing an endless loop in a network is known as error of looping as shown in the following figure.

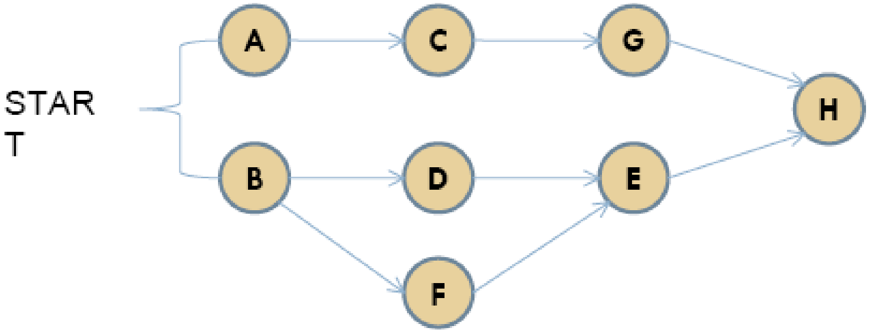


3. Redundancy

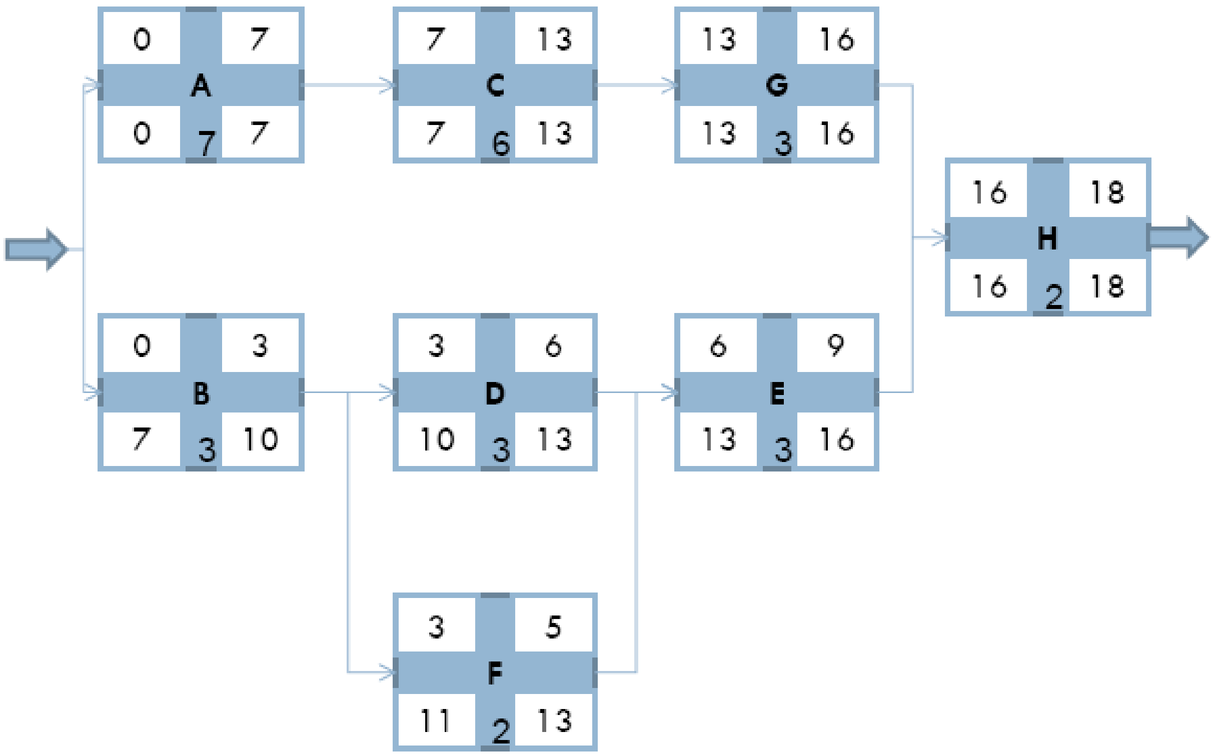
Unnecessarily inserting the dummy activity in network logic is known as the error of redundancy as shown in the following diagram



