Chapter 7: Project Planning: Task Determination and Resource Assignment

The Why, What and How of Project Planning

Defining Project Boundaries and Scope
Breaking Your Project into Phases, Tasks, Milestones
Making Tasks Happen in the Right Order and at the Right Time
Assignment of Resources to Tasks
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Chapter 7

7

Box 7-1

"Jane, so nice of you to stop by. What's on your mind?" Ray asked.
"I've go this really big project and I don't know where to begin. We are developing a brand new 'green' product that can be used by private residences to generate electric power. It includes photovoltaics and windmill technology. The product generates electricity using energy from the wind and the sun. The concept for the product is very exciting and exactly what is needed to help families cope with the rising cost of electricity. But my colleagues and I don't have a clue as to what steps or tasks to take, much less in what order they should be pursued or how much they will cost. Got any ideas?"
"Are you familiar with Microsoft Project?" Ray asked.
"I know it's a project scheduling/costing tool, but that's about it."
"You can learn to use it in a few hours," Ray promised. "I can teach you. One thing it has is templates for doing just about every project type known to man. Those templates consist of steps, tasks sequenced in the proper order. The template I'd start with is the 'new product development template.' That will give you some ideas as to what steps are involved and in what order. You can add or subtract for the tasks it suggests, you can re-sequence the tasks, you can change the duration of the tasks, which you most certainly must do and you can assign resources to the tasks. I will be happy to show you."
"Thanks, Ray. I can always depend on you when I need an answer to a question. And, yes I will take you up on the offer to learn Microsoft Project. That's very generous of you," Jane responded. "But I have one more question. The software required to drive the solar/wind system must determine when to provide power in the home, when to send power into the electric grid, when to use just the solar power source or just the wind power or neither or both. These decisions are based on the amount of sunlight and wind in the ambient environment as determined by sensors as well as the current electricity demand in the residence. The testing of the software with the total system will also entail many steps. I'm probably going to need some very specific task sequences to get this done. Will Microsoft Project provide those?"
"Not likely, although they do have a software development template that will suggest tasks that you could integrate into the new product development template that I suggested earlier. Beyond that, you might need to seek the advice of a software development professional," was Ray's response.

PROJECT PLANNING

Where does planning start?

Planning requires first a formal definition of the project objective as determined in the previous stage. The objective is defined in terms of the specifications or requirements for the final software product. Both customer and contractor must agree on the requirements. The objective should be clear, attainable, specific, and measurable. These were among the concerns of the first stage in the project management lifecycle. As discussed in generality in the previous chapters, definition of the objective requires a thorough consideration of scope. Examples of objective statements might be the following: to transition from physical document management to Internet-based document management; or to convert all financial accounting applications to an ERP-based distributed architecture. These objective statements conform to the standards discussed for objective statements in Chapter Two.

The concept of the project can be derived from a Statement Of Work (SOW) or a Project Overview Statement (POS). These one-page project initiators can be created by anyone in the organization who sees a need. They are graded and considered by a project review committee. The format for the SOW or the POS is to include a brief objective statement, an explanation for why the need exists and what the benefits of the completed project will be.

What is planning?

Planning begins with a determination of the tasks needed to accomplish the objective. Once the tasks are known, planning involves the systematic arrangement of tasks to accomplish an objective. To determine the task detail, the planner (usually, the PM or the PL) starts with the large-grained methodologies discussed in Chapter 4 and further fleshes these down into work packages using **a work breakdown structure** or WBS, like that in Figure 7.1 below. The steps in the methodologies discussed in Chapter 4 provide just the top-level elements of the WBS. Each of these elements must be decomposed into tasks until the level of work packages are reached. For medium-sized projects there can be as many as four or more levels in a WBS. The **work packages** are pieces of work that can be assigned to a single person, take one to four weeks to complete and are largely autonomous and independent of other work packages. Work packages will consist of several tasks, usually.

Project Team Involvement/Commitment

It is important that, once a project gets a preliminary go-ahead, the project manager as well as the project leader and team members be identified as soon as possible thereafter. The project manager should have an opportunity to put together a preliminary plan. Then each team member should be involved in the further refinement of the planning. The people who will be actually doing the work should also be involved in the planning of the work. A preliminary list of tasks should be known. It should become apparent who should be assigned to which tasks. Once tentative assignments are made, the team member so assigned should return an estimated duration for each task.

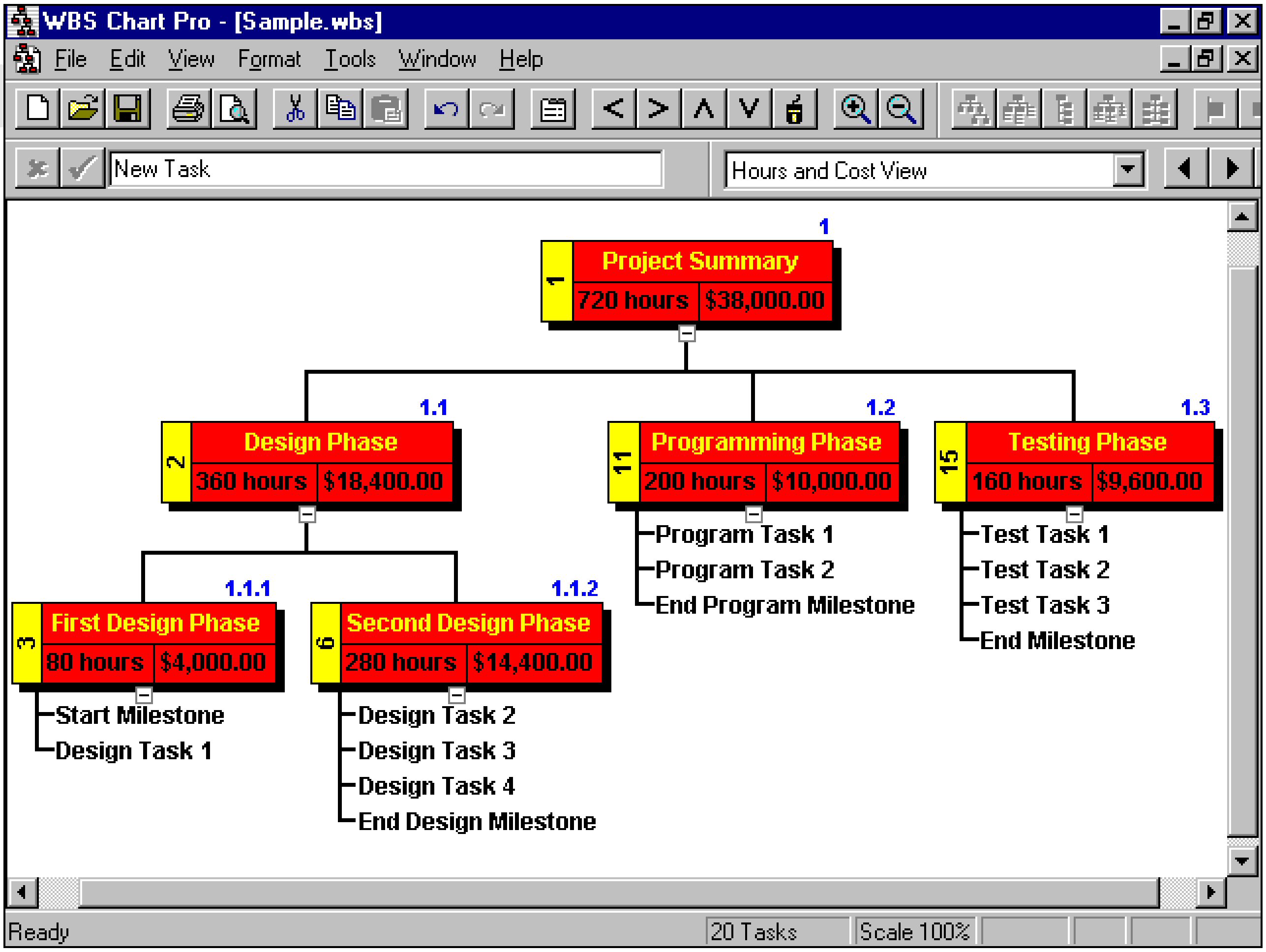


Figure 7.1 A typical WBS (Work Breakdown Structure) (WBS Chart Pro is available at http://www.criticaltools.com)

It seems reasonable thereafter to expect the team-member to deliver on his or her assigned task within the time-period he or she provided. By having the team-members involved in the planning, the members will be committed to accomplishing it according to the plan and within the schedule and budget. Involvement instills a sense of ownership which builds commitment.

The final creation and refinement of the plan should be broken up with detail-minded people doing detail work and anxious team-members doing the risk-related studies, while the confident team-members should resolve roadblocks and come up with contingency actions.

The actual assignment of team-members to tasks, work packages should conform to the following concerns. The task should fit with the technical skills of the assigned team member. If the team member is an expert on embedding Internet socket controls into Visual Studio applications and the task calls for just such a feat, then this could be a perfect match. However, the team member should be available to take on this task at the time that it is needed. There should always be some challenge to the work being assigned, so the assignee has an opportunity to learn and increase his knowledge and skills.

Schedule Planning

In this chapter and the one that follows, we describe the processes for creating a schedule and assigning resources to that schedule. The fundamental entity around which all planning takes place is the **activity**. Clearly, as stated in previous chapters, an activity is a task or step that has a starting time, an ending time and duration. By contrast, it is not an event, which is an instant in time, lacking duration. Activity durations may be deterministic or random. Activities show or exhibit dependencies on other activities, usually. This is to say that before an activity can start, other activities must be completed. But finish/start dependencies is only one type of activity dependency. The others are finish/finish, start/start, start/finish. These are discussed elsewhere in this book. According to PMI's PMBOK, the major processes in this, the second of the four life cycle stages are:

Define Activities involves identification of the specific activities that must be performed to produce the various project deliverables. Various techniques are utilized to do this including the work break down structure delineation.

Sequence Activities involves identifying and documenting interactivity dependencies. For example, the activity 'getting dressed' is preceded by the activity 'getting up' each morning; the activity 'attending class' is preceded by the activity 'driving/walking to class,' and so forth.

Estimate Activity Resources involves estimating the type and quantities of resources required to perform each scheduled activity. For some tasks, system analysts may be required. For others architectural designers may be required. For still others, Java developers may be needed.

Estimate Activity Durations involves estimation of activity durations. For example, only 1 minute may be required to get up each morning, but getting dressed requires 30 minutes. Driving/walking to class takes 20 minutes while attending class is 90 minutes in duration. A separate chapter will be devoted to this most important subject. Estimation can be done well only after resources have been found and assigned to the various tasks that make up the project. As mentioned above, each human resource assigned to a work package may be asked to determine duration—the length of time that person will need to complete the work package.

Develop Schedule involves analyzing activity sequences, activity durations and resource requirements to create the project schedule.

Control Schedule involves controlling changes to the project schedule.

These processes interact with each other and with the processes in the other knowledge areas as well. Each process may involve effort from one or more individuals or groups of individuals based on the needs of the project. In what follows, we discuss each many of these processes in terms of their inputs, outputs, and functionality.

Define Activities

By far the commonest way to perform activity definition is by means of a work break down structure. Work break down structures can be created by decomposition or by recourse to a predefined template. **Decomposition** involves sub-dividing project elements into smaller, and more manageable components in order to provide better management control. Frequently, projects are variants of previously defined, planned, and executed projects. When such is the case a good place in which to start is with an existing template. An existing activity list or a portion thereof from a previous project, is often usable as a **template** for a new project.

