SBS5224 Engineering Management

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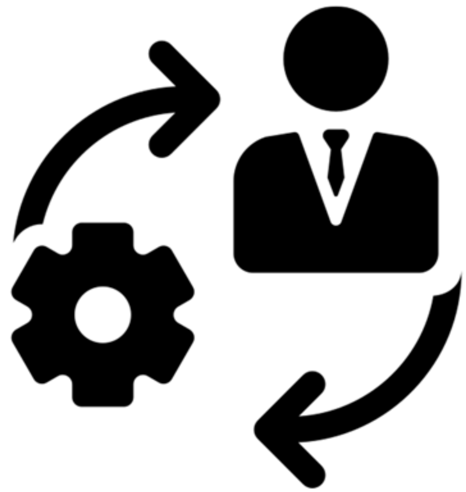


Project Planning and Scheduling

Faculty of Science and Technology

Intended Learning Outcomes

- By the end of this lecture, you will be able to…
  - Define project planning and project scheduling
  - Describe the use of a Work Breakdown Structure (WBS)
  - Discuss the objectives of project planning
  - Explain the principles of planning and scheduling
  - Identify the roles of the parties in project planning
  - Apply the various techniques for planning and scheduling.

Definition

- Project planning
  - The process of identifying all the activities necessary to successfully complete the project.
- Project scheduling
  - The process of determining the sequential order of the planned activities, assigning realistic durations to each activity, and determining the start and finish dates for each activity.

➢ Thus, project planning is a prerequisite to project scheduling because there is no way to determine the sequence or start and finish dates of activities until they are identified.

Definition

- “Project planning” and “project scheduling” are often used synonymously because planning and scheduling are performed interactively.

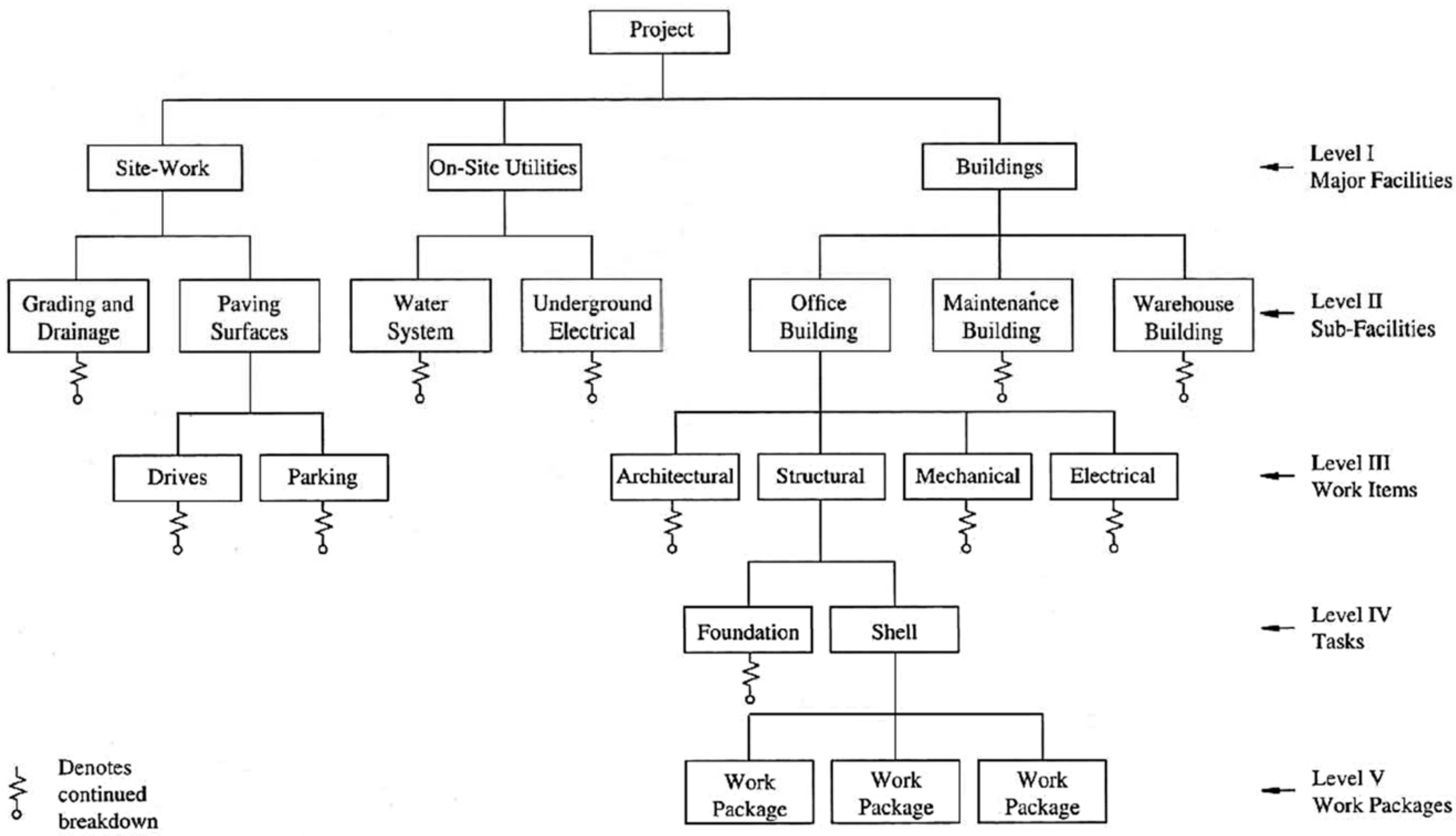
A specific list of activities may be planned and scheduled for a project. → The schedule is reviewed. → Additional activities may be added or some activities may be rearranged in order to obtain the best schedule of events for the project.

- Planning is more difficult to accomplish than scheduling because it demands the ability of the project planner/scheduler to identify all the work required to complete the project.
- The process of developing a well-defined work breakdown structure (WBS) results in a list of activities that must be performed to complete a project.

Work Breakdown Structure (WBS)

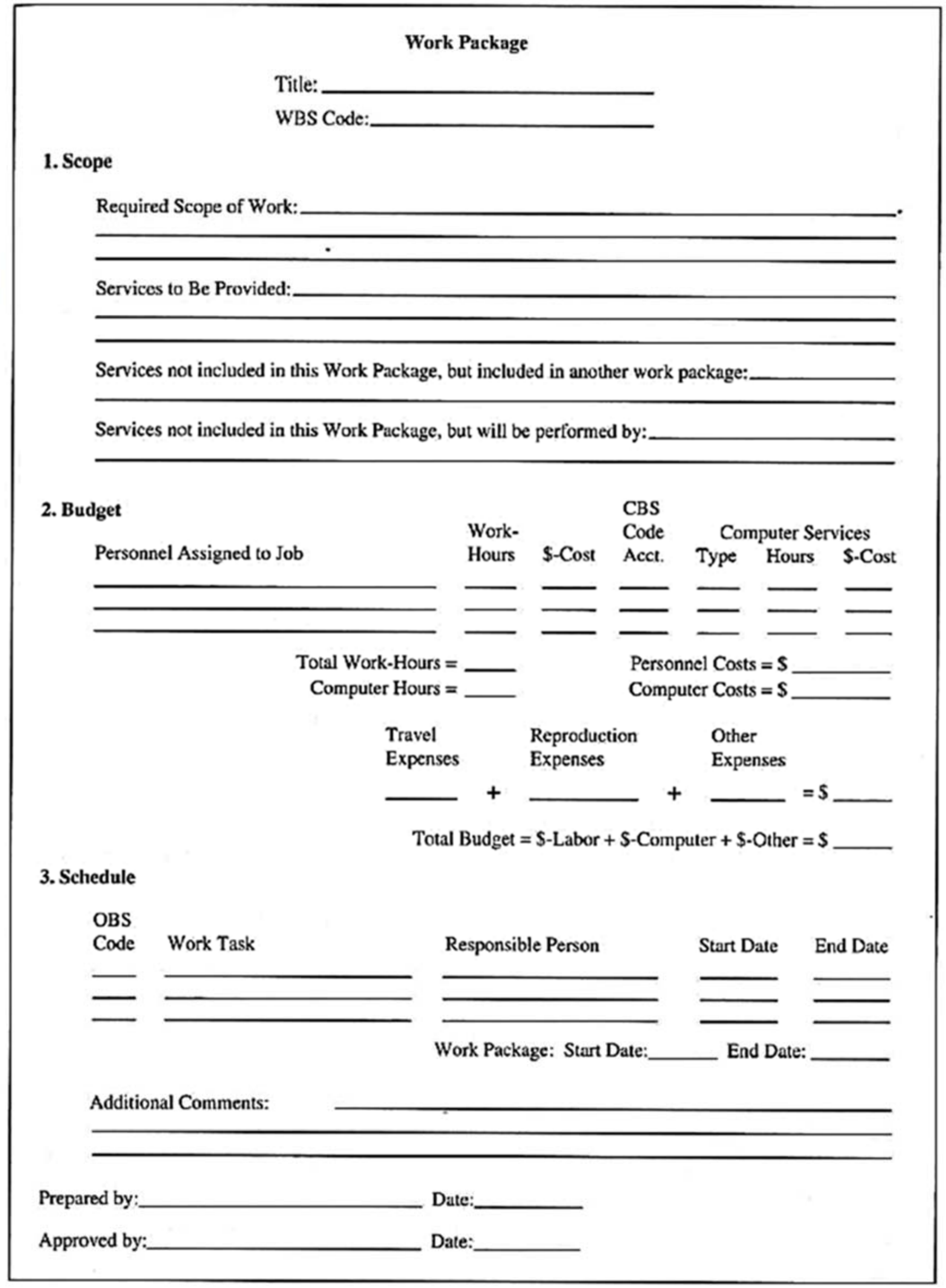
- For any size project, large or small, it is necessary to develop a well-defined Work Breakdown Structure (WBS) that divides the project into identifiable parts that can be managed.
- The concept of the WBS is simple;
  - In order to manage a whole project, one must manage and control each of its parts.
  - It is the cornerstone of the project work plan.
  - It defines the work to be performed, identifies the needed expertise, assists in selection of the project team, and establishes a base for project scheduling and control.
  - It is a graphical display of the project that shows the division of work in a multi-level system.
  - The number of levels in a WBS varies depending upon the size and complexity of the project.
  - The smallest unit in the WBS is a work package, which must be defined in sufficient detail so the work can be measured, budgeted, scheduled, and controlled.

Work Breakdown Structure (WBS)



WBS

- The development of the WBS is a continuing process that starts when the project is first assigned to the project manager and continues until all work packages have been defined.
- After the activities are identified, it is relatively easy for a good planner to determine the schedule for a project.



Work Package

Title: ______

WBS Code: ______

1. Scope

Required Scope of Work: ______

Services to Be Provided: ______

Services not included in this Work Package, but included in another work package: ______

Services not included in this Work Package, but will be performed by: ______

2. Budget

Personnel Assigned to Job	Work-Hours	$-Cost	CBS Code Acct.	Computer Services Type	Computer Services Hours	Computer Services $-Cost

Total Work-Hours = ____ Personnel Costs = $ ____

Computer Hours = ____ Computer Costs = $ ____

Travel Expenses ____ + Reproduction Expenses ____ + Other Expenses ____ = $ ____

Total Budget = $-Labor + $-Computer + $-Other = $ ____

3. Schedule

OBS Code	Work Task	Responsible Person	Start Date	End Date

Work Package: Start Date: ____ End Date: ____

Additional Comments: ______

Prepared by: ______ Date: ____

Approved by: ______ Date: ____

Project Planning

- Project planning
  - The heart of good project management because it provides the central communication that coordinates the work of all parties.
  - Establishes the benchmark for the project control system to track the quantity, cost, and timing of work required to successfully complete the project.
  - Should include a clear description of the required work before the work is started.
    - (It must be recognized that changes are a necessary part of project work, especially in the early development phases. If changes in the work are expected, or probable, then project planning should include provisions for a reasonable allowance of the anticipated changes.)

Desired Results of Planning

- Desired results of project planning and scheduling
  1. Finish the project on time
  2. Continuous (uninterrupted) flow of work (no delays)
  3. Reduced amount of rework (least amount of changes)
  4. Minimize confusion and misunderstandings
  5. Increased knowledge of status of project by everyone
  6. Meaningful and timely reports to management
  7. You run the project instead of the project running you
  8. Knowledge of scheduled times of key parts of the project
  9. Knowledge of distribution of costs of the project
  10. Accountability of people, defined responsibility/authority
  11. Clear understanding of who does what, when, and how much
  12. Integration of all work to ensure a quality project for the owner

Principles of Planning and Scheduling

- There must be an explicit operational plan to guide the entire project.
- The plan must include and link the three components of the project:
  a. Scope
  b. Budget
  c. Schedule

1. To develop an integrated total project plan, the project must be broken into well-defined units of work that can be measured and managed, starting with the WBS.
2. Once this is completed, the project team members who have the expertise to perform the work can be selected.
3. Team members have the ability to
   - Clearly define the magnitude of detail work that is required
   - Define the time and cost that will be required to produce the work.