Class Exercise



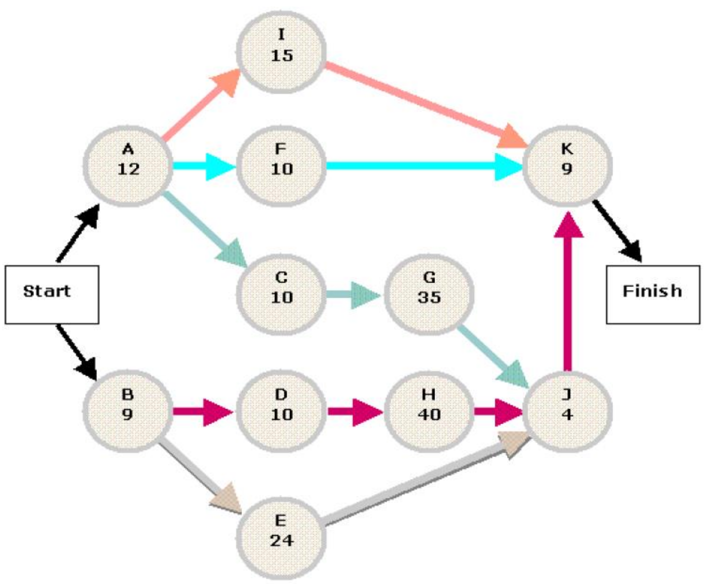
Activity ID	Duration	Dependency
A	7	
B	3	
C	6	A
D	3	B
E	3	D,F
F	2	B
G	3	C
H	2	E,G



In the following example, the Project manager knows the succession of the project activities and the optimistic, pessimistic and most likely time (in weeks) for the following activities:

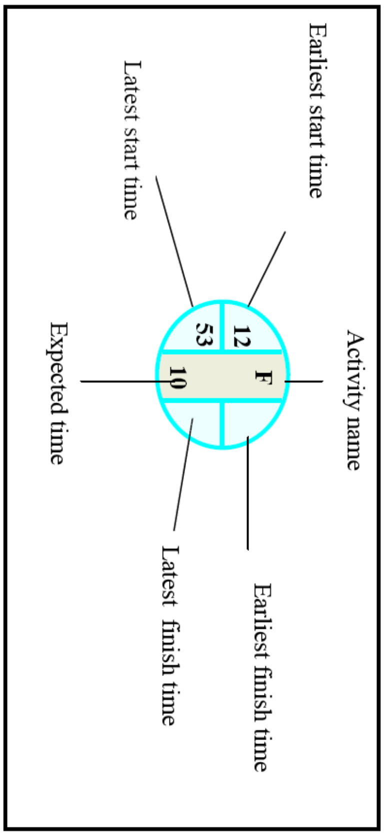
Activity	**Description**	**Predecessors**	**Optimistic time (O)**	**Pessimistic time (P)**	**Most likely time (M)**	***Expected time (O+4M+P)/6***
A	Select administrative and medical staff.	-	9	15	12	*12*
B	Select site and do site survey.	-	5	13	9	*9*
C	Select equipment.	A	8	12	10	*10*
D	Prepare final construction plans and layout.	B	7	17	9	*10*
E	Bring utilities to the site.	B	18	34	23	*24*
F	Interview applicants and fill positions in nursing support staff, maintenance, and security.	A	9	15	9	*10*
G	Purchase and take delivery of equipment.	C	30	40	35	*35*
H	Construct the hospital.	D	35	49	39	*40*
I	Develop an information system.	A	12	18	15	*15*
J	Install the equipment.	E, G, H	3	9	3	*4*
K	Train nurses and support staff	F, I, J	7	11	9	*9*

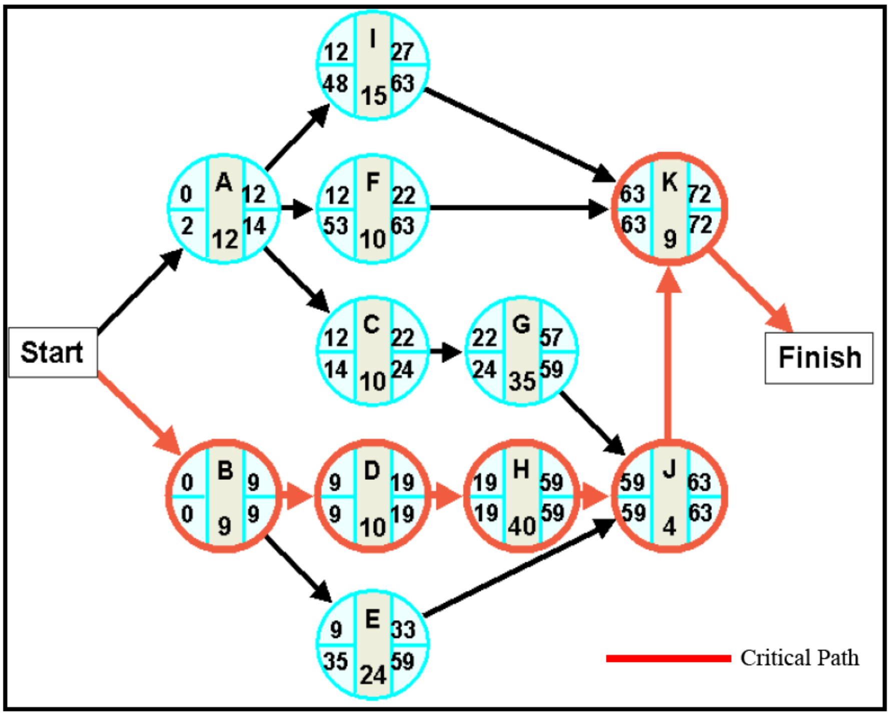
The associated network is:



The earliest start time, earliest finish time, latest start time and latest finish time for each activity are calculated in the following table:

Node	Duration	ES	EF	LS	LF	Slack
A	12	0	12	2	14	2
B	9	0	9	0	9	0
C	10	12	22	14	24	2
D	10	9	19	9	19	0
E	24	9	33	35	59	26
F	10	12	22	53	63	41
G	35	22	57	24	59	2
H	40	19	59	19	59	0
I	15	12	27	48	63	36
J	4	59	63	59	63	0
K	6	63	72	63	72	0



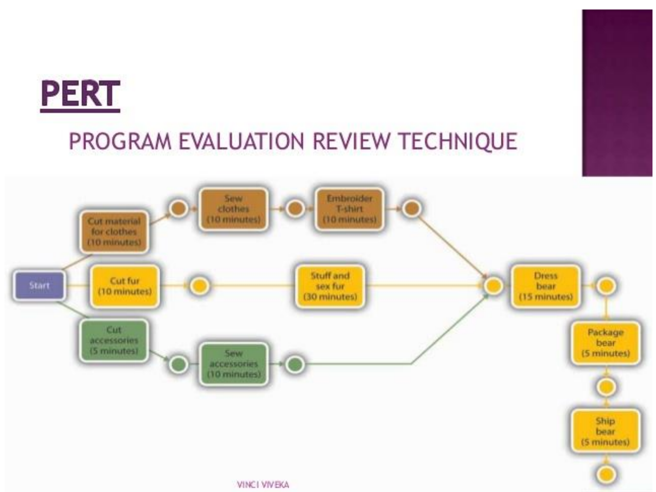


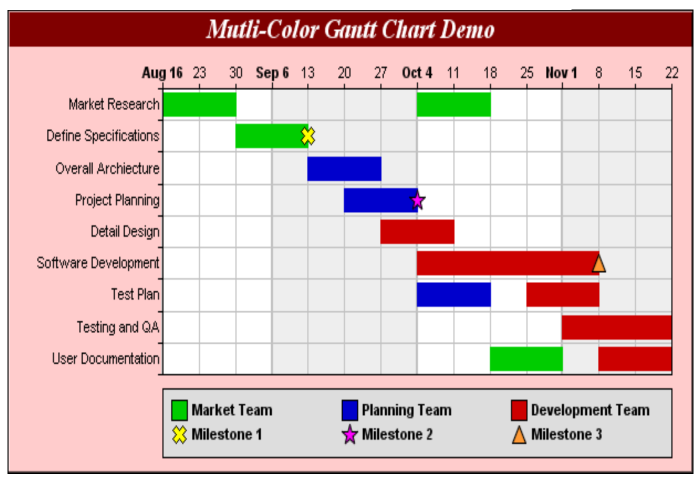
Difference between Gantt and PERT Chart

Key Difference: Gantt charts and PERT charts are visualization tools that project and breakdown the tasks along with the time it takes to do the particular task. Gantt chart is represented as a bar graph, while PERT chart is represented as a flow chart.

Gantt charts and PERT charts are visualization tools that project and breakdown the tasks along with the time it takes to do the particular task. These are time management tools that are used by managers and administrators to display tasks that are required for project completion. The charts schedule, control and administer the tasks that are set by the manager.