Obviously, by reusing an existing template, the time required to formally decompose an existing project is eliminated.

Decomposition is what has to happen in order to create a work breakdown structure (WBS). The question is, how far should you break a project down? A WBS is begun by listing the major components of a project. This is level 1 of the WBS. Level 0 is just the title of the project. One way to start a project is to decide upon what major project type is being implemented and begin with the major phases defined in Chapter 4. Lower levels of the WBS are obtained by breaking down each piece at the level above into its component activities.

The lowest level entries are the work packages of the project. You stop the decomposition process if the following criteria are satisfied:
1. Some person (or group for a larger project) can take responsibility for the work package, and/or can accomplish the activities involved in it.
2. A **rough estimate** of the effort needed to perform the work package can be determined. This might be done by the team professional chosen to perform the work package.
3. The work package can be scheduled. To schedule a work package its precedent activities and their durations should be known. Generally, we expect that precedent activities will be performed before the task can be started.
4. The work package is small and its completion is measurable. A good work package will take from one to four weeks to complete and there is a "measuring stick" for determining when it will be done. The measuring stick might be a specific deliverable or set of related deliverables whose completion is readily discernible.

As discussed in the first chapter, several "models" are incredibly important to the processes of schedule planning. They are the Gantt Chart and the PERT chart or network diagram. These are exhibited and discussed in detail later in the chapter.

The Gantt Chart

The Gantt Chart was invented by Henry Gantt around 1910. It shows what tasks are to be done when on a time line. Today's modern Gantt Charts also show who will do the work and what precedence and subordination relationships exist among the activities. An example appears in Figure 7.2.

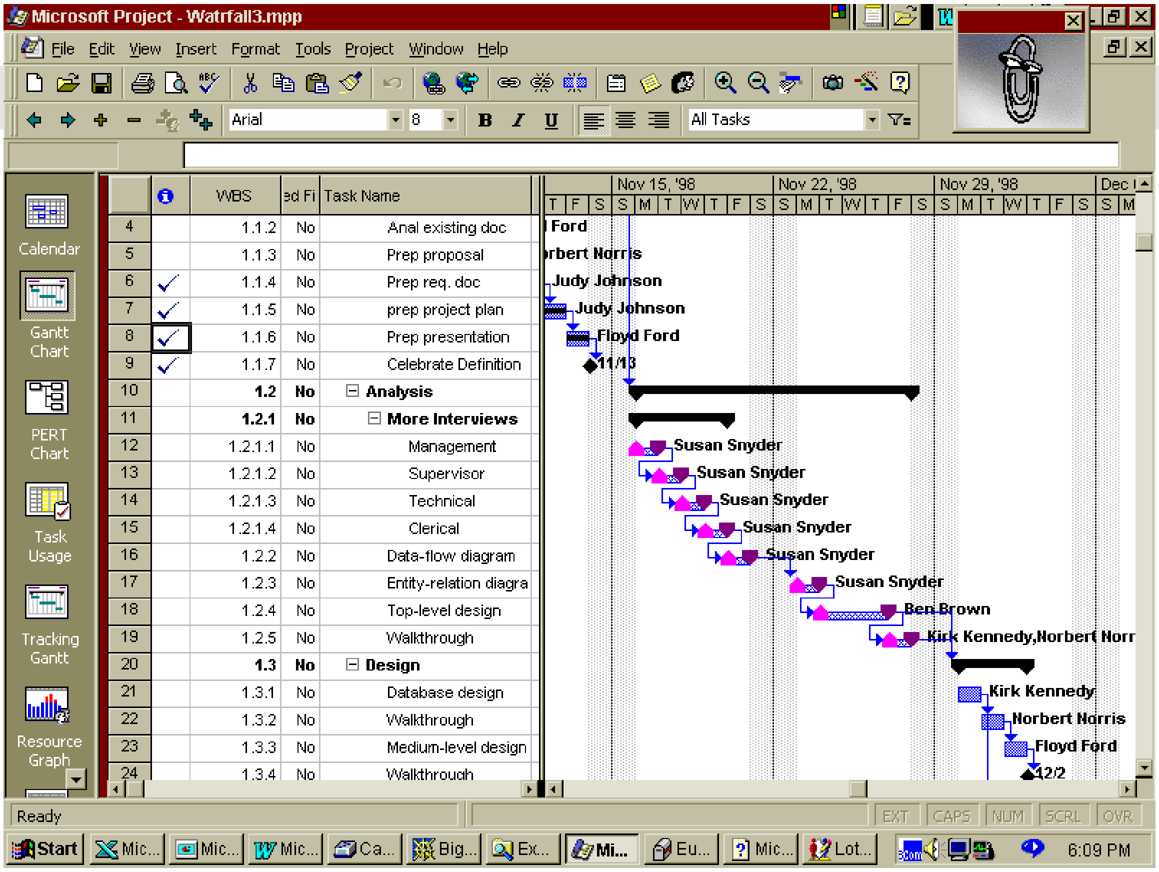


Figure 7.2. The MS Project Gantt Chart

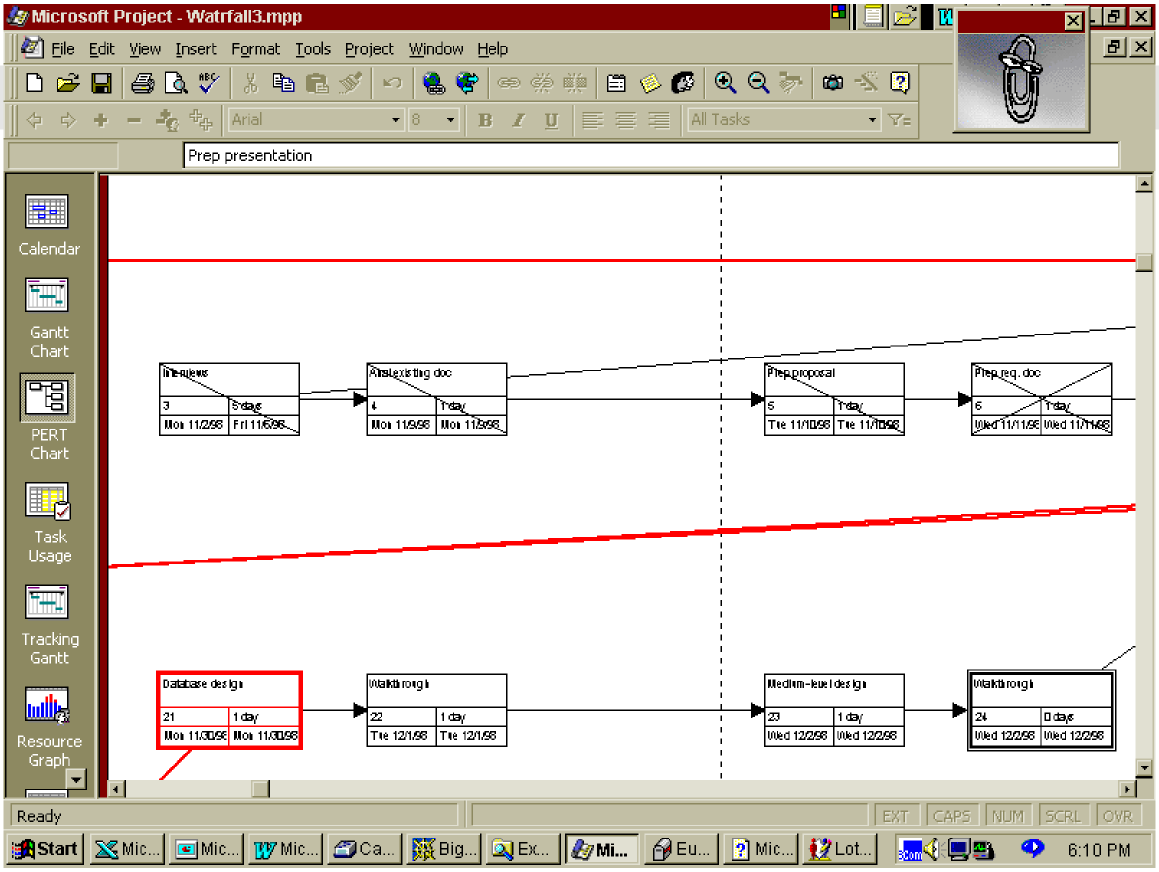


Figure 7.3. The MS Project Network Chart

Human Resource Planning

The management of people is one of the most challenging undertakings an IT professional person can engage in. Unlike computers, people cannot be so consistently and pervasively programmed. This makes planning for their involvement in the project even more important. Nevertheless, people, not computers, are the most important assets of a project.

Just what is human resource planning? The major processes involved in human resource management are described below.

Develop Human Resource Plan requires identifying, assigning, and documenting project roles, responsibilities, and reporting relationships. Key outputs of this process include roles and responsibility assignments, often shown in a matrix form, and an organizational chart for the project.

Acquire Project Team involves getting the needed personnel assigned to and working on the project. Getting personnel is one of the crucial challenges of information technology projects. It must be pointed out that institutions of higher education continue to turn out far fewer qualified personnel for the hundreds of thousands of openings that are created each year. Coopers & Lybrand (now Price Waterhouse Coopers--PWVC) conducted a survey in 1997and found that 70 percent of CEOs in high-tech firms listed the lack of highly skilled, trained workers as the number one barrier to growth. More recently, Bill Gates has devoted a lot of time and energy to encourage more young people in this country to major in computer science. As it stands there are thousands of unfilled openings in information technology related fields that go unfilled each year.[1]

The third and final activity associated with human resource planning is **Develop Project Team**. This involves building individual and group skills to enhance project performance. Building individual and group skills is also a challenge for many information technology projects. The writings of Covey, Senge, and Humphrey as discussed earlier can be very helpful here.

System integrator firms like Accenture, PWC, Cap Gemini Ernst and Young, Hitachi Consulting and many others use a resource scheduling system that provides visibility across all offices. There is also an HR skills database that these contractors use. Project managers should know what the resource requirements are. Based on that, they look at availability. Managers and partners must project when resources will come free. Resources must be renegotiated when a conflict occurs or a project delay has to be negotiated. Inevitably, the conflict gets worked out. The interests of the highest levels of the firm come first in all such negotiations.

Motivation

How to motivate people to do their best is a subject of intense study by psychologists and management theorists. Issues that affect how people work and how well they work include motivation, influence and power, and effectiveness. Of importance in this field is the work of Abraham Maslow and others.

Maslow's needs hierarchy is particularly important to an understanding of why people behave the way they do.

[1] The Information Technology Association of America (ITAA) in cooperation with Virginia Polytechnic Institute and State University conducted a survey of 1500 firms in 1997 and found that there were 345,000 openings for programmers, systems analysts, computer scientists, and computer engineers in information technology.

Sequence Activities

Activities get completed in a logical order if a project is to be completed on time and within budget. For example, assume interviews are being conducted as part of a definition, conceptualization or analysis phase. An interview of the chief information officer and his four top level managers is planned. It would be entirely possible to conduct these interviews in parallel but we cannot proceed with the preparation of the final report until these interviews are complete, compiled and analyzed. In fact, we cannot do the compilations and analyses until all of the interviews are complete and turned in. We would represent this sequence as shown in Figure 7.4 below. And, it would be understood from this sequence that compilation and analysis cannot begin until all interviews are completed. This is known as a FINISH/START relationship between the interview tasks and the compilation task. Similarly, preparation of the report cannot commence until the compilation and analysis is complete. Again this is a FINISH/START sequencing relationship.