Principles of Planning and Scheduling

- The project plan and schedule must clearly define (i) individual responsibilities, (ii) schedules, (iii) budgets, and (iv) anticipated problems.
- Key principles for planning and scheduling:
  1. Begin planning before starting work, rather than after starting work
  2. Involve people who will actually do the work in the planning and scheduling process
  3. Include all aspects of the project: scope, budget, schedule, and quality
  4. Build flexibility into the plan, include allowance for changes and time for reviews and approvals
  5. Remember the schedule is the plan for doing the work, and it will never be precisely correct
  6. Keep the plan simple, eliminate irrelevant details that prevent the plan from being readable
  7. Communicate the plan to all parties; any plan is worthless unless it is known.

Responsibilities of Parties

- The principal parties of owner, designer, and contractor all have a responsible role in project planning and scheduling.

1. Owner
   - Establishes the project completion date, which governs the scheduling of work for both the designer and contractor
   - Sets priorities for the components that make up the project, so as to
     - assist the designer in the process of organizing his/her work and developing the design schedule to produce drawings that are most important to the owner
     - assist in the development of the specifications and contract documents that communicate priorities to the construction contractor.

Responsibilities of Parties

2. Designer (Design Organization)
   - Develops a design schedule that meets the owner's schedule

     (The schedule should include a prioritization of work in accordance with the owner's needs and should be developed with extensive input of all designers who will have principal roles in the design process.)

3. Contractor (Construction Contractor)
   - Develops a schedule for all construction activities in accordance with the contract documents
   - Includes procurement and delivery of materials to the job, coordination of labour and equipment on the job, and interface the work of all subcontractors

     (The construction schedule aims to effectively manage the work to produce the best-quality project for the owner, but not to settle disputes related to project work.)

Project Scheduling

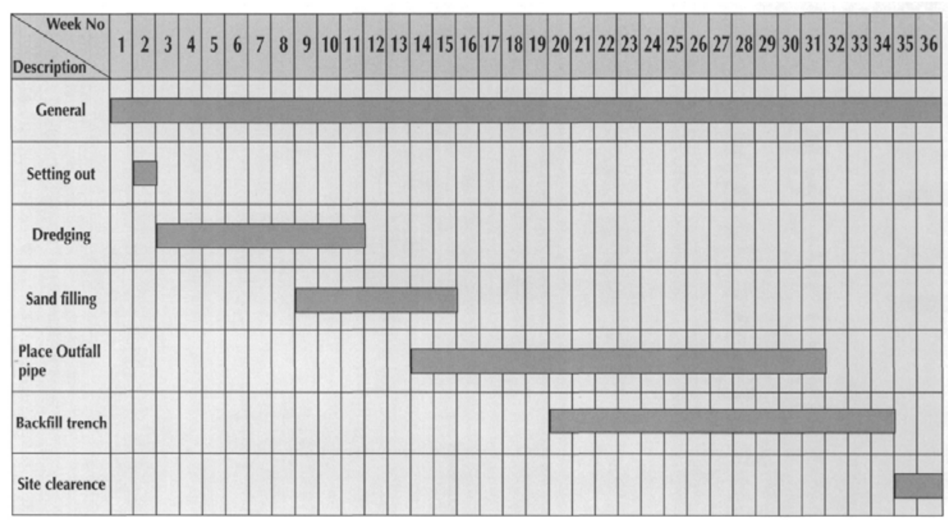
- Purposes of project scheduling
  1. To show the relationship of each activity to others & to the whole project
  2. To identify the precedence relationships among activities
  3. To encourage the setting of realistic time & cost estimates for each activity
  4. To help make better use of people, money, & material resources by identifying critical bottlenecks in the project
- Outcomes of project scheduling
  1. Identified precedence relationships
  2. Sequenced activities
  3. Estimated material and worker requirements
  4. Determined activity times and costs
  5. Determined critical activities

Techniques for Planning & Scheduling

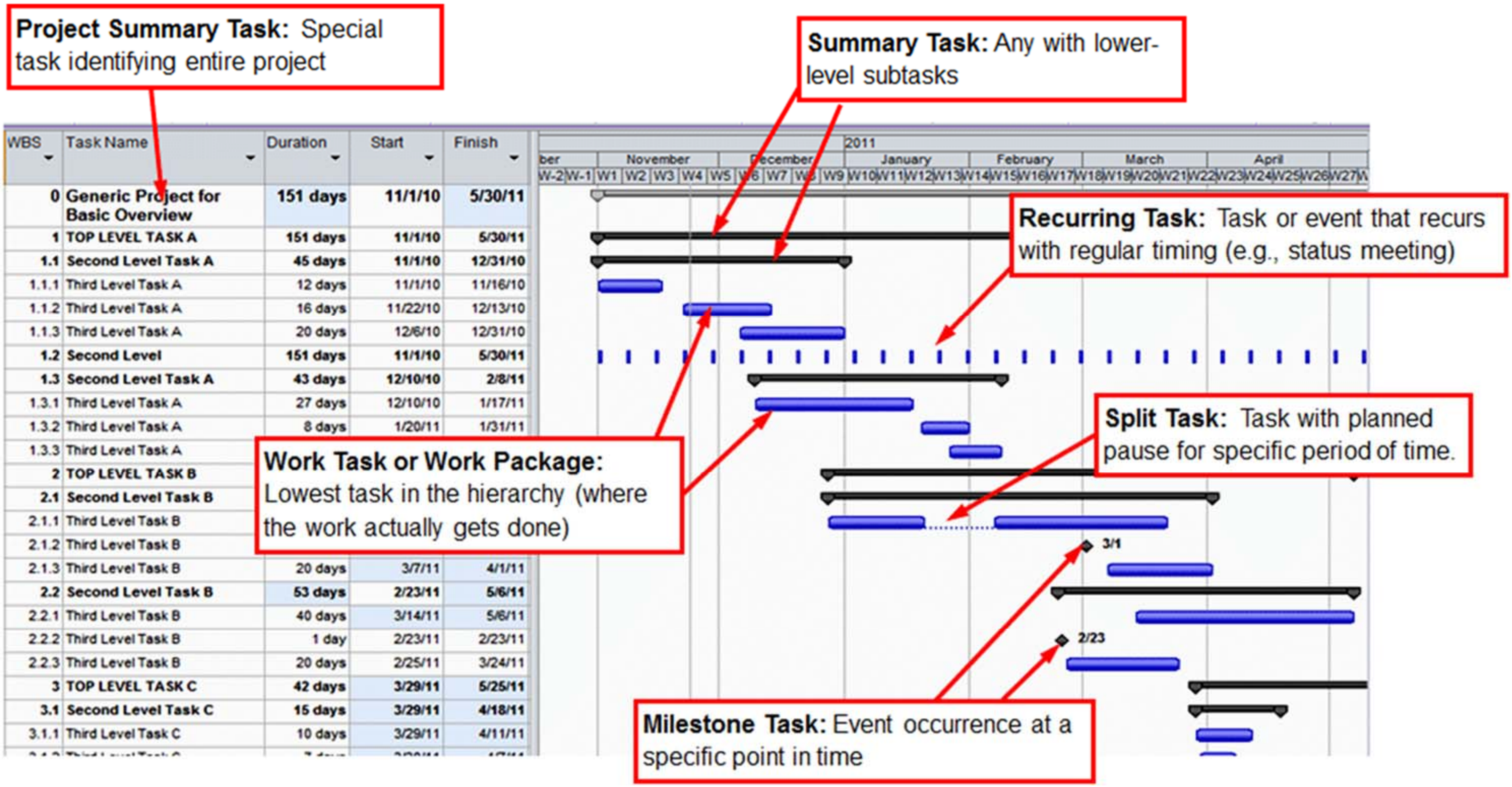
- The technique used for project scheduling varies depending upon the project's
  a. Size
  b. Complexity
  c. Duration
  d. Personnel
  e. Owner's requirements
- Methods of scheduling
  1. Gantt chart
  2. Network Analysis Systems (NAS)
     a. Critical Path Method (CPM) – deterministic approach to scheduling
     b. Program Evaluation and Review Technique (PERT) – probabilistic approach to scheduling

Gantt Chart

- A programme chart, a bar chart, a graphical time-scale of the schedule, developed by Henry L. Gantt.
- Characteristics:
    - Simple, easy to use/interpret, does not require extensive interrelationships of activities
    - Difficult and require significant time to update, does not show interdependences of activities, does not integrate costs or resources with the schedule
    - An effective technique for overall project scheduling, but has limited application for detailed contraction work.
- The activities involved in a project and the time taken for each activity is displayed in this chart.



Gantt Chart

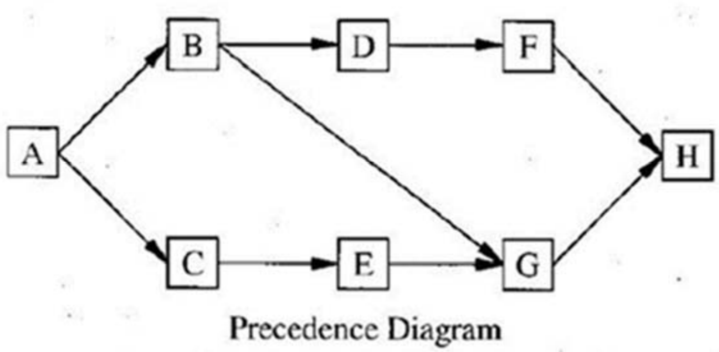

Project Summary Task: Special task identifying entire project
Summary Task: Any with lower-level subtasks
Recurring Task: Task or event that recurs with regular timing (e.g., status meeting)
Split Task: Task with planned pause for specific period of time.
Work Task or Work Package: Lowest task in the hierarchy (where the work actually gets done)
Milestone Task: Event occurrence at a specific point in time
WBS
Task Name
Duration
Start
Finish
2011
November
December
January
February
March
April
0 Generic Project for Basic Overview 151 days 11/1/10 5/30/11
1 TOP LEVEL TASK A 151 days 11/1/10 5/30/11
1.1 Second Level Task A 45 days 11/1/10 12/31/10
1.1.1 Third Level Task A 12 days 11/1/10 11/16/10
1.1.2 Third Level Task A 16 days 11/22/10 12/13/10
1.1.3 Third Level Task A 20 days 12/6/10 12/31/10
1.2 Second Level 151 days 11/1/10 5/30/11
1.3 Second Level Task A 43 days 12/10/10 2/8/11
1.3.1 Third Level Task A 27 days 12/10/10 1/17/11
1.3.2 Third Level Task A 8 days 1/20/11 1/31/11
1.3.3 Third Level Task A
2 TOP LEVEL TASK B
2.1 Second Level Task B
2.1.1 Third Level Task B
2.1.2 Third Level Task B
2.1.3 Third Level Task B 20 days 3/7/11 4/1/11
2.2 Second Level Task B 53 days 2/23/11 5/6/11
2.2.1 Third Level Task B 40 days 3/14/11 5/6/11
2.2.2 Third Level Task B 1 day 2/23/11 2/23/11
2.2.3 Third Level Task B 20 days 2/25/11 3/24/11
3 TOP LEVEL TASK C 42 days 3/29/11 5/25/11
3.1 Second Level Task C 15 days 3/29/11 4/18/11
3.1.1 Third Level Task C 10 days 3/29/11 4/11/11
3/1
2/23

Network Analysis Method (NAS)

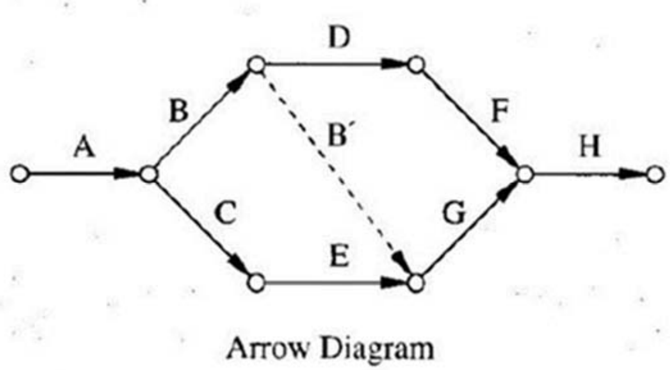
- Provides a comprehensive method for project planning, scheduling, and controlling.
- A general title for the technique of defining and coordinating work by a graphical diagram that shows work activities and the interdependences of activities.
- Steps of CPM/PERT:
  1. Define the project and all of its significant activities or tasks
  2. Develop relationships among the activities
     (Decide which activities must precede and which must follow others)
  3. Draw the network connecting all of the activities
  4. Assign time and cost estimates to each activity
  5. Compute the longest time path through the network – the critical path
  6. Use the network to help plan, schedule, monitor, and control the project

Critical Path Method (CPM)

- Developed in 1956, now commonly used in engineering and construction industry.
- The most commonly used NAS for project management.
- Characteristics:
  - Simple concept, computations only require basic arithmetic, a large number of computer programs are available to automate the work required of CPM scheduling.
  - The most difficult task is identifying and interfacing the numerous activities that are required to complete a project, i.e. development of the CPM network diagram.
  - If a well-defined WBS is developed first, the task of developing a CPM diagram is greatly simplified.