The chart shows a horizontal bar which represents the task, while the length of the bar shows the time required to complete the task. On an x-y axis, the x axis represents the time for project completion. Independent tasks are connected using arrows, which show the relationship between two independent tasks. The relationship stems from the dependency of one task on another, where one task must be finished in order to being the other task. A limitation of the Gantt chart is that they do not efficiently represent the dependency of one task to another. Gantt charts are also limited to small projects and are not effective for projects with more than 30 activities.





PERT charts can manage large projects that have numerous complex tasks a very high inter-task dependency. The PERT chart has numerous interconnecting networks of independent tasks. The events in a PERT chart are in logical sequence so that no other task can begin until the previous task is completed. A PERT chart may have multiple pages with many sub-tasks. PERT chart is useful when trying to manage multiple tasks that will occur simultaneously. This chart is a bit complicated to use and are often used with Gantt charts in order to simplify the tasks better.

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 be lend resources to critical path activities;
- Activity start and end date.

Summary

□ Bar chart (Gantt chart)

• Graphical representation employed since early 1900's
• Horizontal axis = timescale
• Vertical scale lists activities

□ Bar chart (Gantt chart)

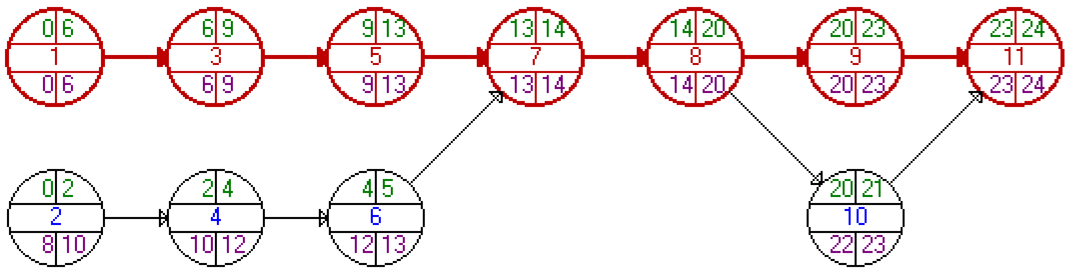
• *Advantages*
– Easy to read
– Good communication tool
– Easy to update
• *Disadvantages*
– Does not show interrelationships
– Cannot evaluate impact of delays = does not provide adequate documentation for claims

□ Network Diagrams

• Displays project graphically
• Presents activities as they relate to each other
– Logic ties
– Predecessors and successors
• Computer software enables greater use of network diagrams

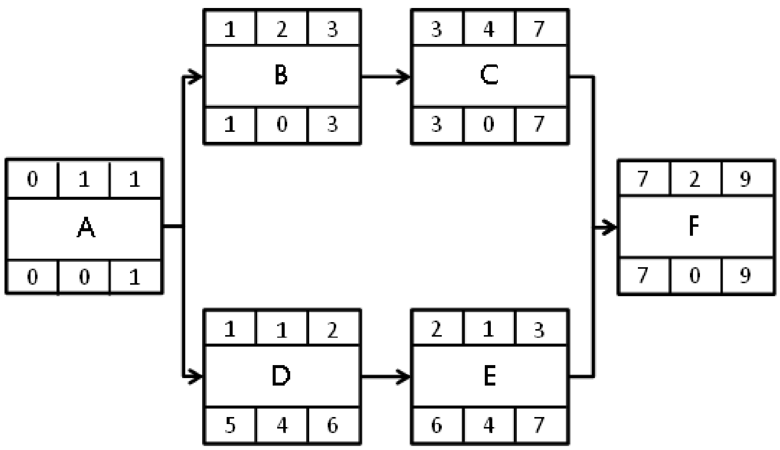
□ CPM Scheduling

• Activity-on-Arrow Diagrams a.k.a. Arrow Diagramming Method (ADM)
– Original CPM developed by duPont in late 1950's
– Shows relationship and activity on arrows connected by nodes



- Activity-on-Node Diagrams
– Arrows show relationship only
– Originally developed as PERT by the U.S. Navy also during late 1950's
– Precedence Diagramming Method (PDM)
- Incorporates additional precedence relationships
- Time-lag factors

- **Early Start (ES)**
– Earliest time an activity can start according to its assigned relationships
– Determined by forward pass



- **Early Finish (EF)**
– Earliest time an activity can finish
– EF = ES + activity duration

- **Forward Pass**
– Completed left to right
– Calculates ES, EF, and project duration
– Where 2 or more chains converge on a single activity, the larger value controls