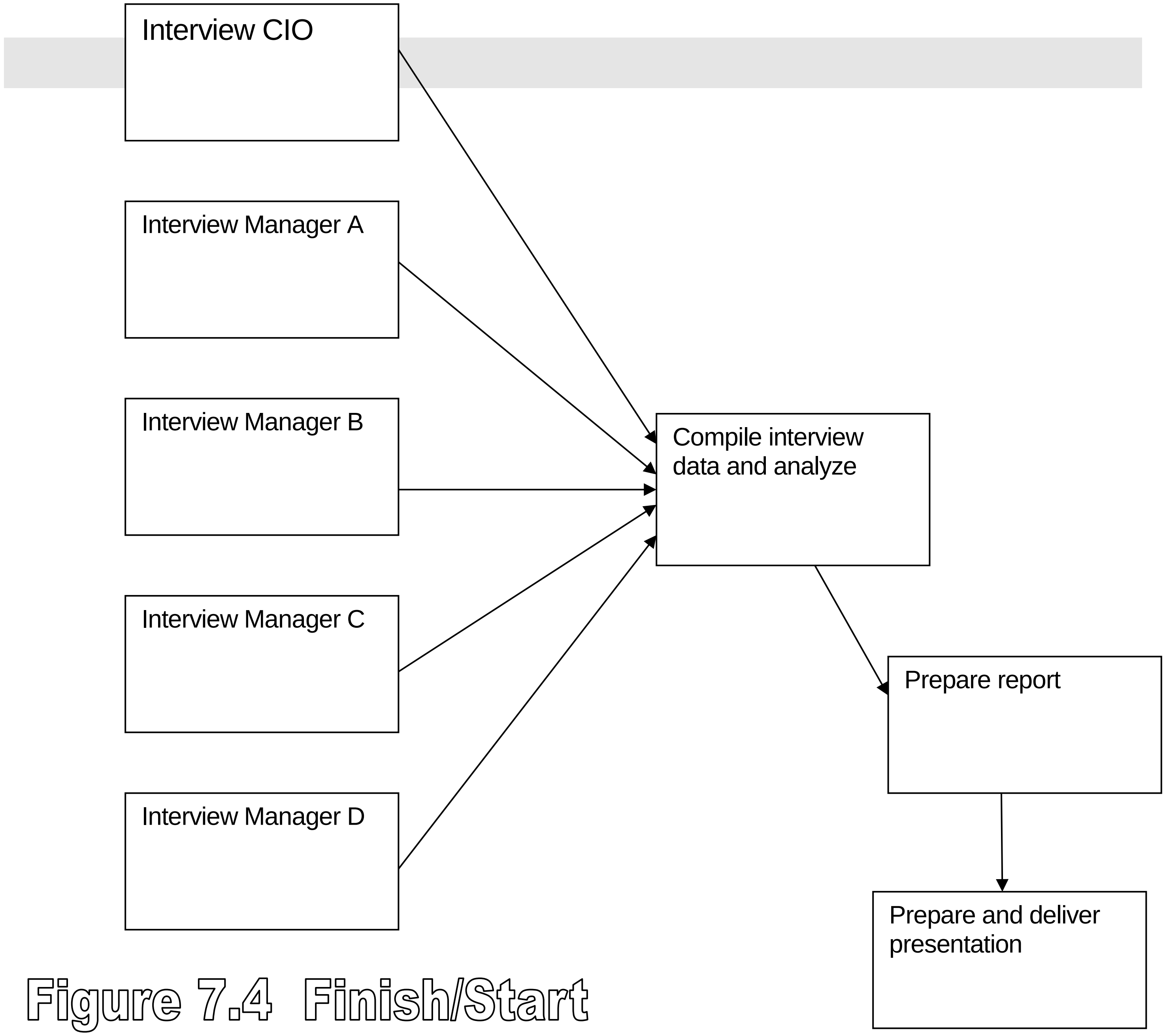


Figure 7.4 Finish/Start Sequencing Relationships

Clearly, in any kind of FINISH/START sequencing, all incoming activities or tasks must be complete before the next activity can commence.

Must project scheduling software packages such as MS PROJECT, support the following sequence relationships:

FINISH/START, START/START, FINISH/FINISH, START/FINISH

A START/START relationship is appropriate when one activity can start as long as another activity has started. A FINISH/FINISH relationship allows one activity to finish once another activity has finished. A START/FINISH relationship allows one activity to finish once another activity has started.

Project Networks

Project networks are important tools for project planning, execution and control. They help us visualize what must precede what, or for that matter what must succeed what. But that is all they do. They do not show us on a timeline when a task is scheduled to begin or end, for example; for that we need a Gantt chart. From them, however, we can determine:

1) the project duration;
2) the critical path[2];
3) tasks on the critical path;
4) tasks not on the critical path;
5) slack associated with non-critical tasks;
6) earliest start, earliest finish, latest start and latest finish times;

as we shall see in what follows. So let's get started.

Translations to Project Networks

Occasionally, project network information is supplied in tabular form rather than as the actual network and it is up to us to translate this into a network. Consider the following:

NAME	DURATION	PREDECESSORS
A	5	
B	10	
C	5	A, B
D	20	A, B
E	5	C
F	10	D, E

Table 7.1 Table of Tasks, their Durations and Predecessors

Clearly, A and B are both start nodes in this case, since they have no predecessors. Since F does not appear in the predecessor column on the right, it is a predecessor to nothing, meaning that it has no successors. If F has no successors, it must be a stop node. Since all of the other tasks appear on the predecessor list, F must be the only stop node, as all of the other tasks have successors. The network corresponding to Table 7.1 appears below.

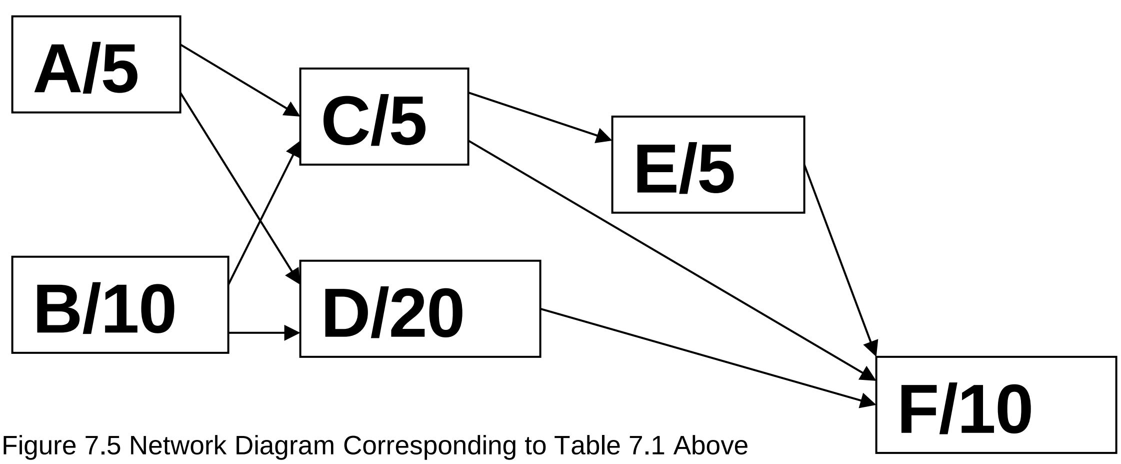


Figure 7.5 Network Diagram Corresponding to Table 7.1 Above

[2] The longest path through the network and the one that determines total project duration.

The network diagram above is known as an activity-on-node diagram. Often, in textbooks you will find discussions of activity-on-arrow diagrams. For technical reasons, activity-on-arrow diagrams have fallen into disrepute; they are never used in software packages created to support project management. For illustrative purposes, the activity-on-arrow diagram for the diagram exhibited in Figure 7.5 above is exhibited below.

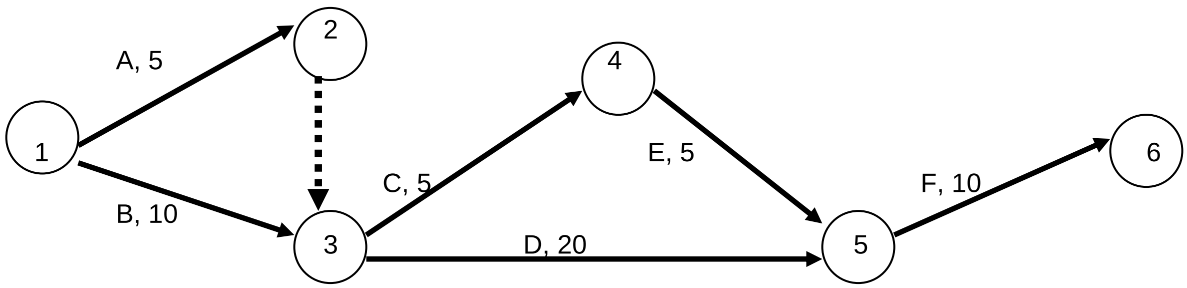


Figure 7.6 Activity-on-arrow Diagram Corresponding to Activity-on-Node Diagram Above

Notice in Figure 7.6, that a dashed line appears from node two to node three above. This is because in the activity on arrow diagram, two arrows, both having the same origin and destination nodes, are not allowed. The dashed line leading from node two to node three is referred to as a "dummy" activity. Dummy activities have zero duration; they are needed to show when two activities emanating from the same node are both predecessors to one or more successor activities, as is the case above. It is one of the reasons for why activity-on-node network diagrams are preferred to activity-on-arrow diagrams.

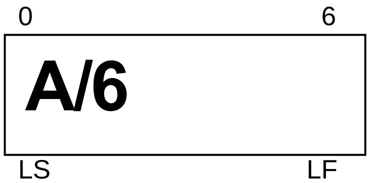
A Mechanism for Determining Start Dates, and Finish Dates in any Project Network: The Critical Path Method (CPM)

What we describe in the section is known as the Critical Path Method. This technique, commonly known as the Critical Path Method, was invented in the 1950's to assist with the scheduling and control of projects. In addition to start and finish dates, the Critical Path Method finds the critical path, which is the longest path through the network and the path that determines total project duration. Four our purposes in what follows, we shall represent a node by the following simplified notation:

The Letter "N" is the label for the task, while the number "K" will be understood as its duration. For discussion purposes, we shall use "days" as the units on time, but in actuality, any time units could be used. The designations at each of the four corners of the box—ES, EF, LS, LF—represent the following:

ES – earliest start for the node, assumed to be at the beginning of the day
EF – earliest finish for the node, assumed to be at the end of the day
LS – latest start for the node, assumed to be at the beginning of the day
LF – latest finish for the node, assumed to be at the end of the day
K -- the duration of the node (number following the slash)

In what follows, we shall always start on day 0; hence, the starting node will always have an ES of 0. We shall assume that the start will commence at the start of business on day 0 or whatever the starting date is. After determining the ES, EF, LS, LF numbers we will then assign calendar dates to each of them. We shall also assume that the finish will be so no later than close of business on day k. Thus $EF_j = ES_j + k$. For example, suppose that N = A and k = 6. Then the ES and EF numbers would be as shown below:



Now, let's see how this works out for a successor task.