(Activity-on-node/AON network)



(Activity-on-arrow/AOA network)

Activity — The performance of a task required to complete the project, such as, design of foundations, review of design, procure steel contracts, or form concrete columns. An activity requires time, cost, or both time and cost.

Network — A diagram to represent the relationship of activities to complete the project. The network may be drawn as either an "arrow diagram" or a "precedence diagram."

Duration (D) — The estimated time required to perform an activity. The time should include all resources that are assigned to the activity.

Early Start (ES) — The earliest time an activity can be started.

Early Finish (EF) — The earliest time an activity can be finished and is equal to the early start plus the duration.

$$EF = ES + D$$

Late Finish (LF) — The latest time an activity can be finished.

Late Start((LS) — The latest time an activity can be started without delaying the completion date of the project.

$$LS = LF - D$$

Total Float (TF) — The amount of time an activity may be delayed without delaying the completion date of the project.

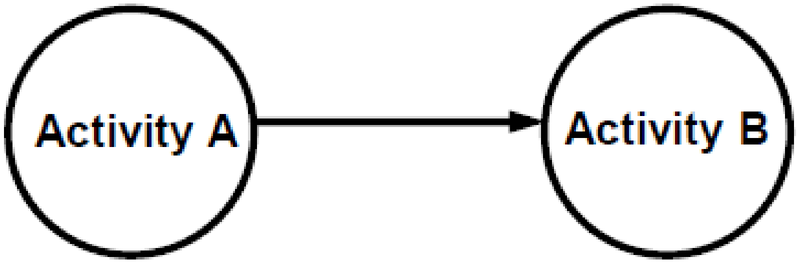
$$TF = LF - EF = LS - ES$$

Free Float (FF) — The amount of time an activity may be delayed without delaying the early start time of the immediately following activity.
$FF_i = ES_j - EF_i$, where the subscript i represents the preceding activity and the subscript j represents the following activity.

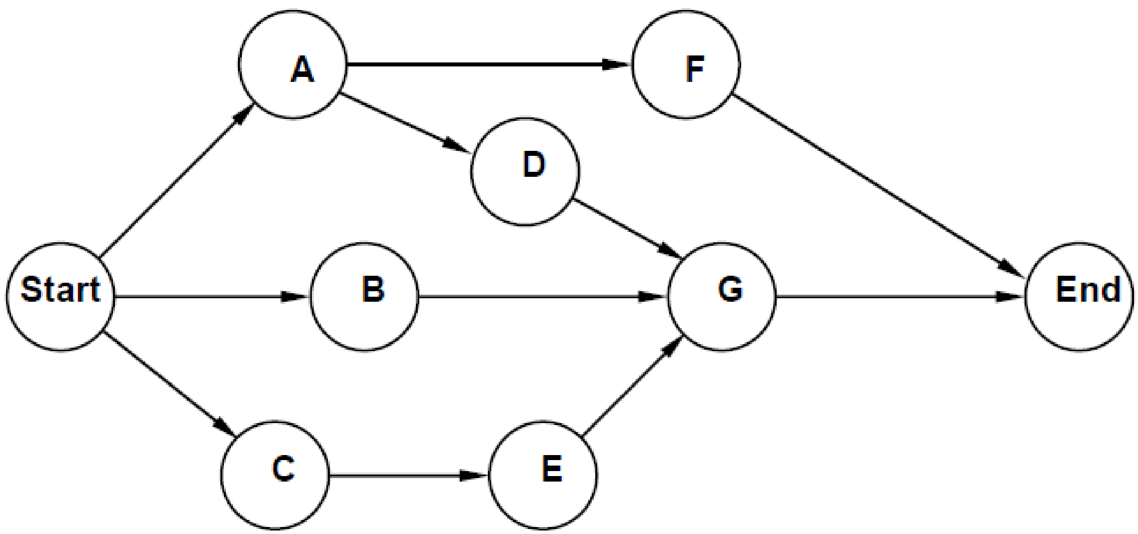
Critical Path — A series of interconnected activities through the network diagram, with each activity having zero, free and total float time. The critical path determines the minimum time to complete the project.

Dummy Activity — An activity (represented by a dotted line on the arrow network diagram) that indicates that any activity following the dummy cannot be started until the activity or activities preceding the dummy are completed. The dummy does not require any time.

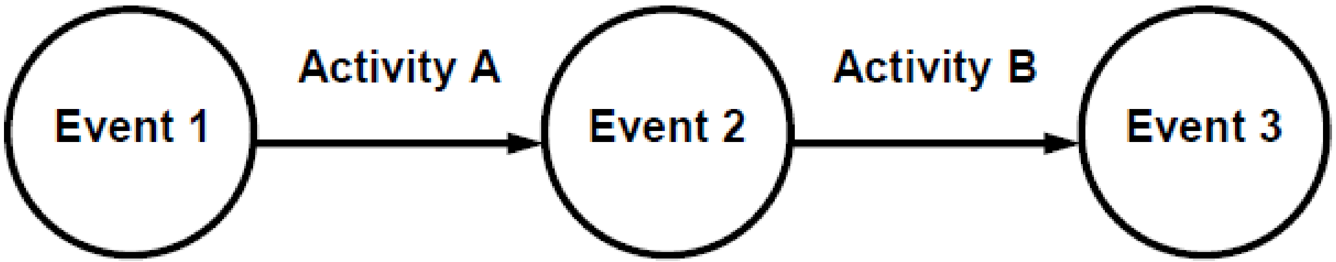
Method 1: Activity-On-Node (AON)



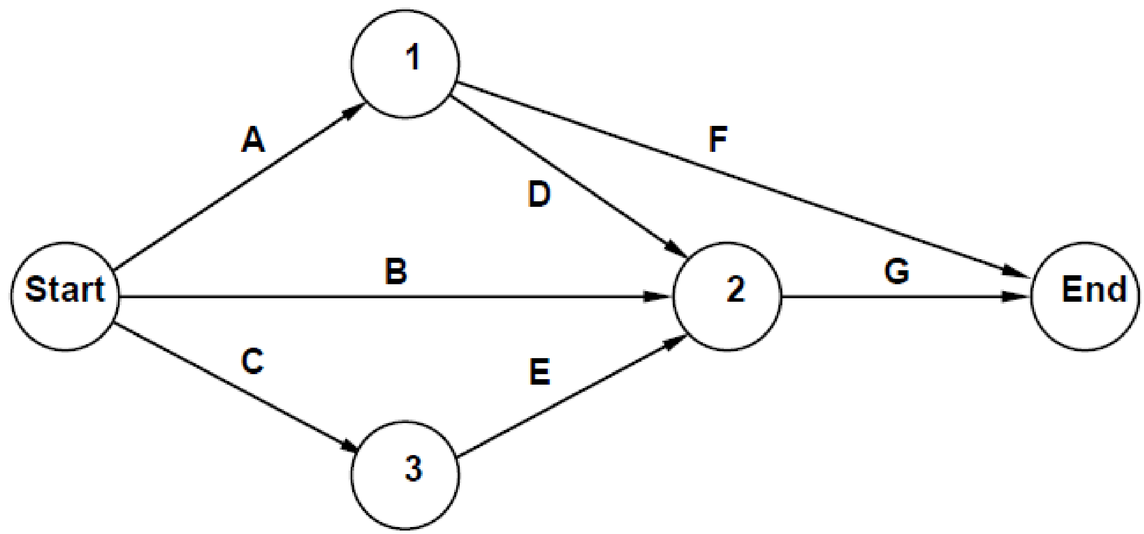
Activity	Predecessor
A	-
B	-
C	-
D	A
E	C
F	A
G	B,D,E



Method 2: Activity-On-Arrow (AOA)



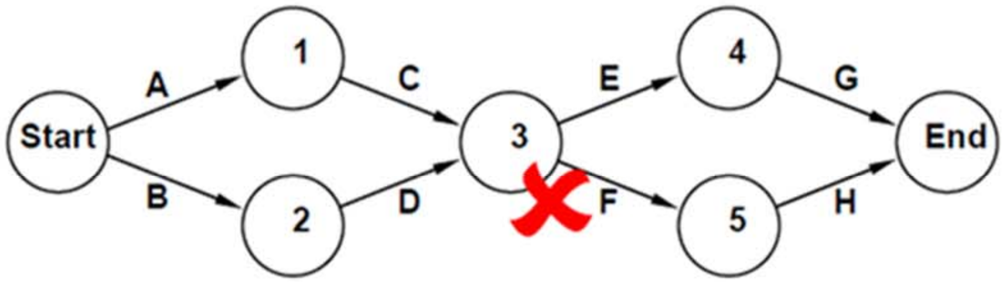
Activity	Predecessor
A	-
B	-
C	-
D	A
E	C
F	A
G	B,D,E

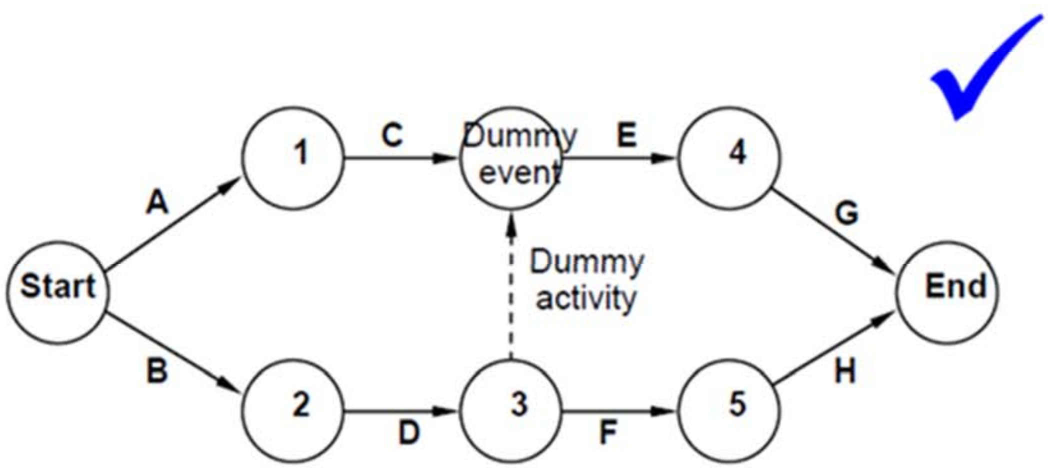


Method 2: Activity-On-Arrow (AOA)

- Use of dummy activity – it consumes neither time nor resource!

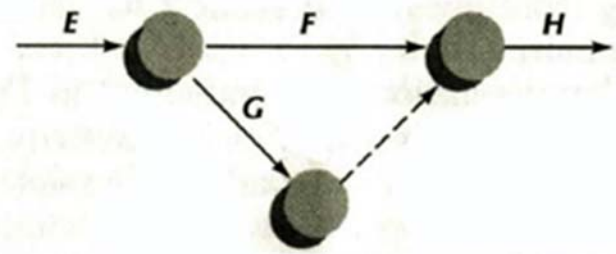
Activity	Predecessor
A	-
B	-
C	A
D	B
E	C,D
F	D
G	E
H	F



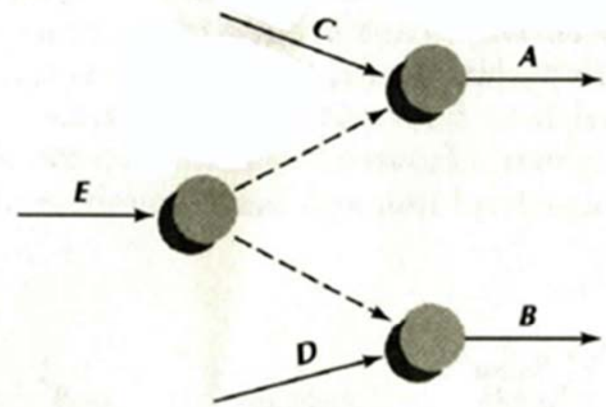


Dummy Activity

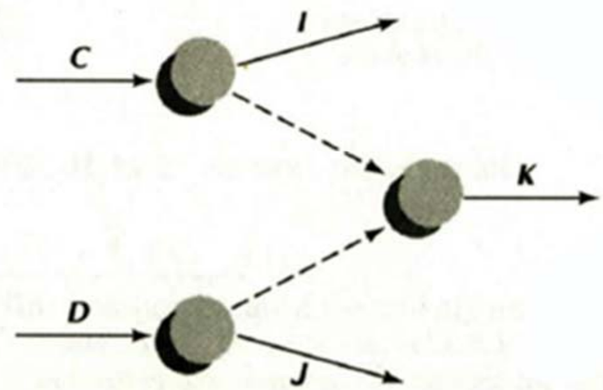
- Only in Arrow Diagram



a. Activities *F* and *G* have the same predecessor (*E*) and the successor (*H*).