- **Backward Pass**
– Completed right to left or end back to the beginning
– Calculates LF, LS
– Where 2 or more chains converge on a single activity, the smallest value governs

- **Float**
– "slack time"
– Difference between earliest and latest
– Allows activity to begin later than ES and not prolong the project
– Two types of float: *total* and *free* float
- Total float – leeway in start and completing an activity without delaying the project

• Free float – “activity float”, time the start of an activity can be delayed without delaying the start of a successor activity

TF = LF – (ES + activity duration)

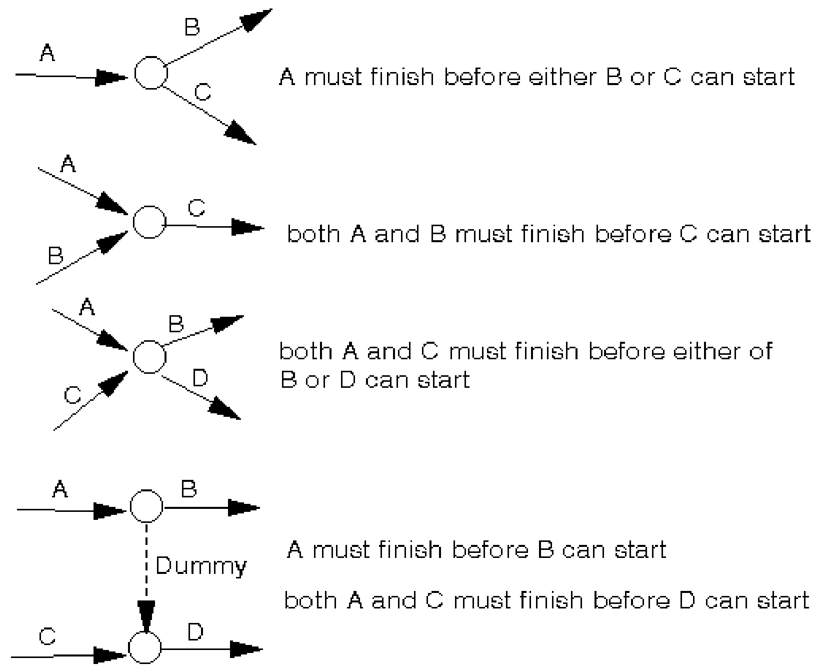
TF = LS – ES *or* LF – EF

FF = ES of successor – LF of predecessor

• **Critical Path**

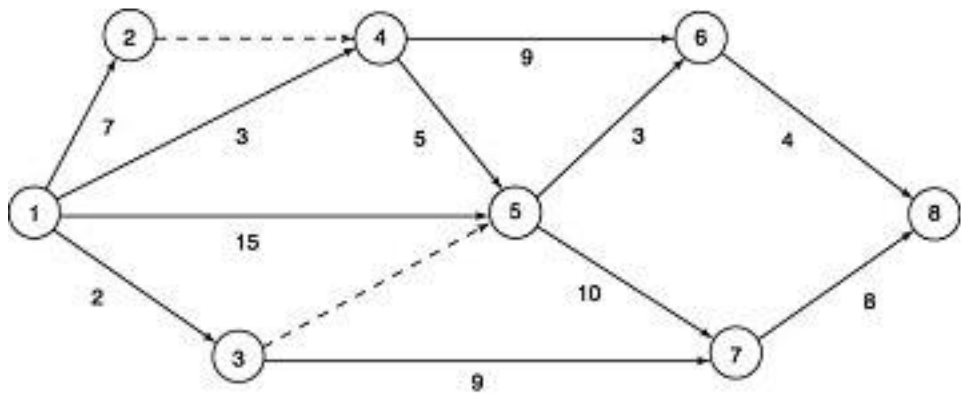
– Continuous chain of activities with longest durations

– Determines project duration



PROBLEMS

1. Redraw the accompanying network diagram, adding early and late event times to the diagram. Mark the critical path. Prepare an activity-time tabulation showing early start, late start, early finish, late finish, and total float.