The immediate successor will start on the same day as the day the immediate predecessor finishes, in this case day 6, where it is understood that the starting time is at the beginning of business on that day.

To find all of the ES and EF numbers for all nodes, a forward pass from the left-most start node is made through the network. In each case, the ES number will be the largest EF number of all the adjacent predecessors.

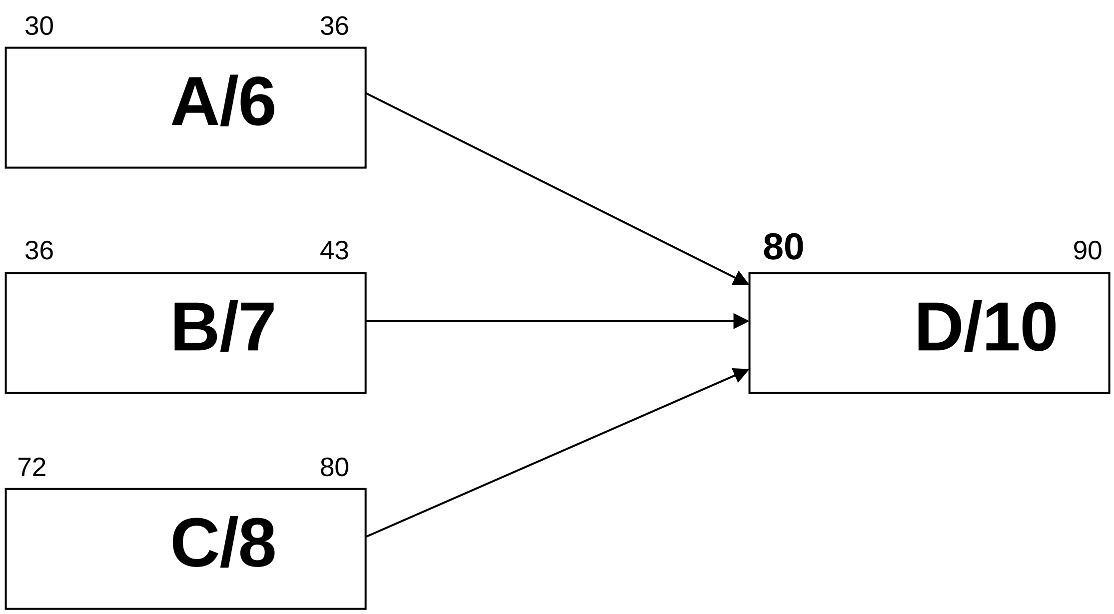


Figure 7.7 Precedence Relations and their Impact on ES Earliest Start Numbers

ES, Earliest Start, numbers in a network with only FS (FINISH/START) relationships, must always reflect the fact that the subsequent tasks cannot start until ALL of the immediately precedent tasks are completed. Consider Figure 7.7. What we learn from Figure 7.7 is that the earliest start number for a subsequent task like D above must be equal to the largest of the EF, Earliest Finish, numbers for all of the immediately preceding tasks. The rule is simply to *find the largest of all of the EF numbers for all adjacent predecessors, using the result as the ES number for the adjacent successor task*. Thus, ES_{j+1} = MAX(Efj for all adjacent predecessors). The reason for this rule is obvious—the earliest the successor can start is after the last of all the adjacent predecessors has finished when the precedence relation is FINISH/START, which is the default or assumed relation in any project network.

Here task D is known as a merge activity. A **merge activity** is any activity or task that has more than one immediate predecessor.

The latest start LS and latest finish LF numbers are determined by starting from the last node (stop node) and proceeding backward toward the start node(s). At this juncture the forward pass has been completed and all of the earliest start and earliest finish numbers are known.

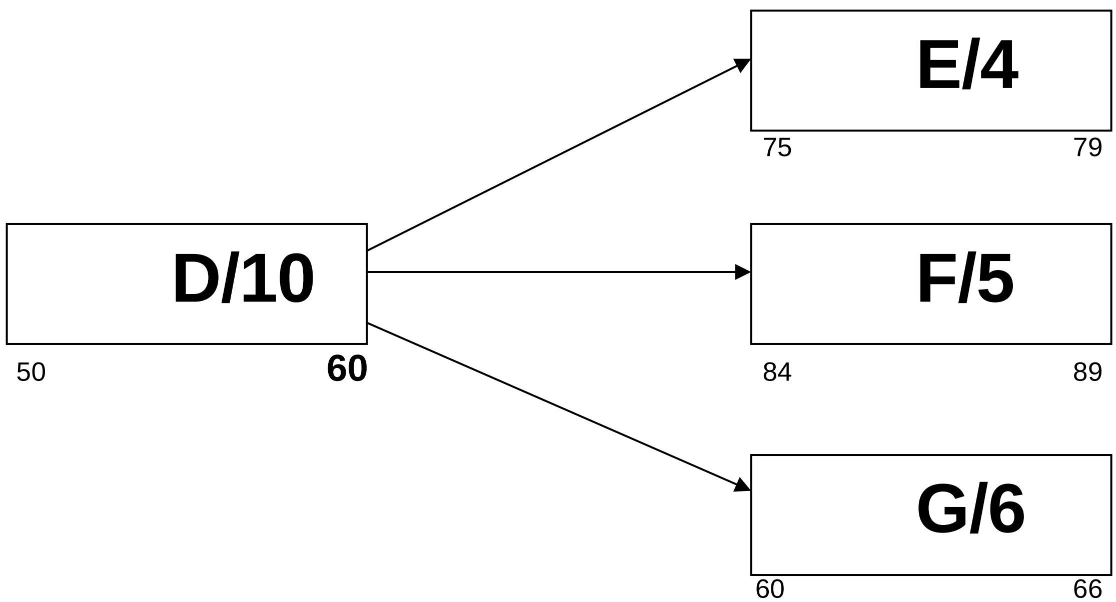


Figure 7.8 Successor Relations and their Impact on LF, latest Finish, Numbers

LF, Latest Finish, numbers in a network with only FS (FINISH/START) relationships, must always reflect the fact that adjacent predecessor tasks cannot finish later than the smallest of ALL of the immediately successor latest start times. Consider Figure 7.8. What we learn from Figure 7.8 is that the latest finish number for a subsequent task like D above must be 1 less than the smallest of the LS, Latest Start, numbers for all of the immediately succeeding tasks. The rule is simply to *find the smallest of all of the LS numbers for all adjacent successors and subtract 1 from that, using the result as the LF number for the adjacent predecessor task*. Thus, LF_{j-1} = MIN(LS_j of all of the adjacent successors). The reason for this rule is again obvious—the latest the predecessor can finish is before all the adjacent successors latest start when the precedence relation is FINISH/START, which is the default or assumed relation in any project network.

Notice in Figure 7.8 above, that the LS number for node D is 50 or 10 less than the LF number for the node. Thus, $LS_j = LF_j - K$. Observe that this relation holds for nodes E, F and G as well in Figure 7.8 above.

Node D in Figure 7.8 above is known as a burst node. A **burst node** is any node that has more than one immediate successor nodes.

To summarize, the rules are as follows:

1) The ES_1 always is assigned a value of 0

2) $EF_j = ES_j + K$

3) ES_{j+1} = MAX(EF_j of all adjacent predecessors)

4) LF_{j-1} = MIN(LS_j of all of the adjacent successors)

5) $LS_j = LF_j - K$

Consider the following network.

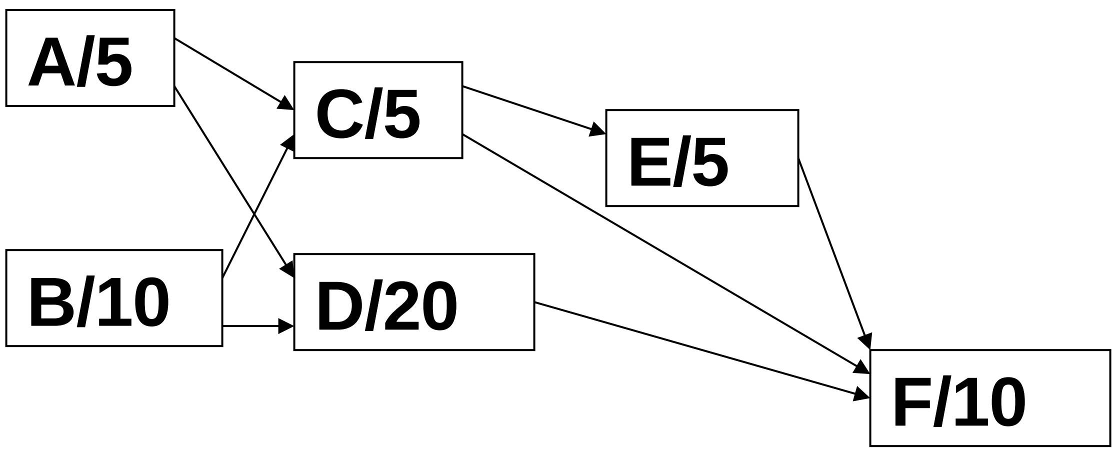


Figure 7.9 Network Diagram

First, we make a forward pass through the network starting with nodes A and B and using rules 1 and 2 above. The result is shown below in Figure 7.10.

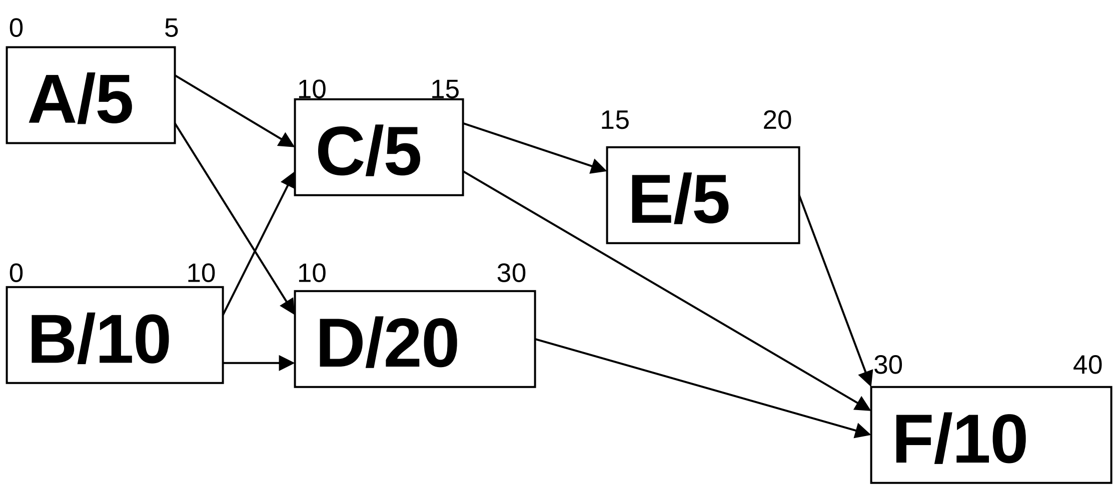


Figure 7.10. Network Diagram with ES and EF Numbers Shown

From Figure 7.10 above, we learn that it takes 40 “days” to complete the entire project, that the project duration will be 40 days. Further, we learn that if task C starts at its earliest possible time, that would be 10 and that its earliest finish would be day 15, close of business, etc.

Next, we make a backward pass starting with node F and applying rules 3 and 4. The result is shown below in Figure 7.11.