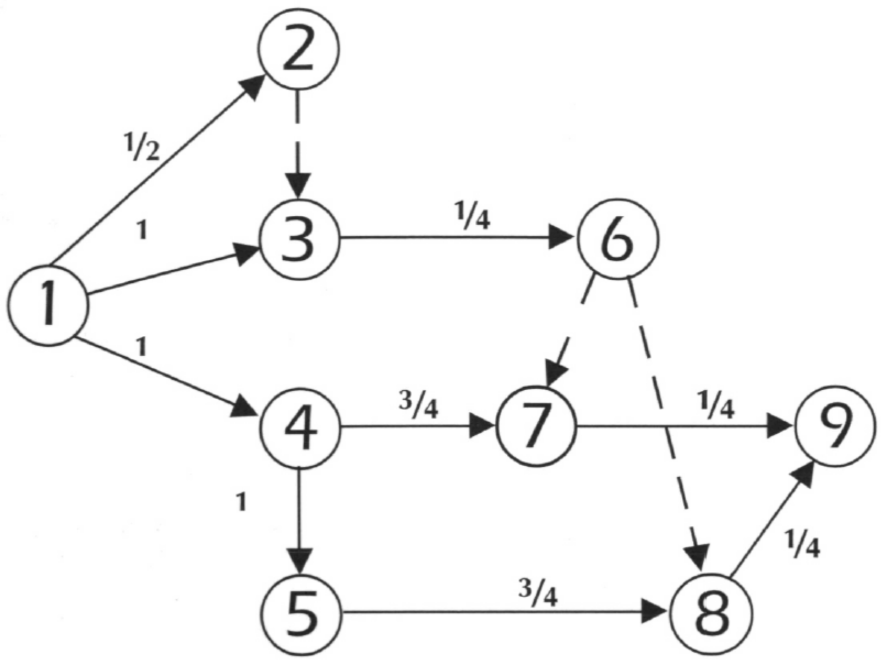
b. Activities *A* and *B* have a common predecessor (*E*), but they have different predecessors (*C* and *D*).



c. Activities *C* and *D* have a common successor (*K*), but different successors (*I* and *J*).

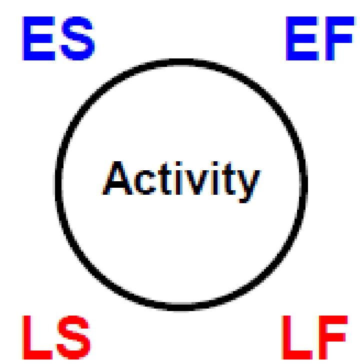
Example

Activity	Description	t_e (in days)
1-2	Obtain material	1/2
1-3	Obtain mixer	1
1-4	Dig hole 1	1
2-3	(Dummy)	0
4-5	Dig hole 2	1
3-6	Mix concrete	1/4
4-7	Set up pylon 1	3/4
5-8	Set up pylon 2	3/4
6-7	(Dummy)	0
6-8	(Dummy)	0
7-9	Concreting of pylon 1 by pouring concrete into hole 1	1/4
8-9	Concreting of pylon 2 by pouring concrete into hole 2	1/4



Node

- Determine the activity information
  - Earliest Start time (ES) & Earliest Finish time (EF)
  - Latest Start time (LS) & Latest Finish time (LF)
  - For an activity, the times can be presented as shown:



  - Total Float is the allowable delay of an activity.

- Identify the critical path
  - Longest path in network
  - Shortest time project can be completed
  - Any delay on critical path activities delays project
  - Critical path activities have zero slack

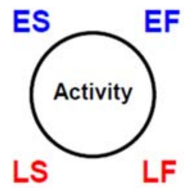
Computation

a. Forward Pass Computation
   - Involves the computation of the Earliest Start time (ES) of each activity.
   - When two activities merge, the later of the Earliest Finish time (EF) becomes the ES of the successor activity.
   - The Earliest Finish time (EF) of the last node is the overall duration of the project.

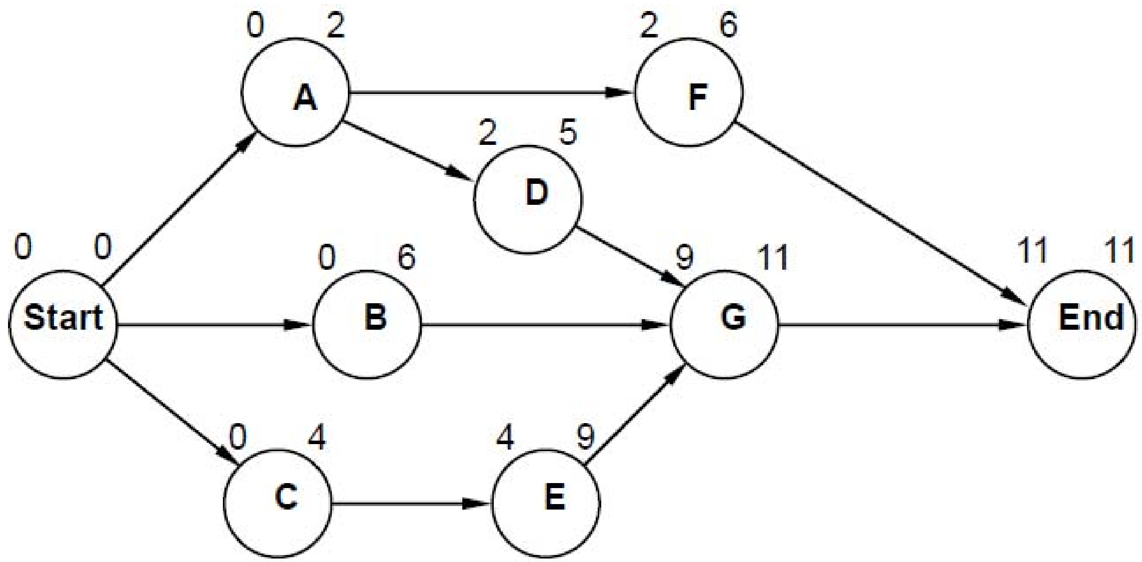
b. Backward Pass Computation
   - Provides the Latest Finish time (LF) by which an activity must be completed if there is to be no delay in the project.

Forward Pass Procedure

- Determine ES & EF times for each activity,
  1. $EF_i = ES_i + D_i$
  2. ES_i = Maximum EF_j of predecessor(s)



Activity	Predecessor	D, Duration (days)
A	-	2
B	-	6
C	-	4
D	A	3
E	C	5
F	A	4
G	B,D,E	2



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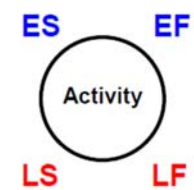

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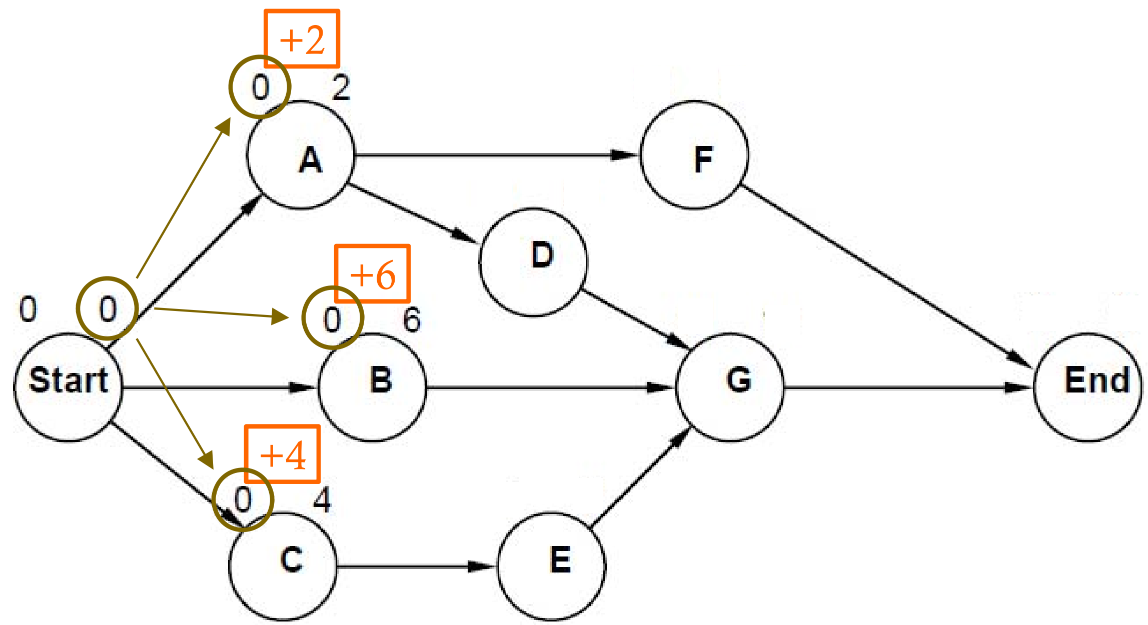

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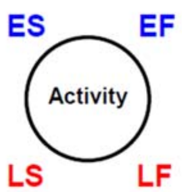

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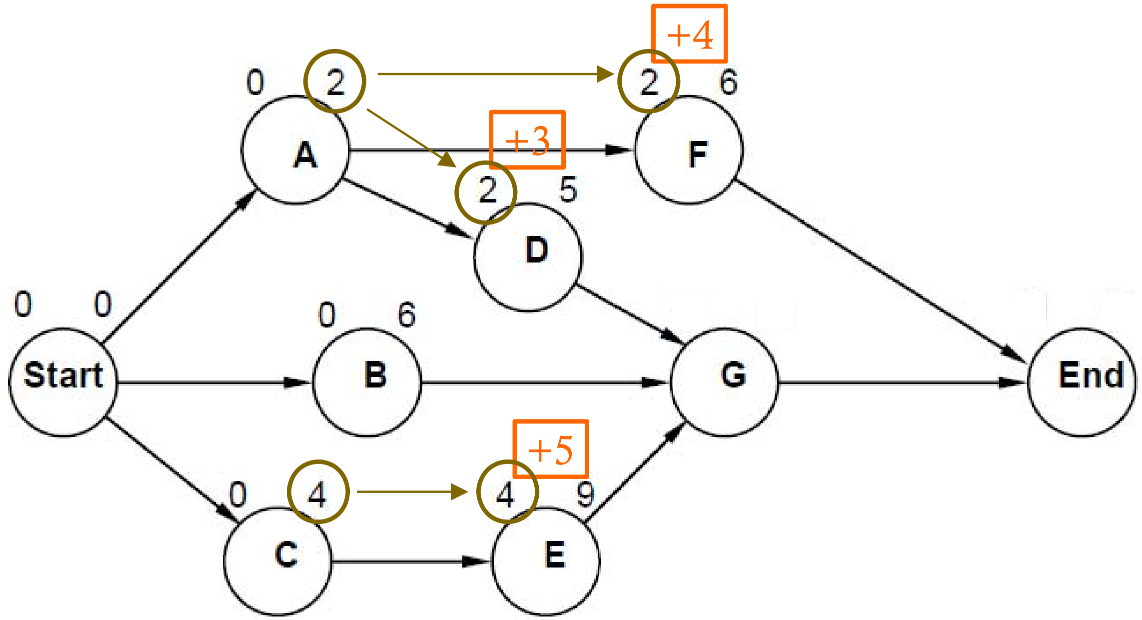

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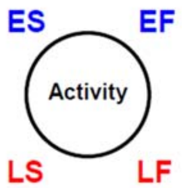

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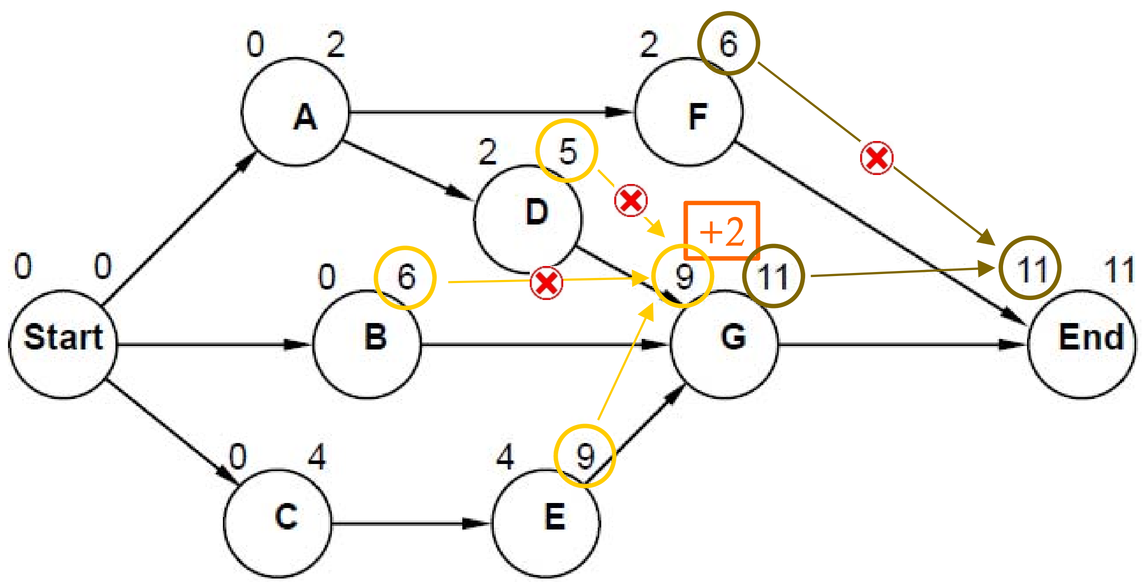
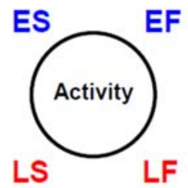