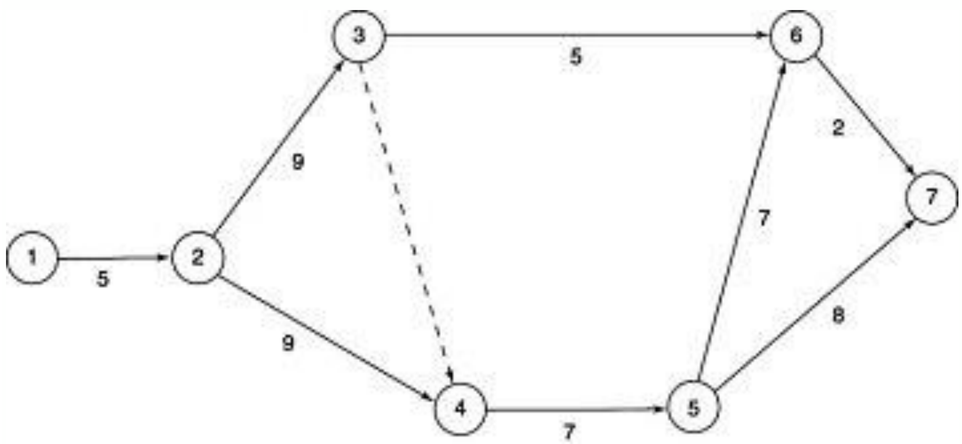
2. What effect will the delays in Activities 1, 2, and 3 of Figure 16–1 have on project completion? Explain.

3. For the network of Problem 5, assign resources based on an early start schedule. Indicate the total resource requirements for each time period. Level the resource requirements as much as possible utilizing float. The resource requirements for each activity are as follows

Activity	Workers Required
1–2	6
2–3	4
2–4	15
3–4	10
3–6	5
4–5	6
5–6	5
5–7	8
6–7	4

4. What advantages do CPM diagrams have over conventional bar graph schedules?

5. Redraw the accompanying network diagram, adding early and late event times to the diagram. Mark the critical path. Prepare an activity-time tabulation showing early start, late start, early finish, late finish, and total float.



6. How does the actual progress at the end of the second week in Figure 16–1 compare with the scheduled progress? Express your answer as the percentage of scheduled progress that has actually been achieved.
7. Draw an activity-on-arrow network diagram representing the following logical relationships.

Activity	Depends on Completion of Activity
A	—
B	—
C	—
D	A
E	B
F	C
G	B
H	D and G
I	B
J	—
K	I and F

8. For the LSM diagram of Figure 1–22, over what linear distance does the Base Course activity extend at any particular time?
9. Redraw the precedence diagram of Figure 16–15 adding the relationships given below. Enter the early start, late start, early finish, late finish, and total float times on the diagram. Mark the critical path

Activity Relationships

Start to Start	Finish to Start	Finish to Finish	Lag Time
8 to 7			3
	7 to 10		2
		8 to 11	4

10. Utilizing a personal computer program, solve Problem 1.

REFERENCES

1. Ahuja, H. N. *Project Management,* 2nd ed. New York: Wiley, 1994.
2. Arditi, David, and M. Zeki Albulak. "Line-of-Balance Scheduling in Pavement Construction," *ASCE Journal of Construction Engineering and Management,* vol. 112, no. 3 (1986), pp. 411–424.
3. Clough, Richard, Glenn A. Sears, and Keoki Sears. *Construction Project Management,* 4th ed. New York: Wiley, 2000.
4. Harris, Robert B. *Precedence and Arrow Networking Techniques for Construction.* New York: Wiley, 1978.
5. Johnston, D. W. "Linear Scheduling Method for Highway Construction," *ASCE Journal of the Construction Division,* vol. 107, no. C02 (1981), pp. 247–261.
6. Moder, Joseph J., Cecil R. Phillips, and Edward W. Davis. *Project Management with CPM, PERT and PRECEDENCE Diagramming,* 3rd ed. New York: Van Nostrand Reinhold, 1983.
7. O'Brien, James J., and Frederic L. Plotnick. *CPM in Construction Management,* 5th ed. Boston: McGraw-Hill, 1999.
8. Pinnell, Steven S. "Critical Path Scheduling: An Overview and a Practical Alternative," *Civil Engineering—ASCE* (May 1981).
9. Vorster, M. C., Y. J. Beliveau, and T. Barna. "Linear Scheduling and Visualization," *Transp. Res. Rec. 1351* (1992). Transportation Research Board, Washington, DC, pp. 32–39.
10. Whitehouse, Gary E. "Critical Path Program for a Microcomputer," *Civil Engineering—ASCE* (May 1991), pp. 54–56.
11. Yamin, Rene A., and David J. Harmelink. "Comparison of Linear Scheduling Model (LSM) and Critical Path Method (CPM)," *ASCE Journal of Construction Enginering and Management,* vol. 127, No. 5 (2001), pp. 374–38