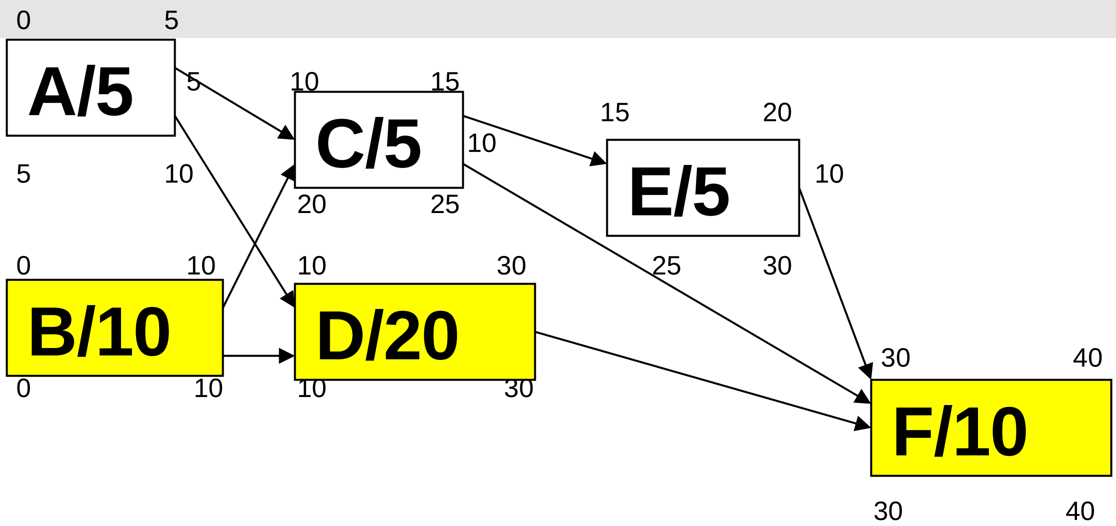


Figure 7.11. Network Diagram with all ES, EF, LS and LF Numbers Shown. High-lighted boxes show critical path.

Determination of the Critical Path

By definition, the critical path is the longest path through the network. We have to ask ourselves, what are the paths through the network? The list shown below enumerates all of the paths.

PATH	DURATION
A – C – E -- F	25
A – C – F	20
A – D – F	35
B—C—E—F	30
B – D – F	40
B—C—F	25

From this list we learn that the longest path is B – D – F. This is the critical path; its nodes have a shaded background in Figure 7.11 above. Note that, on the critical path the latest start LS and latest finish LF numbers are identical to the earliest start ES and the earliest finish EF numbers, respectively. In fact, this is how we can discern whether a particular node is on the critical path or not. If the earliest start number is equal to the latest start number (i.e., $ES_j = LS_j$), the node is on the critical path. Conversely, if the earliest finish number is equal to the latest finish number (i.e., $EF_j = LF_j$), the node is on the critical path.

The Concept of Slack

By definition, slack is the difference between the latest times and the earliest times. Thus

Slack = $S_j = LS_j - ES_j = LF_j - EF_j$, assuming Finish/Start relationships between nodes.

Clearly, slack is zero for activities (tasks) that are on the critical path. For non-critical tasks, slack is exhibited in Figure 7.11 as the number in the middle and just after each box associated with a non-critical task. Task A is 5 days of slack, while tasks C and E each have 10 days of slack. A Gantt Chart is a nice way to exhibit all of this. The Gantt Chart produced by WINQSB for the network above appears below.

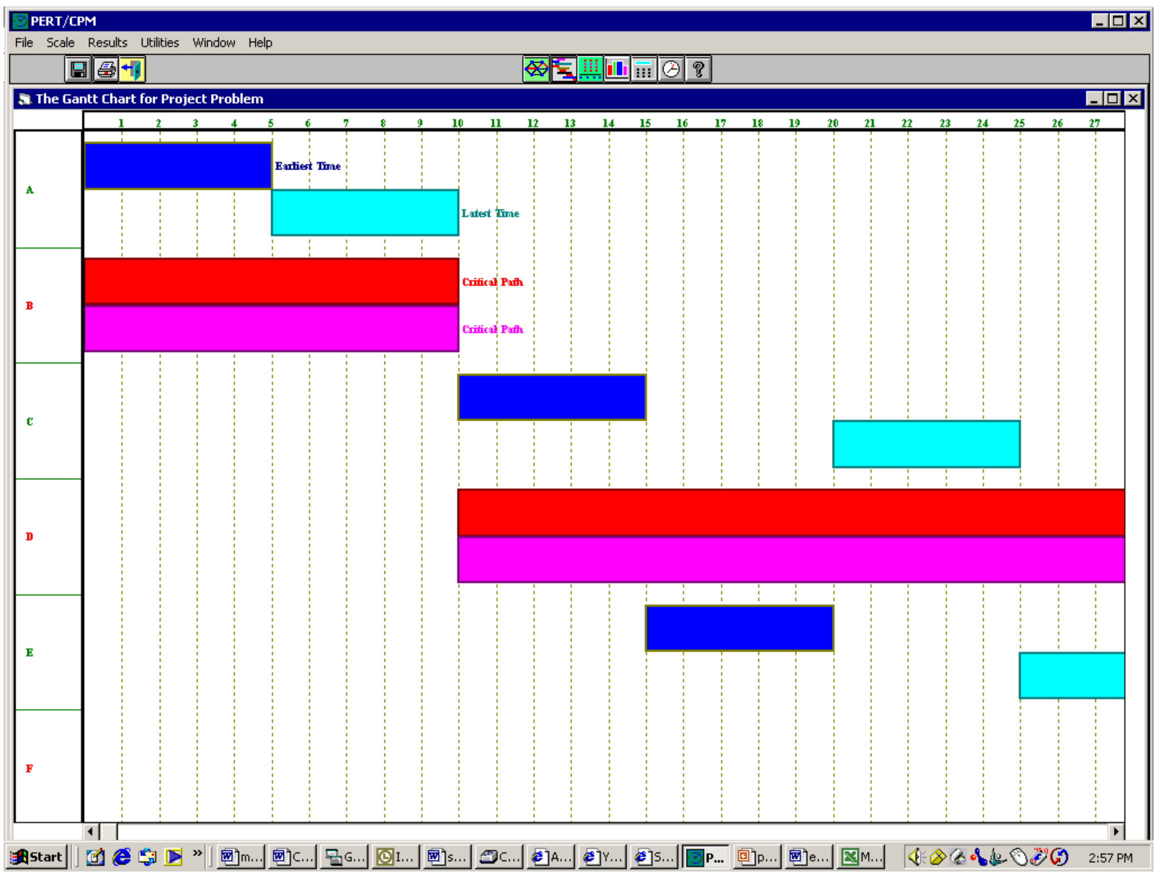


Figure 7.12. Gantt Chart

Notice, how the non-critical tasks are shown in two shades of blue—dark blue for an early-start and an early-finish schedule and light blue for a late-start and a late-finish schedule. Critical tasks are shown in red and magenta.

This raises an interesting question and one that has been debated in the project management literature for years. What's best—an early-start, a late-start or something in-between. Most people would argue for an early start. But because of Parkinson's Law, the task might not then get finished until its latest finish. Thus, in the case of Task C, everyone knows that its latest finish time is day 25. Parkinson's law[3] says it won't get finished until day 25. Instead of taking five days and finishing on day 15, the task winds up taking 15 days and finishing up at the close of business on day 25. While this would not cause a delay in the project; however, if costs on that task were running at $1000/day, the task would wind up costing $10,000 more than it should have.

PERT (Program Evaluation and Review Technique)

Unlike the Critical Path Method, PERT allows for the task durations to take on random, rather than deterministic values. The advantage here is that durations are, in general random. So being able to represent them as random when they are in fact random, adds an additional degree of realism and authenticity to the network model. Of course, if a particular task duration were in fact deterministic (nonrandom), it could still be represented as so.

There are other advantages to a probabilistic representation of the project network as used in PERT. A variance can be calculated. The variance tells its analyst how much variability there is in the project's critical path and hence how likely it is that the project may not be completed by its scheduled due date.   From this variance, it is possible to determine the probability the project or a milestone within it can be completed by a certain due date. Such calculations are impossible with deterministic network methods like CPM.

The Beta Distribution

Traditionally, each task duration is assumed to conform to a beta distribution. Correctly parameterized, the beta distribution resembles the popular normal distribution, but with an advantage. The beta distribution does not possess those infinite tails that result in samples which are significant outliers from the duration mean. As can be seen in Figure 7.13 below, the beta distribution looks like a normal distribution, except for those infinite tails. Clearly, it is an inverted bell-shaped curve. Such a distribution is said to be unimodal, i.e., having only one peak. We notice one other distinction between the beta distribution and the normal distribution. The beta does not have to be symmetric.

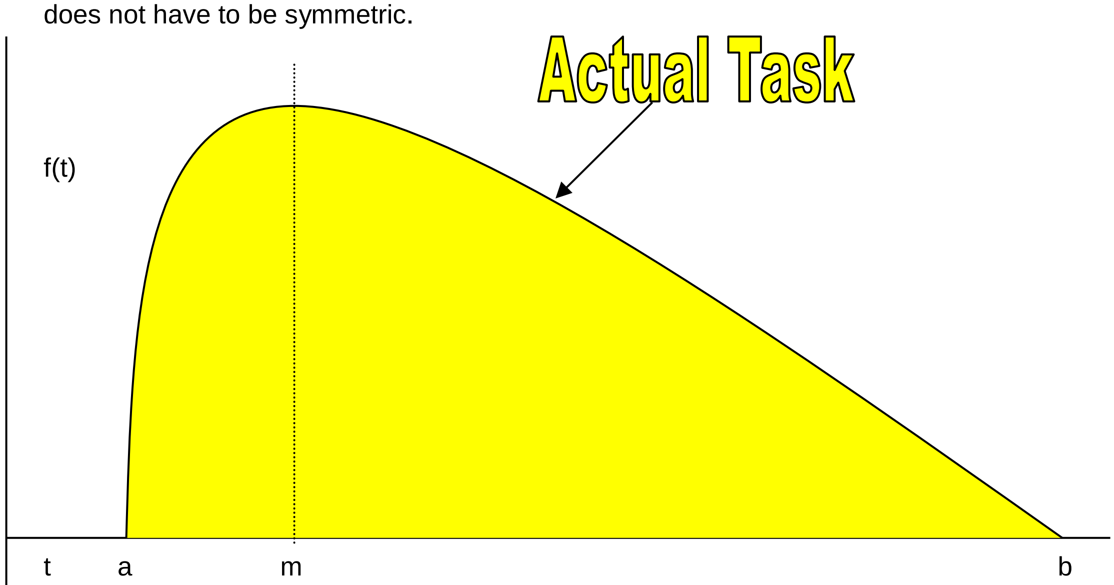


Figure 7.13 The Beta Distribution, defined by the time parameters a, m, b

[3] Parkinson's Law asserts that the amount of time required to complete a task will fill up the amount of time allotted for it. There are many 'cultural' reasons for why this is so. For example, early finishes are dis-rewarded by asking that person to do additional work.