Backward Pass Procedure

- Determine LS & LF times for each activity,
  1. $LS_i = LF_i - D_i$
  2. LF_i = Minimum LS_j of successor(s)



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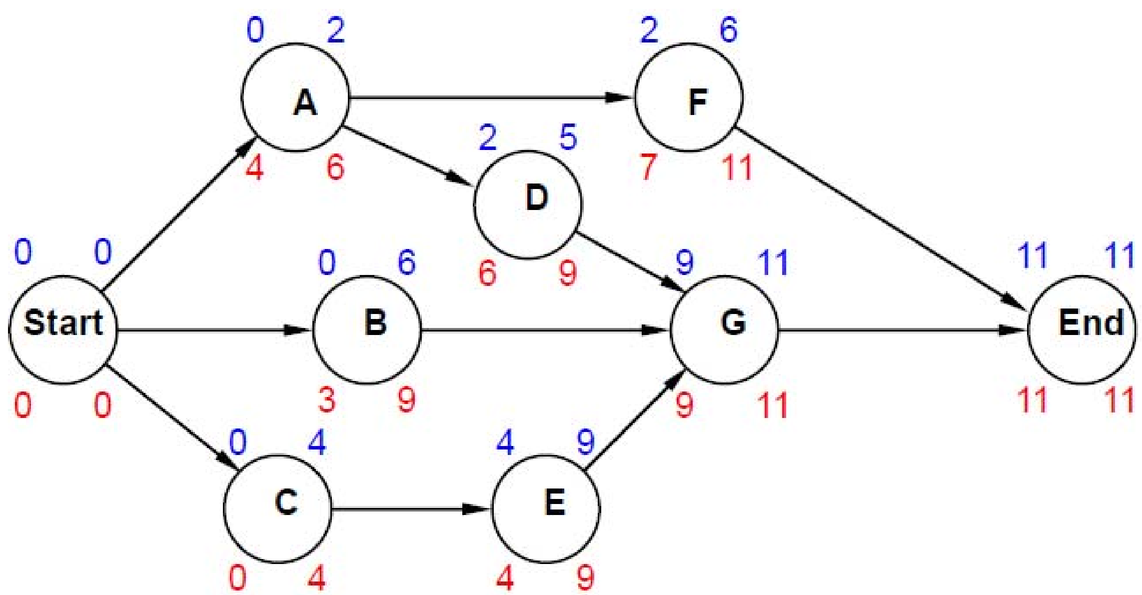

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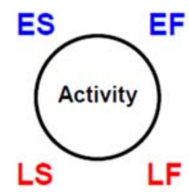

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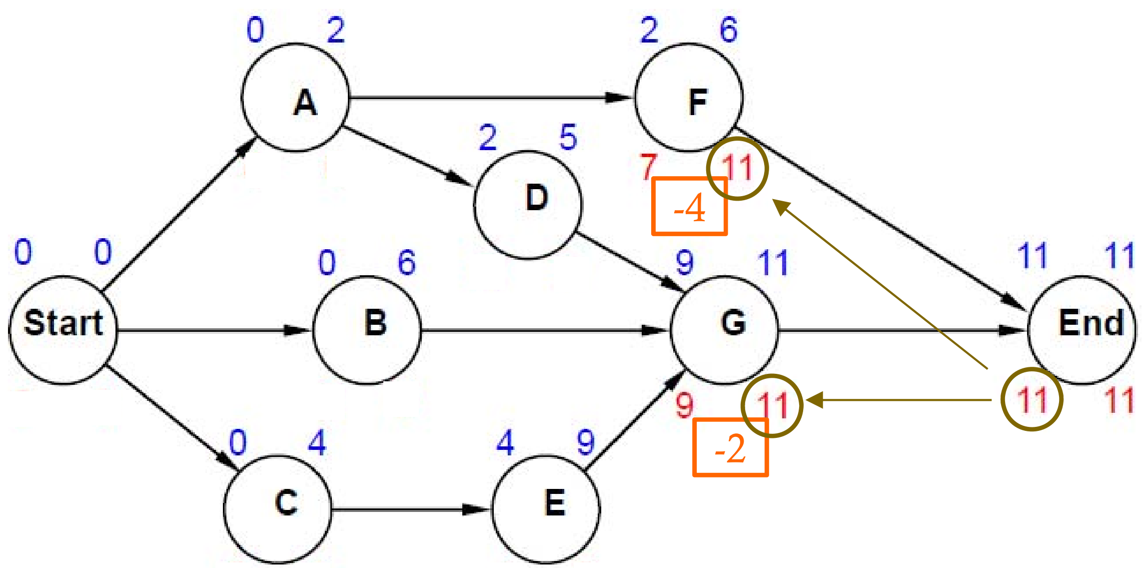
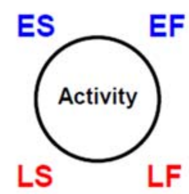
E	C	5
F	A	4
G	B,D,E	2

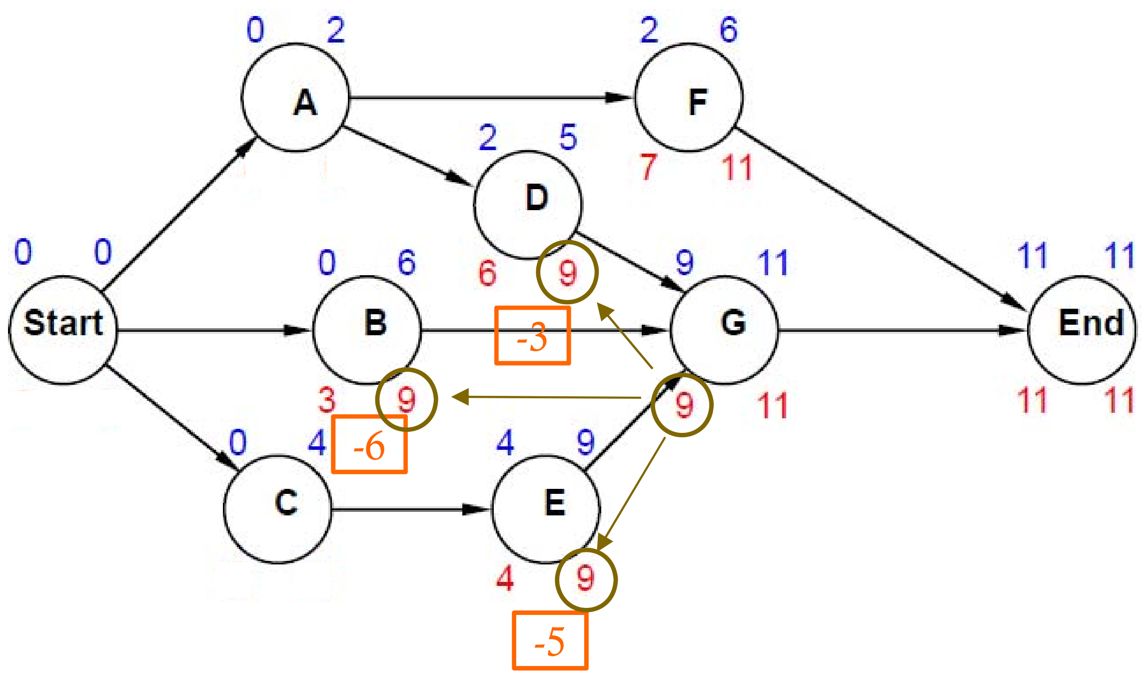


Backward Pass Procedure

- Determine LS & LF times for each activity,
  1. $LS_i = LF_i - D_i$
  2. LF_i = Minimum LS_j of successor(s)



Activity	Predecessor	D, Duration (days)
A	-	2
B	-	6
C	-	4
D	A	3
E	C	5
F	A	4
G	B,D,E	2



Backward Pass Procedure

- Determine LS & LF times for each activity,
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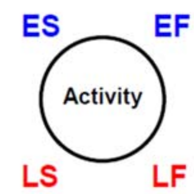
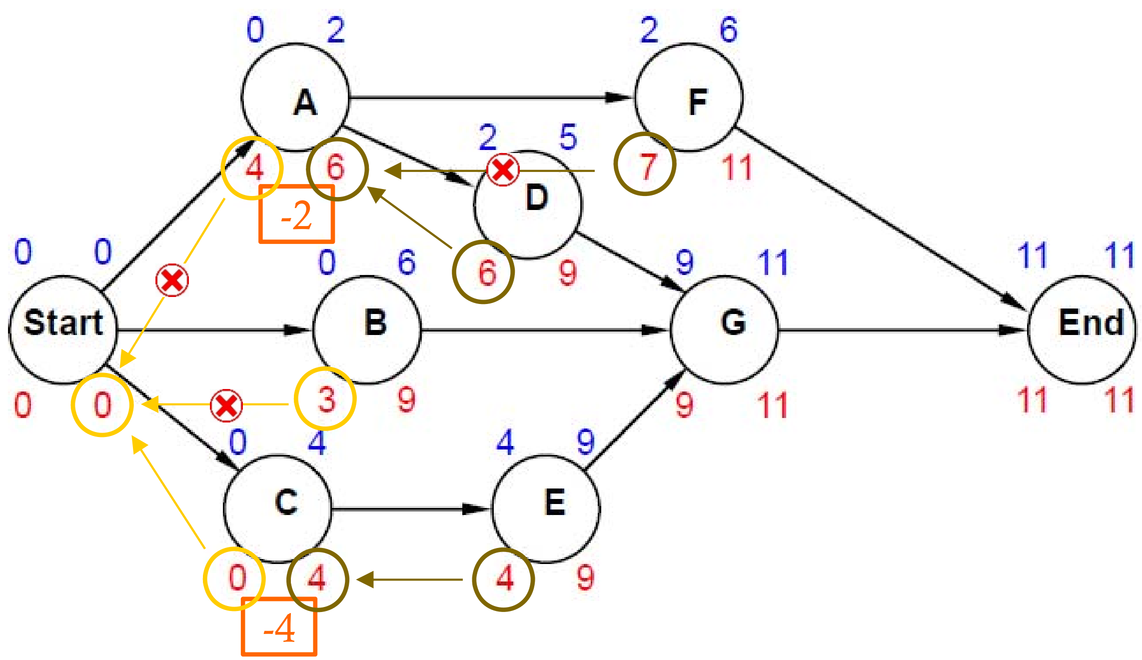
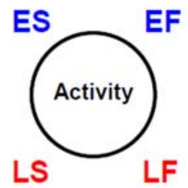


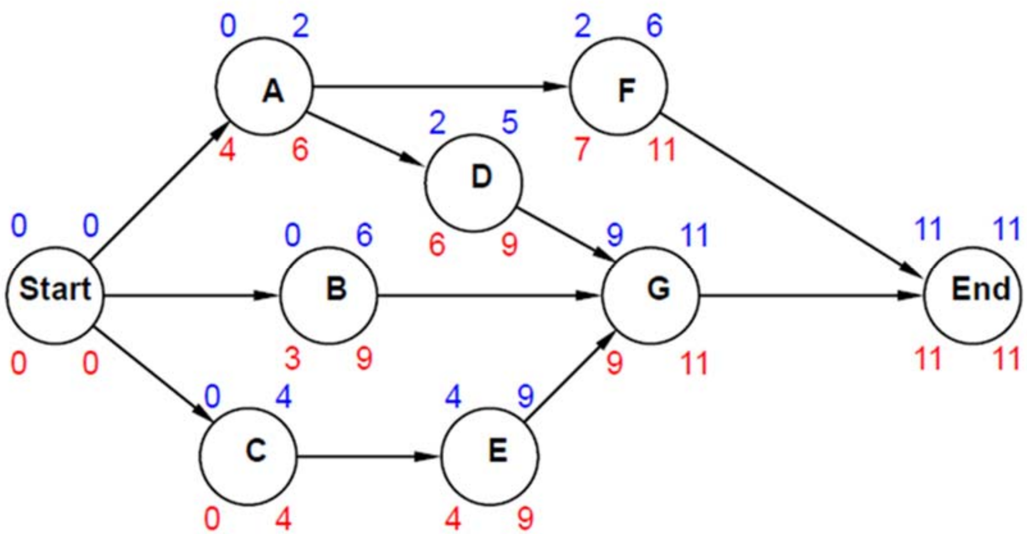
Activity	Predecessor	D, Duration (days)
A	-	2
B	-	6
C	-	4
D	A	3
E	C	5
F	A	4
G	B,D,E	2