The beta distribution requires three parameters, each representing the completion time of a particular task. The parameters are referred to as the optimistic completion time a, the most likely completion time m and the pessimistic completion time b. The letters a, m, b are used to represent these three times, as illustrated in Figure 7.13 above. Instead of representing the task duration with a single number as we did for the Critical Path Method and similar techniques, each task duration is represented with three numbers. If the three numbers are all close together, then there is little variability in the associated task's duration. Conversely, if the difference between b and a is large, then there is wide variability. If m is closer to a than b, the distribution is skewed toward a; similarly, if m is closer to b than a, the distribution is skewed toward b. In either of these cases, the distribution is non-symmetric. Only when m is exactly in the middle between a and b is the distribution symmetric.

The three parameters {a, m, b} are usually given the following interpretation. First, the most likely number m is akin to a mean or an average. The optimistic number is a best case scenario in which everything "goes like clockwork" and there are no problems, no delays, everything runs exactly as contemplated. The pessimistic number is a worst case scenario in which everything goes wrong. New undiscovered and unplanned-for work surfaces. Resources don't materialize when needed, and the deliverables required don't arrive when scheduled.

A possible disadvantage of probabilistic PERT is that it does require three "guesses" for each task duration instead of one. However, if the three estimates for a, m, and b are determined by someone knowledgeable about these values, they convey more information in them than just the single estimate. Secondly, if a, m, and b are determined from historical data as stored in a database, then there is even more reason to use the three-estimate probabilistic approach suggested here. There is far more information brought to the analysis than use of just the single estimates. That information tells the analyst something about the variability of the task. Task variability leads to determination of process variability and ultimately project variability. It is a goal (and has been since the beginning) of the quality movement to reduce variability. By reducing variability, tasks, processes and projects become more consistent, more predictable and less costly to complete.

For each task, it is necessary to calculate a mean and variance. The mean is simply the expected duration of the task, while the variance is a measure of the variability of the task as we have said. The standard formulas for task mean and task variance, assuming a beta distribution are:

$$\text{mean} = (a + 4m + b)/6$$

$$\text{variance} = (b - a)^2/36$$

The first formula above asserts that the mean is a weighted average of the parameters a, m and b in which the most likely parameter m receives four times as much weight as do the other two—a and b. The variance is simply a measure of the square of the difference between b and a. Since the standard deviation is always the square root of the variance, it should be apparent that

$$\text{standard deviation} = (b - a)/6$$

Neither the standard deviation nor the variance are at all affected by choice of value for the most likely parameter, m. However, the following relationships must hold: a<=m and m<=b.

Activity	Predecessors	Optimistic	Most Likely	Pessimistic
1. Select stakeholders	--	10	15	18
2. Develop requirements	--	30	45	60
3. Determine system size	--	8	12	20
4. Determine prospective vendors	--	2	3	8

5. Form evaluation team	1	5	7	9
6. Issue RFP's	2,3,4,5	4	5	8
7. Bidder's Conference	6	1	1	1
8. Review submissions	7	22	25	35
9. Select vendor short list	8	2	5	9
10. Check vendor references	9	2	4	8
11. Vendor demonstrations	9	15	20	30
12. User site visit	9	3	5	6
13. Volume sensitive test	12	8	12	20
14. Select vendor	10,11,13	2	2	2
15. Negotiate contracts	13	9	12	22
16. Cost-benefit analysis	14, 15	3	3	3
17. Obtain stakeholder approval	16	3	4	5

Table 7.2 Activities and their Time Estimates

Using the formulas for mean and variance given above, it is possible to perform these calculations for each of the 17 tasks in Table 7.2. Table 7.3 exhibits the results of those calculations.

Activity	Predecessors	Mean	Variance	Standard Dev.
1. Select stakeholders	--	14.6667	1.7778	1.3333
2. Develop requirements	--	45	25	5
3. Determine system size	--	12.6667	4	2
4. Determine prospective vendors	--	3.6667	1	1
5. Form evaluation team	1	7	0.4445	0.6667
6. Issue RFP's	2,3,4,5	5.3333	0.4445	0.6667
7. Bidder's Conference	6	1	0	0
8. Review submissions	7	26.1667	4.6945	2.1667
9. Select vendor short list	8	5.1667	1.3611	1.1667
10. Check vendor references	9	4.3333	1	1
11. Vendor demonstrations	9	20.8333	6.2500	2.5000
12. User site visit	9	4.8333	0.2500	0.5000
13. Volume sensitive test	12	12.6667	4	2
14. Select vendor	10,11,13	2	0	0
15. Negotiate contracts	13	13.1667	4.6944	2.1667
16. Cost-benefit analysis	14, 15	3	0	0
17. Obtain stakeholder approval	16	4	0.1111	0.3333

Table 7.3 Activities and their time estimates

Researchers have discovered that the critical path mean T_e (or expected duration) is simply the sum of the means t_c of all tasks that make up the critical path. Thus,

$$T_e = \Sigma t_c$$

Likewise, The variance for the entire project duration is computed as the sum of the variances of the activity durations along the critical path: Thus,

$$V_e = \Sigma V_c$$

Using the parameters T_e, V_e one can calculate the probability that the project will be completed on any given day. In general, the probability the project will be completed by its expected duration, T_e, is .5. To perform such a calculation a standard normal random variate is calculated from T_e, V_e. The reason for using a standard normal is because the project's expected duration or mean is the sum of a rather larger number of random variables, usually. By the central limit theorem, the sum of a collection of non-normal random variates is normal as the number of random variates get large.

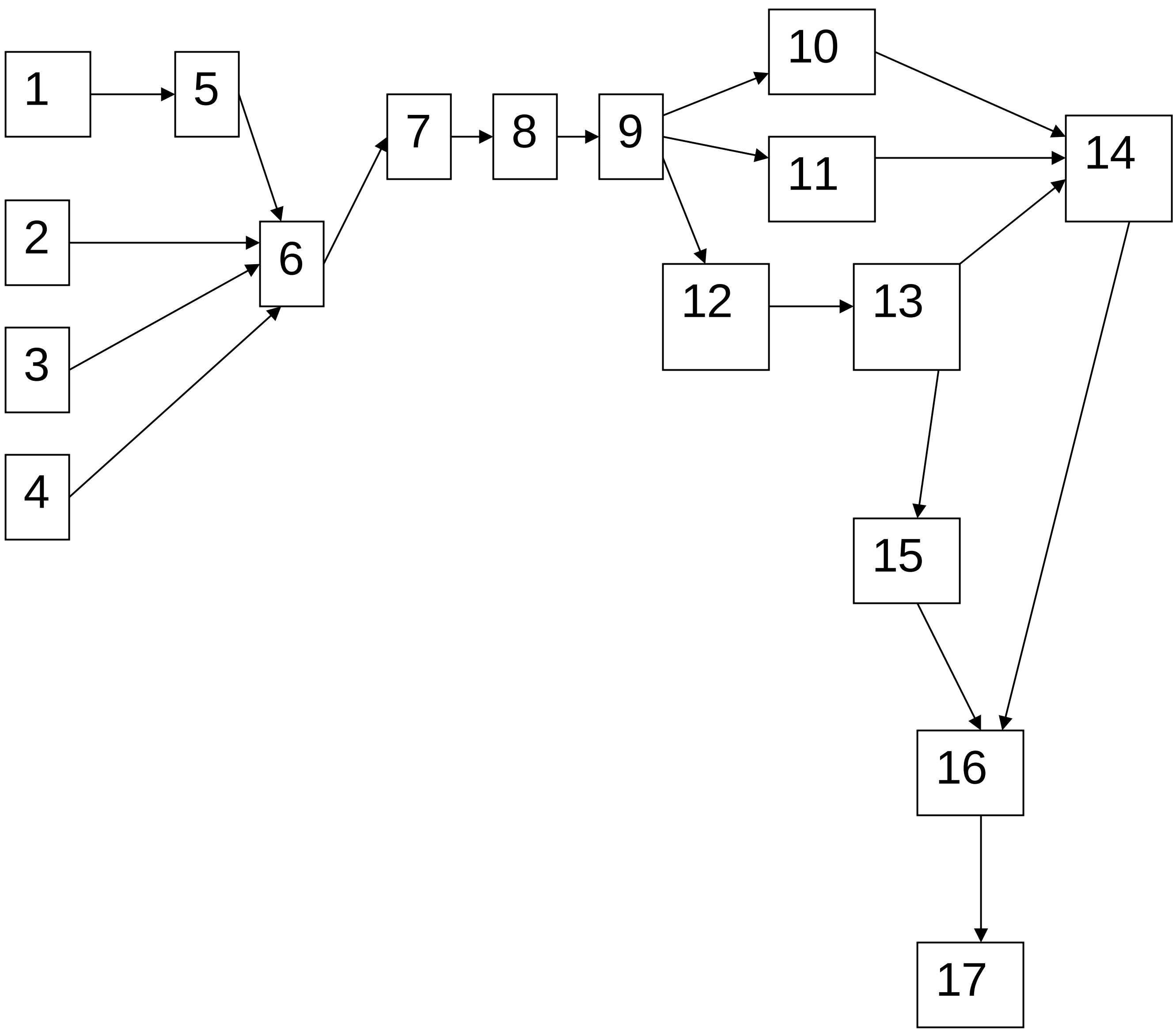


Figure 7.14 Network Diagram for PERT model

PERT is criticized because it gives overly optimistic results and because the beta distribution produces errors in estimating the overall project duration. Even so, PERT gives project managers something they could never get out of the critical path method—a way to calculate the probability of completing the project (or any task for that matter) by a certain date.

Resource Management

Human resource management is one of the four facilitating knowledge areas identified in PMBOK. "People are our most important asset," according to the CEO's of some firms. Yet, the Information Technology Company of America maintains that there are over 300,000 jobs for IT professionals that either go unfilled or are filled with people who are unqualified. Coopers & Lybrand conducted a survey in the late 1990's and found that 70% of CEOs in high tech firms listed the lack of highly skilled, trained workers as the number one barrier to growth. As a result some companies are offering interest-free loans to people seeking education and training in information technology. As a consequence of these employment shortages, human resource management for information technology projects takes on an increasingly critical role.

One problem is how to get more women interested in IT careers. There are problems with the stereotyping that girls are not good at math. Computer games target boys, so girls are less interested in computers. Online discussion groups are largely male-oriented and sexist.

There are four major processes involved in human resource management and they include organizational planning, staff acquisition, and team development.

Organizational planning involves identifying assigning, and documenting project roles, responsibilities, and reporting relationships. Key outputs of this process include roles and responsibility assignments, as are often shown in matrix form, and an organization chart for the project.

Staff acquisition involves getting the needed personnel assigned to and working on the project. Getting the right personnel is one of the crucial challenges of information technology project managers.

Team development involves building individual and group skills to enhance project performance. Building individual and group skills is also a challenge for many information technology projects.

Manage Project Teams involves motivating team members and tracking their performance, providing timely feedback, resolving issues and managing conflicts. Occasionally, changes to human resource assignments have to be undertaking to advance the interests of the project.

There is a substantial body of literature dealing with people involved in projects. The many topics include coaching, communicating, coping with conflict, delegating, mentoring, negotiating, and team building. These are the disciplines involved with the processes of human resource management.

MOTIVATING AND MANAGING PEOPLE

Abraham Maslow, the father of humanistic psychology and a respected industrial psychologist of the 1950s, rejected the conventional wisdom of the discipline of psychology of that day and developed his own theory. He is best known for his needs hierarchy depicted below. Existing psychological thought held that human beings were largely controlled by and a product of their environments. Maslow argued that conventional thought failed to recognize the unique qualities of human behavior: love, self-esteem, belonging, self-expression, and creativity. He argued that these unique qualities enable people to make independent choices, which give them full control of their destiny.

5. Self actualization

4. Esteem

3. Social (love, belonging)

2. Safety

1. Physiological

Figure 7.15 Maslow's Needs Hierarchy

Maslow developed the hierarchy of needs delineated in Figure 7.15 above--a pyramid structure illustrating Maslow's theory that people's behaviors are guided or motivated by a sequence of needs. The meaning of the hierarchy is the following: Once a persons' physiological needs are satisfied, safety needs will guide behavior. Once safety needs are satisfied, social needs become the focal point, and so one up the hierarchy.

Building on Maslow's hierarchy, another psychologist, Frederick Herzberg (1968) found that people were motivated to work mostly by feelings of personal achievement and recognition. Motivators, Herzberg found, included achievement, recognition, the work itself, responsibility, advancement, and growth.

Thamhain and Wilemon conducted research on ways for project managers to influence workers. They identified nine influence bases available to project managers:

1. Authority--the legitimate hierarchical right to issue orders.
2. Assignment--the PM's perceived ability to influence a worker's later work assignments.
3. Budget--the project manager's perceived ability to authorize others' use of discretionary funds.
4. Promotion--the ability to improve a worker's position.
5. Money--the ability to increase a worker's pay and benefits.
6. Penalty--the project manager's perceived ability to dispense or cause punishment.
7. Work challenge--the ability to assign work that capitalizes on a worker's enjoyment of doing a particular task, which taps an intrinsic motivation factor.
8. Expertise--the project manager's perceived special knowledge that other deem important.
9. Friendship--the ability to establish friendly personal relationships between the project manager and others.

Senior management grants authority to the project manager.

Thamhain and Wilemon found that project were more likely to fail when project managers relied too heavily on using authority, money or penalty to influence people. When project managers used work challenge and expertise to influence people, projects were more likely to succeed. The effectiveness of work challenge in influencing people is consistent with Maslow's and Herzberg's research on motivation.

Influence is related to the highly studied concept of power. The five main types

of power include:
1. Coercive power, which involves using punishment, threats, or other negative approaches to get people to do things they do not want to do.
2. Legitimate power, which is getting people to do things based on a position of authority.
3. Expert power, which involves using one's personal knowledge and expertise to get people to change their behavior.
4. Reward power, which involves using incentives to induce people to do things.
5. Referent power, which is based on an individual's personal charisma.

ORGANIZATIONAL PLANNING
Organizational planning for a project involves identifying, documenting, and assigning project roles. responsibilities, and reporting relationships. Among the tools used are an organization chart, a responsibility assignment matrix and a staffing management plan. The organization chart exhibits the lines of reporting authority. The responsibility assignment matrix shows who has what responsibility relative to each of the tasks that make up the project.

STAFF ACQUISITION
Staff acquisition usually requires the project manager to negotiate with line managers and upper-level managers for the human resources that are needed.

TEAM DEVELOPMENT
The five phases of team development (Keller) should be adhered to and the time to start that is in the second stage—Planning and Budgeting.

Chapter 7: Definitions

Activity

Burst activity

Early finish

Early start

Late finish

Late start

Merge activity

Staff acquisition

Task

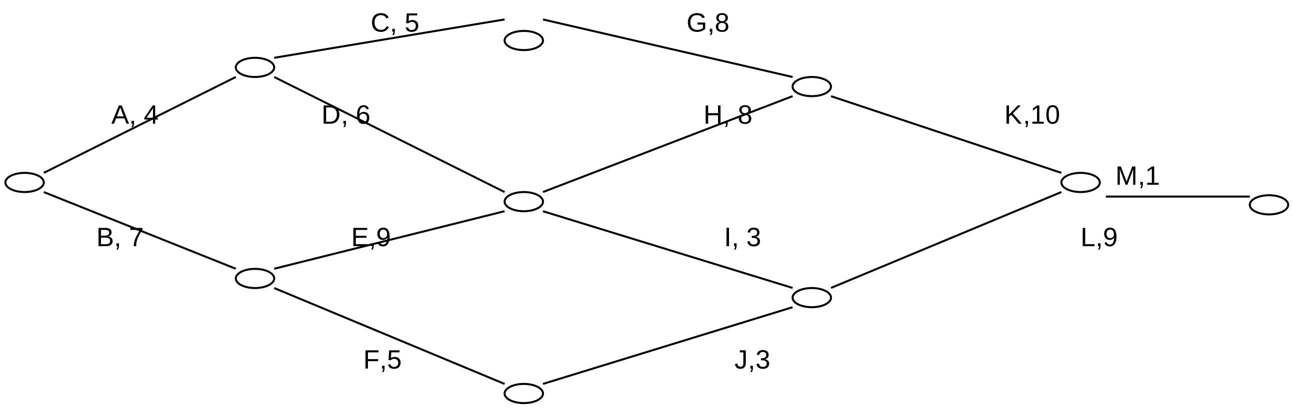
Team development

Chapter 7: Exercises

1. Draw an activity on node representation for the following network information. Find the critical path, and determine its length. For each activity determine its earliest start time, its earliest finish time, its latest start time and its latest finish time.

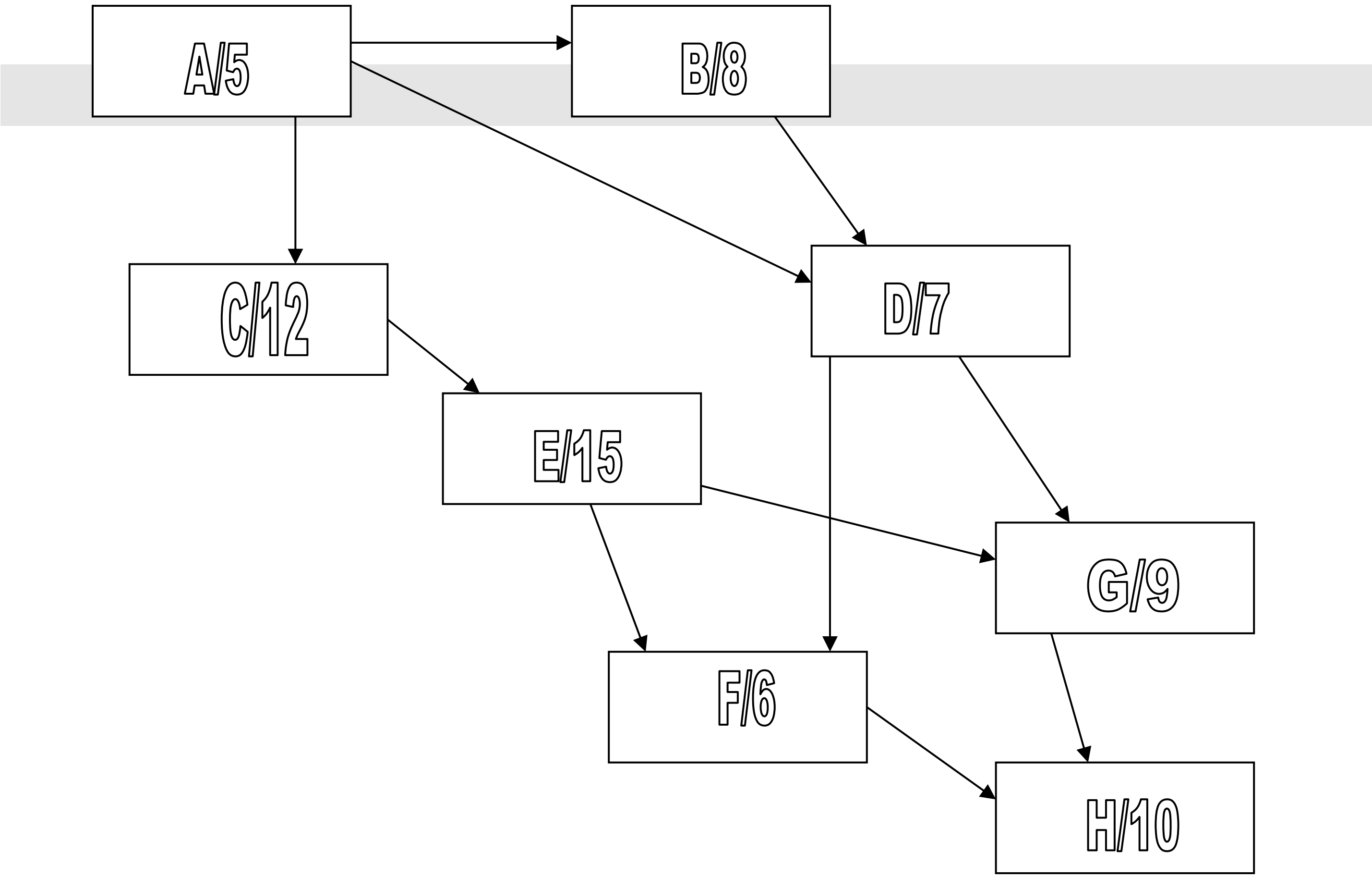
ACT.	DURATION	PRECEDENT ACTIVITY
A	5	-
B	6	-
C	8	A, B
D	7	A, B
E	9	B, C
F	8	C, D
G	10	E,F

2. Translate this diagram to an activity in the box format. Calculate ES, EF, LS and LF times and the slack for each activity in the figure below, where an activity is represented by an arrow.



3. In problem 2 above, determine the critical path and determine the activity with the greatest slack.

4. Find all the paths through the network below. Find the critical path for this project (the one shown below). The number in each box represents the duration in days of the associated task. For each task, determine ES, EF, LS, LF and slack. Place the ES number on the upper corner left above each block, the EF number on the upper right above each block, the LS number on the lower left corner below each block and the LF number on the lower right below each block.



5. Draw an activity on node representation for the following network information. Find the critical path, and determine its length. For each activity determine its earliest start time, its earliest finish time, its latest start time and its latest finish time.

ACT.	DURATION	PRECEDENT ACTIVITY
A	**9**	**-**
B	**8**	**A**
C	**12**	**A**
D	**12**	**B, C**
E	**11**	**B, C**
F	**6**	**D, E**
G	**9**	**D,E,F**

6. As a newly-appointed project manager, you are well aware that there is a terrific rush at the end to get projects done on time within your organization. In the past these gigantic midnight madness initiatives have been effective. You have to decide whether you will continue to reward the heroics that are necessary to effect such completions. What is the effect of rewarding heroics on project completions? Will you continue to reward them?