Critical Path Analysis

- Float = LS – ES or LF – EF



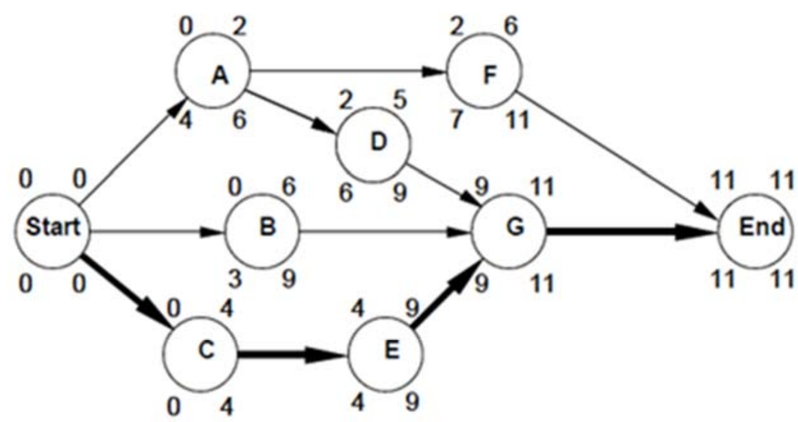


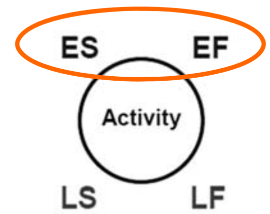
Activity	Float (days)
A	4 – 0 = 4
B	3 – 0 = 3
C	0 – 0 = 0
D	6 – 2 = 4
E	4 – 4 = 0
F	7 – 2 = 5
G	9 – 9 = 0

- Zero slack on activities C, E, & G (longest total time) → critical path
- Any delay on activities of critical path will delay project

Gantt Chart Method

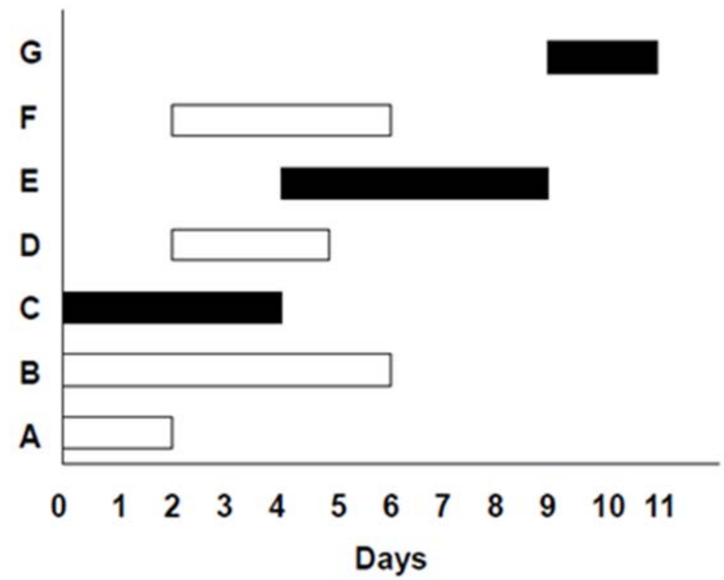
- Earliest Start time (ES)





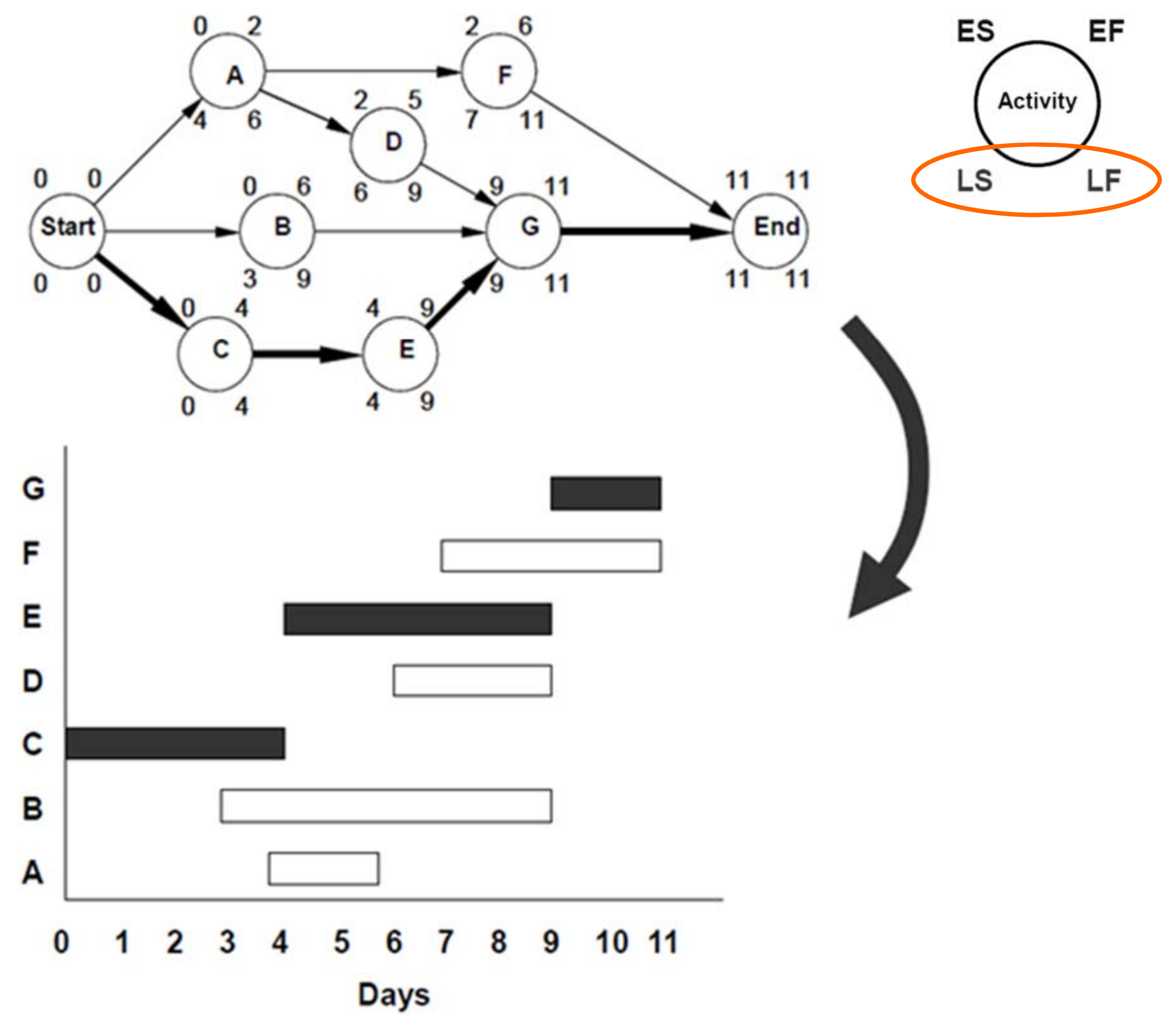
- Critical Path

Start → C → E → G → End



Gantt Chart Method

- Latest Start time (LS)

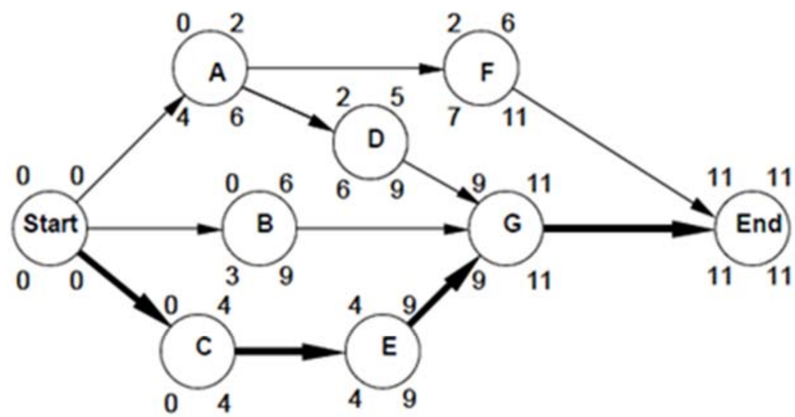


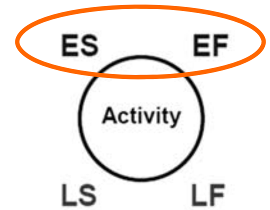
  - Critical Path

Start → C → E → G → End

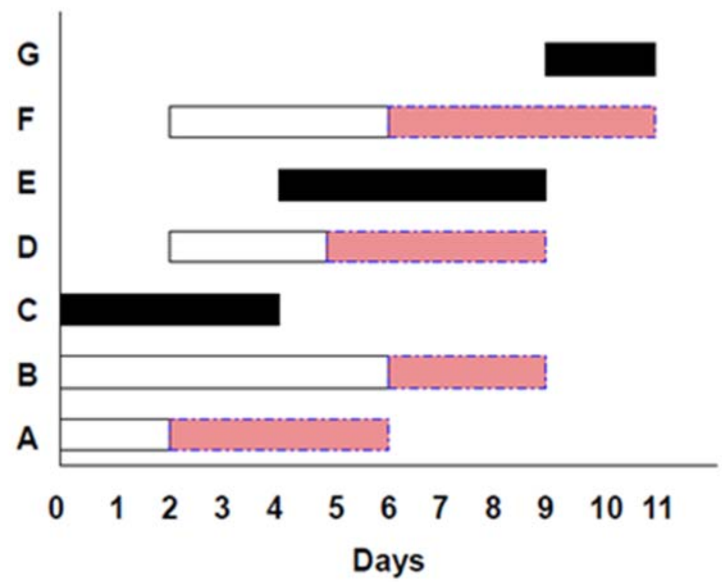
Gantt Chart Method

- Earliest Start time with Float



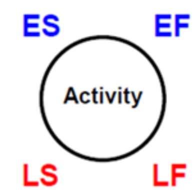


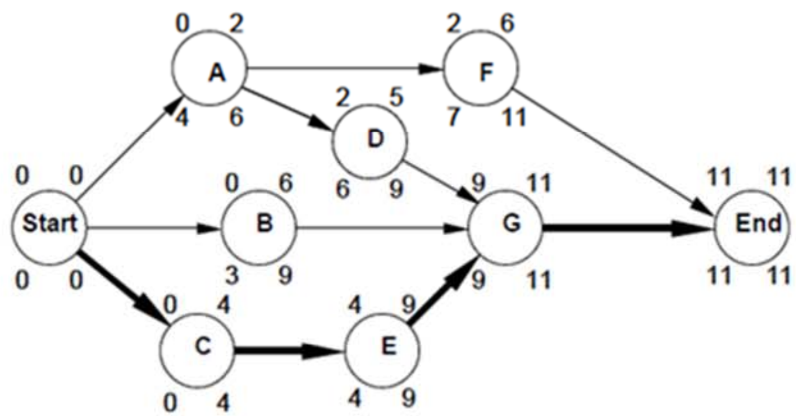
Activity	Float (days)
A	4 – 0 = 4
B	3 – 0 = 3
C	0 – 0 = 0
D	6 – 2 = 4
E	4 – 4 = 0
F	7 – 2 = 5
G	9 – 9 = 0



Cost Distribution

- The distribution of costs with respect to time



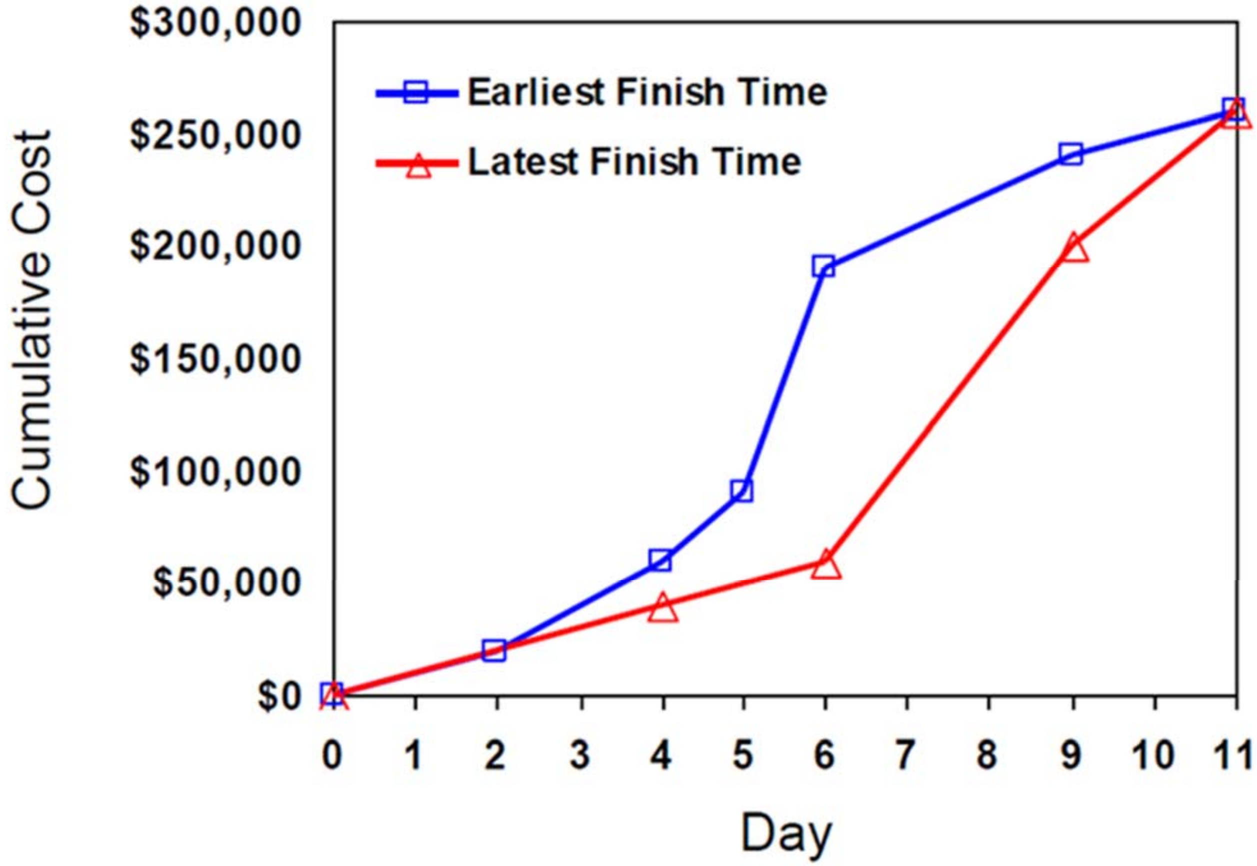


Earliest Finish Time	Activity	Given Cost	Cumulative Cost
2	A	$20,000	$20,000
4	C	$40,000	$60,000
5	D	$30,000	$90,000
6	B F	$60,000 $40,000	$190,000
9	E	$50,000	$240,000
11	G	$20,000	$260,000

Latest Finish Time	Activity	Given Cost	Cumulative Cost
4	C	$40,000	$40,000
6	A	$20,000	$60,000
9	B D E	$60,000 $30,000 $50,000	$200,000
11	F G	$40,000 $20,000	$260,000

Cost Distribution

- S-Curve



Cost Distribution

- Some of the S-curves are calculated based on the Start times (ES & LS) instead of the Finish times (EF & LF).
- Each activity may have its expenses distributed either evenly or in a certain pattern:
  - e.g. Activity A costs $20,000 for 2-day work

    i.e. each day costs = $20,000/2 days

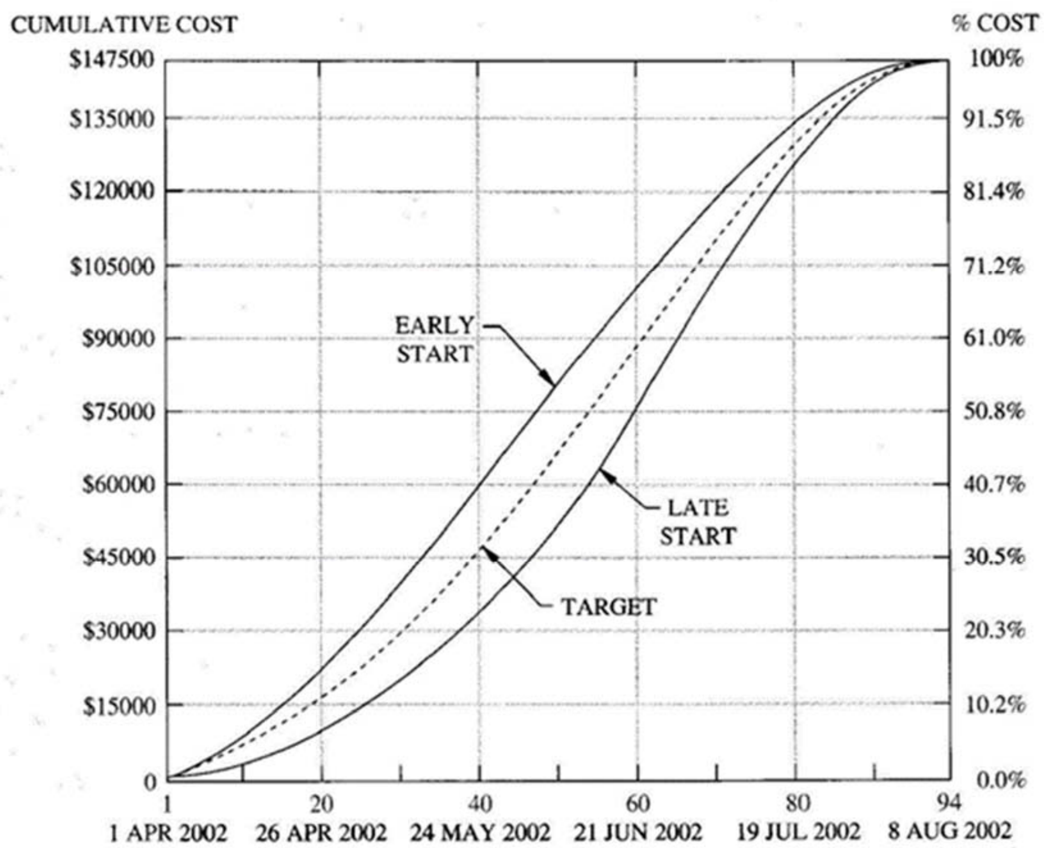
    average = $10,000/day

    Or Day 1 = $15,000 and Day 2 = $5,000
- The target schedule is the midpoint between Earliest Start (ES) and Latest Start (LS):
  - e.g. for Activity D, ES = Day 2, LS = Day 6

    Target schedule = Day 4

Cost Distribution

- Illustrative S-Curve for cumulative cost curve on Early Start and Late Start, and Target Schedule



PERT

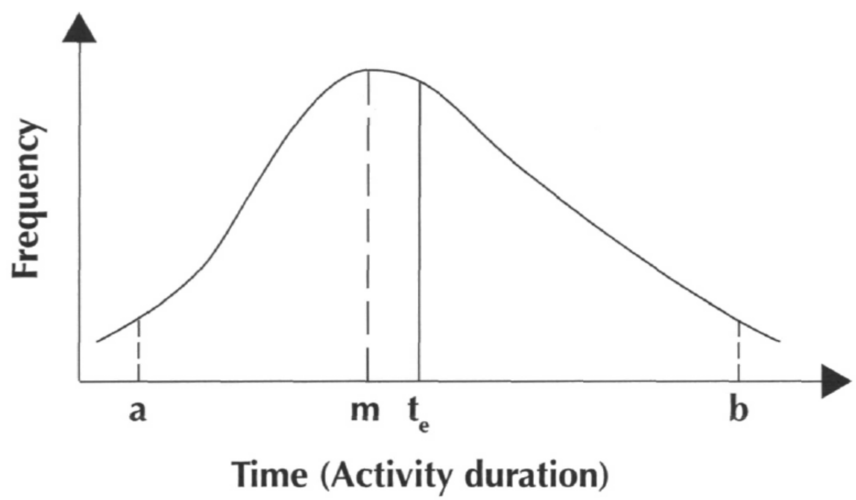
- Program Evaluation and Review Technique (PERT)
  - The application of the critical path method (CPM) to calculate project duration with uncertainty.
  - It uses three quantities in estimating the duration of a single activity:
    1. The optimistic time
    2. The pessimistic time
    3. The most likely time

- Similarity with CPM
  - Both make use of a network diagram and use critical path analysis to represent and analyze a project.

- Difference from CPM
  - CPM uses only a single time estimate for an activity.
  - PERT is usually applied to projects which are carried out under considerable uncertainty and is used to predict the probability of completion of a certain project within a certain period of time.

PERT

- Probability concept
  - The optimistic time (a) , i.e. the shortest duration which could be anticipated for an activity
  - The pessimistic time (b), i.e. the duration of the activity when everything takes a long time to complete
  - The most likely time (m)

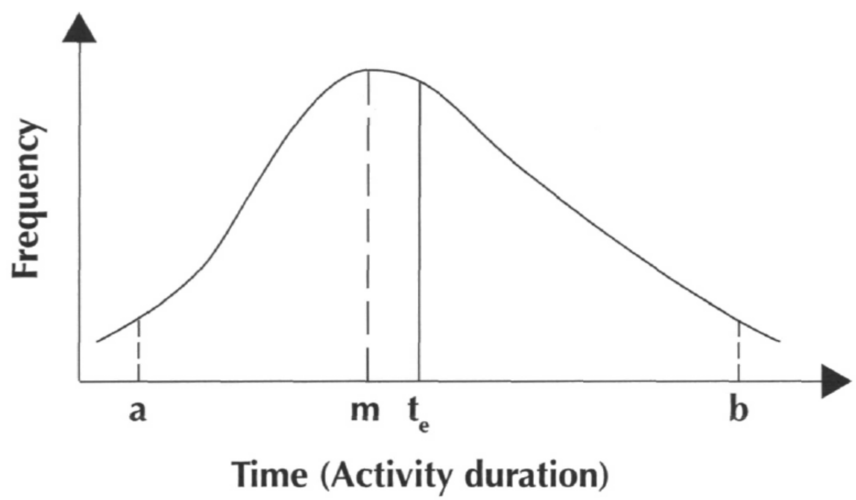


- It is empirical that when an activity is repeating many times, the activity durations recorded will follow a β-distribution.
- The optimistic and pessimistic times could only occur once when under hundred times.
- Hence, the two vertical lines (i.e. a and b) divide the area under the β-curve into the ratio of 1:99.

PERT

- Probability concept
  - The activity duration time (t_e) of an activity is given by the expected time or mean time required to complete the activity:

$$t_e = \frac{a + 4m + b}{6}$$

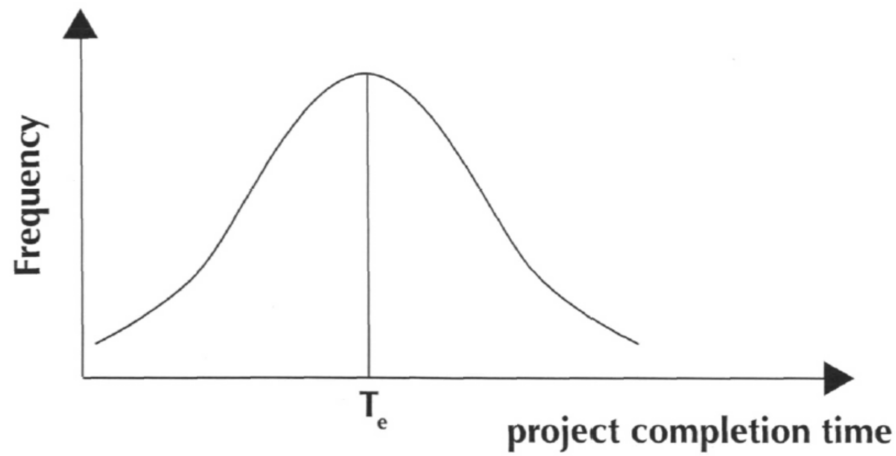


- The vertical line through t_e in the β-curve divides the area under the curve into two equal halves.
- The standard deviation (s) and the variance (v) of the β-distribution are given by:

$$s = \frac{b - a}{6} \qquad v = s^2 = \left(\frac{b - a}{6}\right)^2$$

PERT

- Although the duration of an individual activity follows a β-distribution, the completion time for a series of activities in a chain takes the form of a normal distribution (this is also empirical).



- Normal distribution for the project completion time, where T_e is the expected project completion time.

PERT Analysis

- Example (based on the same example for CPM)

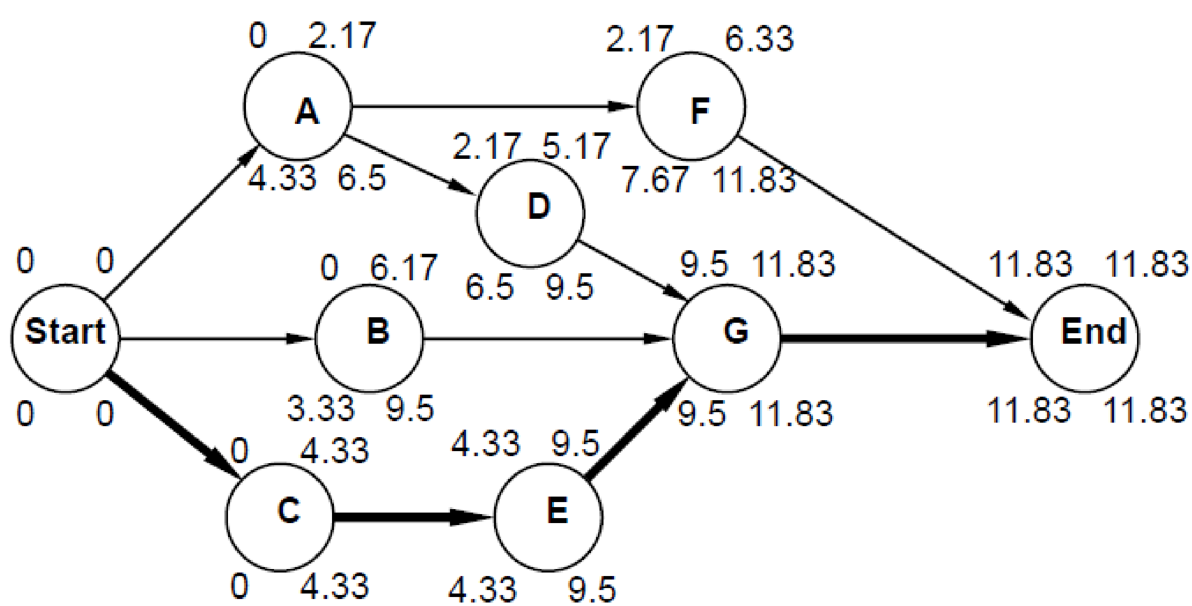
Activity	Predecessor	m (days)	a (days)	b (days)	t_e (days)	s^2 (days)
A	-	2	1	4	2.17	0.250
B	-	6	5	8	6.17	0.250
C	-	4	2	8	4.33	1.000
D	A	3	1	5	3.00	0.444
E	C	5	4	7	5.17	0.250
F	A	4	3	6	4.17	0.250
G	B,D,E	2	1	5	2.33	0.444

Given

Calculated

PERT Network

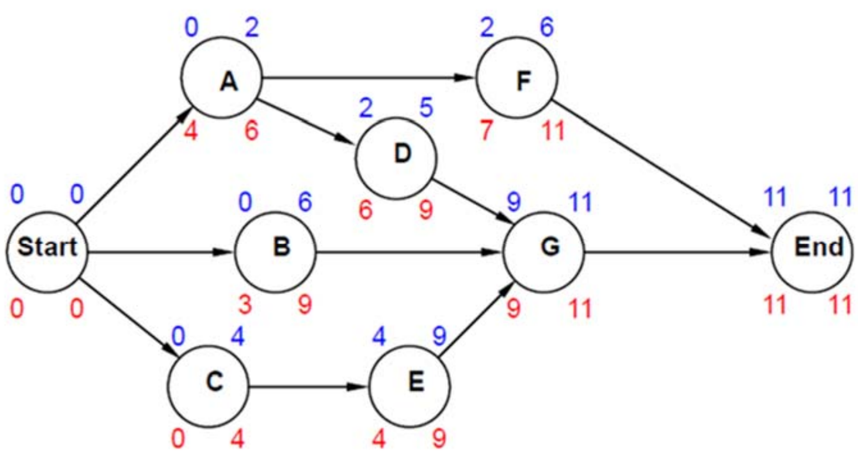
- A PERT network is constructed based on t_e (instead of using m).
- Forward pass and backward pass procedures similar to those used in the CPM are performed.
- The total duration is found to be 11.83 days.



Comparison

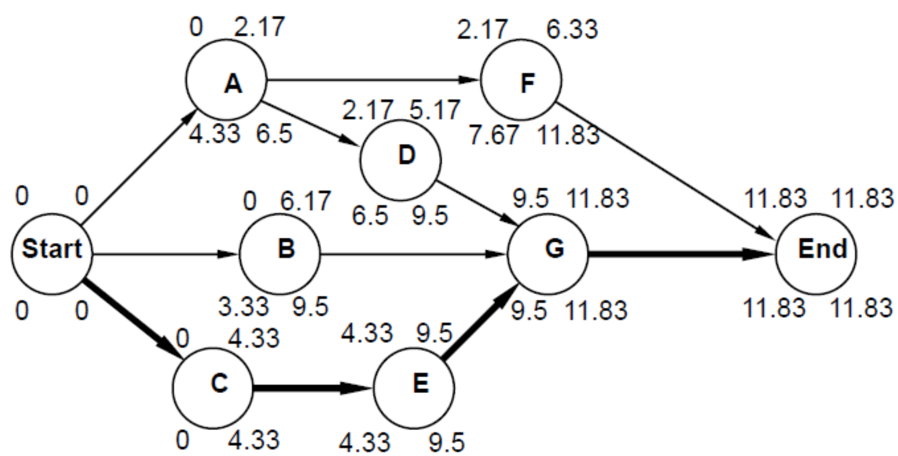
- CPM

Activity	Predecessor	D, Duration (days)
A	-	2
B	-	6
C	-	4
D	A	3
E	C	5
F	A	4
G	B,D,E	2



- PERT

Activity	Predecessor	m (days)	a (days)	b (days)	t_e (days)	s^2 (days)
A	-	2	1	4	2.17	0.250
B	-	6	5	8	6.17	0.250
C	-	4	2	8	4.33	1.000
D	A	3	1	5	3.00	0.444
E	C	5	4	7	5.17	0.250
F	A	4	3	6	4.17	0.250
G	B,D,E	2	1	5	2.33	0.444



Uncertainty Analysis

- When the times of individual activity are uncertain, the total project completion time becomes uncertain.
- It is assumed that the variance in the total project completion time (V) can be computed by adding the variances along the critical path,

$$V = S^2 = \sum s^2 \text{ for all activities on the critical path}$$

- In the example,

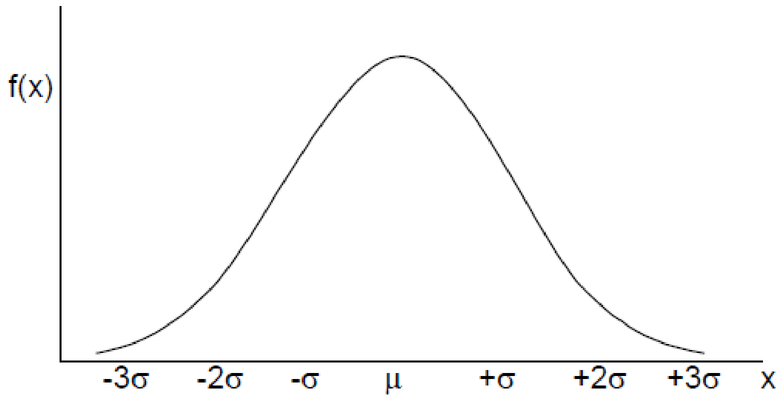
$$V = S^2 = s_C^2 + s_E^2 + s_G^2$$
$$= 1.000 + 0.250 + 0.444$$
$$= 1.694$$

$$S = \sqrt{V} = \sqrt{1.694} = 1.302$$

Activity	Predecessor	s^2 (days)
A	-	0.250
B	-	0.250
C	-	1.000
D	A	0.444
E	C	0.250
F	A	0.250
G	B,D,E	0.444

Uncertainty Analysis

- It is also assumed that the distribution of project completion time is normal based on central limit theorem.



<u>Normal distribution</u>

μ = mean
σ = standard deviation

$$\text{Probability density function} = f(x) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left[-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right]$$

Boundaries	Area under normal curve
$\mu \pm \sigma$	0.683
$\mu \pm 2\sigma$	0.954
$\mu \pm 3\sigma$	0.997

Uncertainty Analysis

- Knowing the mean and standard deviation of a normal distribution, the probability of completing the project by a particular target time can be computed.

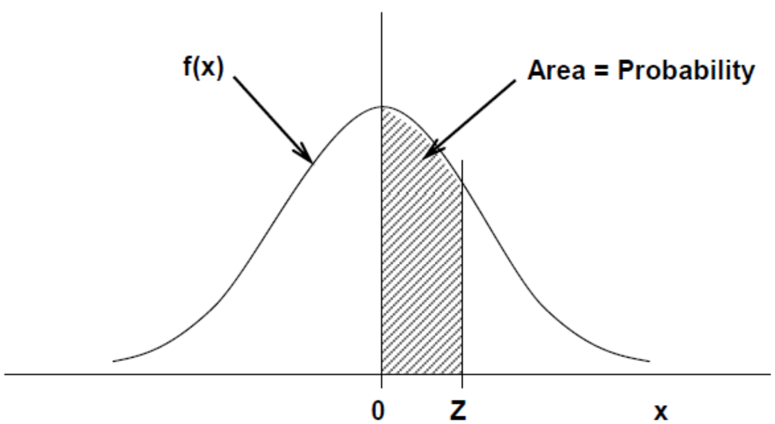
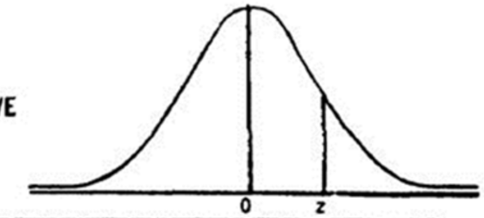


TABLE FOR AREAS UNDER THE STANDARD NORMAL CURVE

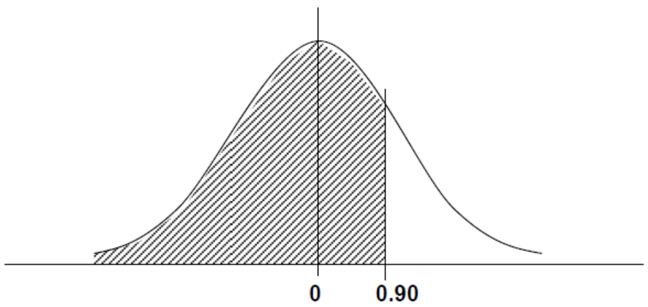


z	0	1	2	3	4	5	6	7	8	9
0.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0754
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
0.6	.2258	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2518	.2549
0.7	.2580	.2612	.2642	.2673	.2704	.2734	.2764	.2794	.2823	.2852
0.8	.2881	.2910	.2939	.2967	.2996	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3907	.3925	.3944	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	.4192	.4207	.4222	.4236	.4251	.4265	.4279	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	.4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767
2.0	.4772	.4778	.4783	.4788	.4793	.4798	.4803	.4808	.4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	.4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	.4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	.4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.4987	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990
3.1	.4990	.4991	.4991	.4991	.4992	.4992	.4992	.4992	.4993	.4993
3.2	.4993	.4993	.4994	.4994	.4994	.4994	.4994	.4995	.4995	.4995
3.3	.4995	.4995	.4995	.4996	.4996	.4996	.4996	.4996	.4996	.4997
3.4	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4998
3.5	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998
3.6	.4998	.4998	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
3.7	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
3.8	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
3.9	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000

Uncertainty Analysis

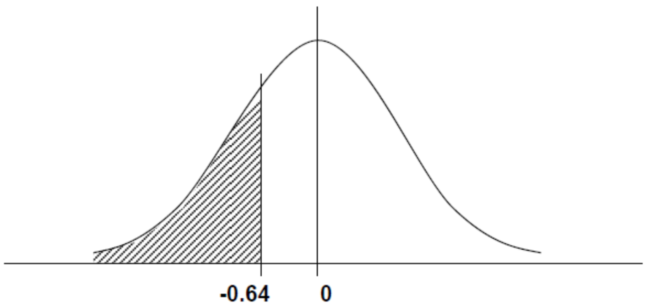
- Example 1
  - Probability of completing the project on or before 13 days,

$$P(T \leq 13) = 0.5 + P(Z \leq (13 - 11.83)/1.302)$$
$$= 0.5 + P(Z \leq 0.90)$$
$$= 0.5 + 0.3159$$
$$= 0.8159$$



- Example 2
  - Probability of completing the project on or before 11 days,

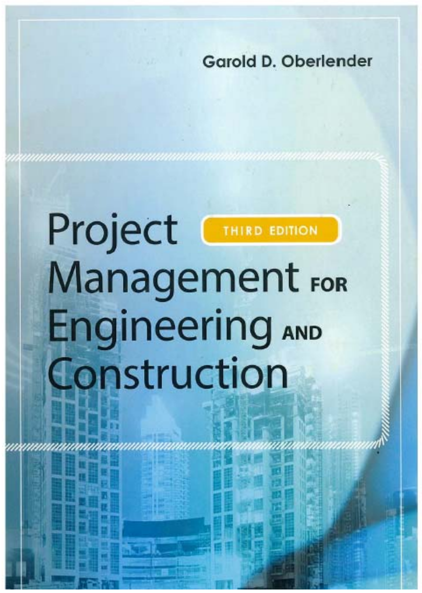
$$P(T \leq 11) = 0.5 + P(Z \leq (11 - 11.83)/1.302)$$
$$= 0.5 + P(Z \leq -0.64)$$
$$= 0.5 - P(Z \leq 0.64)$$
$$= 0.5 - 0.2389$$
$$= 0.2611$$

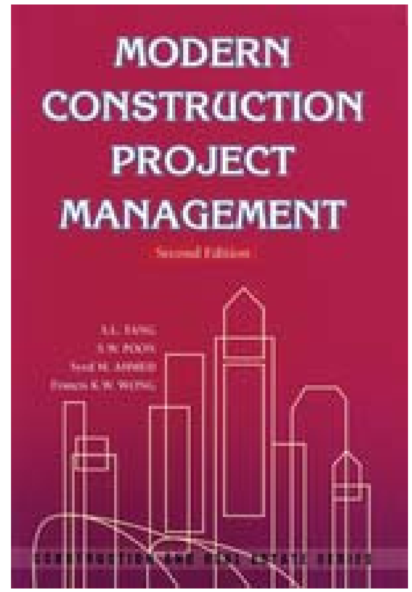


Checklist

- Can you
  1. Differentiate between project planning and project scheduling?
  2. Suggest the advantages of using a well-defined WBS?
  3. Describe the expected outcomes of planning and scheduling?
  4. Identify the responsibilities of the various parties in planning?
  5. Plot a Gantt Chart?
  6. Determine the critical path of a project?
  7. Determine the overall duration of a project?
  8. Determine the cost distribution of a project?
  9. Determine the probability that a project will complete on or before a certain numbers of days?

Reference





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