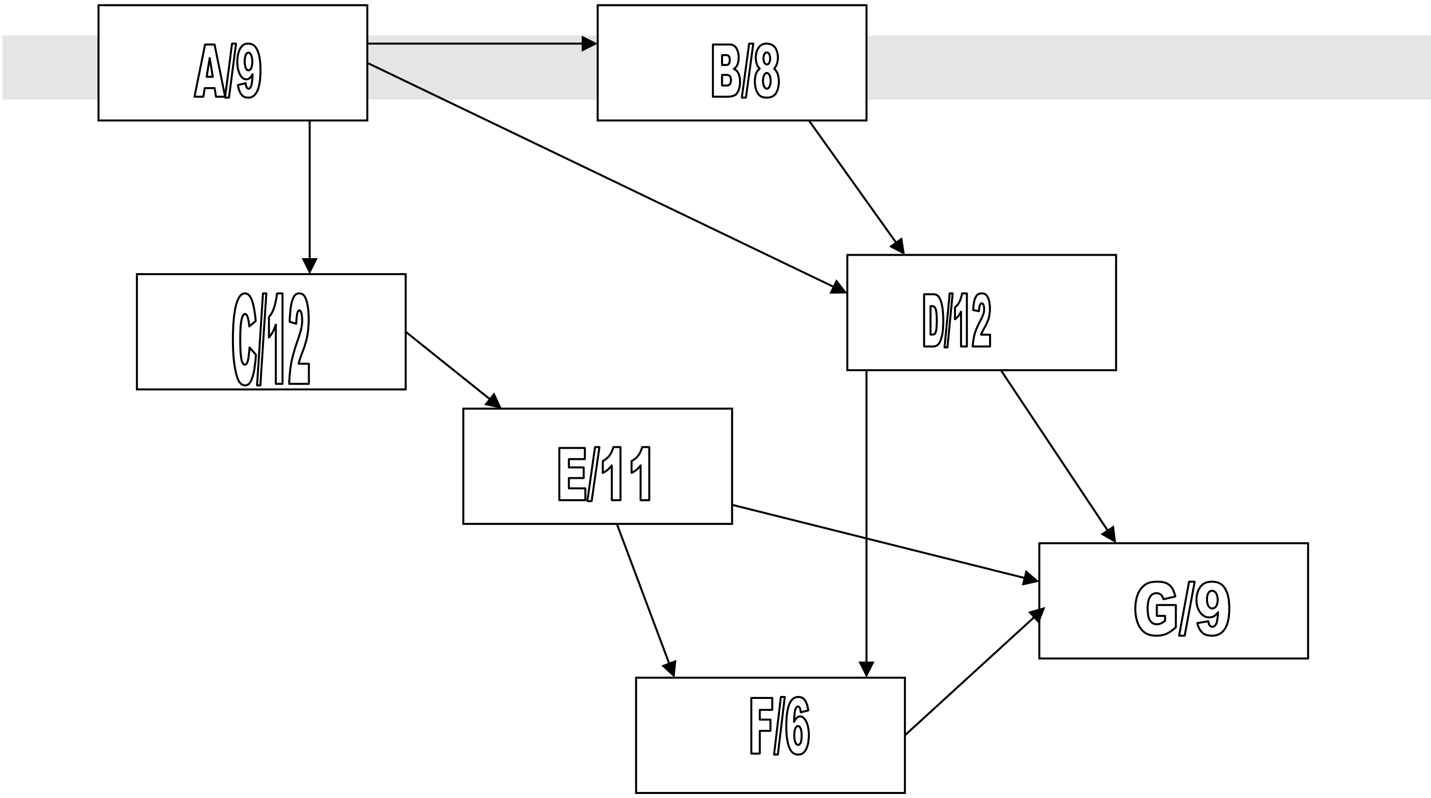
7. Draw an activity on node representation for the following network information. Find the critical path, and determine its length. For each activity determine its earliest start time, its earliest finish time, its latest start time, its latest finish time and the slack time.

ACT.	DURATION	PRECEDENT ACTIVITY
A	**6**	**-**
B	**4**	**-**
C	**8**	**A, B**
D	**9**	**A, B**
E	**3**	**B, C**
F	**5**	**C, D**
G	**6**	**E,F**

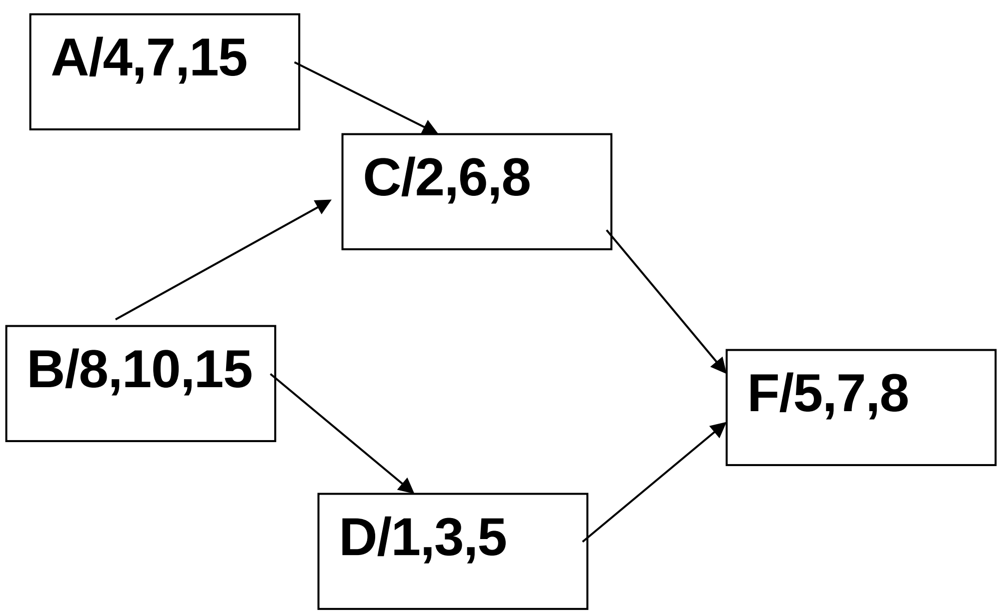
8. A list of major tasks required to create a software product is provided below. Also given are the predecessor tasks together with the number of days required to accomplish each task. Use an activity on node representation. For each node box, determine the ES (earliest start), EF (earliest finish), LS (latest start), and LF (latest finish) numbers**. Draw the NETWORK diagram (activity-in-box) and determine the critical path**.

TASK	DESCRIPTION	PREDECESSOR.	DAYS
A	Interview management	--	2
B	Interview operations	--	4
C	Interview technical staff	--	2
D	Prep req. document	A,B,C	2
E	Prep RFP and transmit	D	2
F	Await receipt of proposals	E	14
G	Write Acceptance Criteria	D	2
H	Prototype solution	E	10
I	Test prototype	H	5
J	Develop prototype project plan	H	3
K	Evaluate proposals	G, F, I, J	2
L	Request final bid	K	1
M	Make vendor decision	L	1

9. Find all the paths through the network below. Find the critical path for this project. The number in each box represents the duration in days of the associated task. For each task, deter mine ES, EF, LS, LF and slack. Place the ES number on the upper corner left above each block, the EF number on the upper right above each block, the LS number on the lower left corner below each block and the LF number on the lower right below each block.

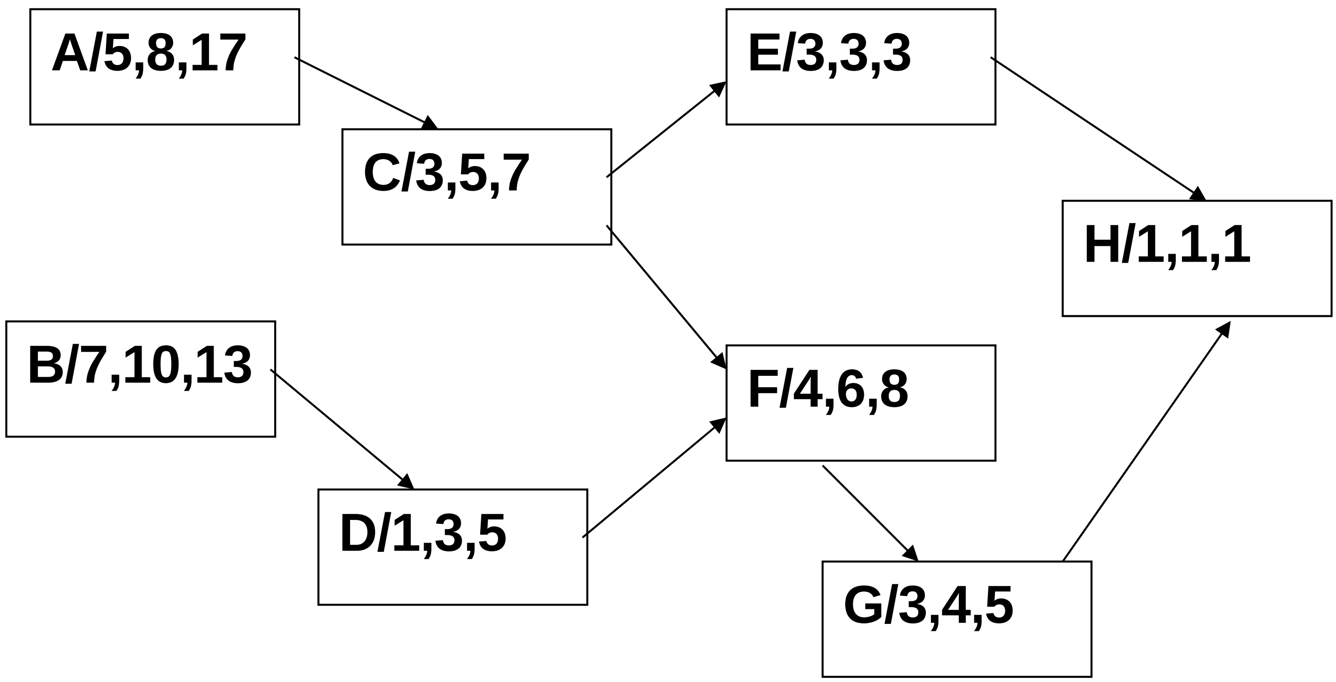


10. For the PERT network shown below, find the critical path and its expected mean duration. Assume all durations are in days. Find the standard deviation of the critical path. What is the probability the project depicted by this network will be finished in 23 days? In 19 days? In 25 days.



11. For each activity box in the figure above, find the ES, EF, LS, and Lf times.

12. For the PERT network shown below, find the critical path and its expected mean duration. Assume all durations are in days. Find the standard deviation of the critical path. What is the probability the project depicted by this network will be finished in 20 days? In 25 days? In 30 days.



13. For each activity box in the figure above, find the ES, EF, LS, and Lf times.

Brief Case 1. A pair of authors have decided to write a textbook and publish it with a major textbook company. The textbook is to submitted to the publisher in camera-ready form by the authors. The authors must complete the entire book project within two years—730 days. A list of activities, estimated activity times, and predecessors for this project are given in the Table below.

ACTI VITY	DESCRIPTION	PREDEC ESSOR	A	M	B
A	Write Prospectus, table of contents, preface, 2 chapters	-	75	100	120
B	Send material in A out for review	A	30	60	90
C	Write next four chapters	A	120	150	180
D	Revise table of contents, preface, first 2 chapters based on reviewers comments	B	20	20	20
E	Sign contract with publisher	D	15	30	45
F	Complete last nine chapters	C, E	180	200	300
G	Revise manuscript as required	F	60	100	180
H	Have figures professionally drawn	F	12	15	24
I	Have manuscript edited and printed on “blue-line” paper ready fir camera	F	30	60	75
J	Obtain permission to use published excerpts	H	100	120	150
K	Prepare detailed marketing plan	E	15	30	45
L	Edit and re-print entire manuscript one more time	H	60	75	120
M	Promote book at national meeting	K	5	5	5
N	Publish and distribute textbook	L	30	30	60

a. Analyze the project using WINQSB's PERT_CPM module. Will the authors meet the two-year deadline? What is the critical path? Print out the solution page as well as the PERT network.

b. Activity A is known as a "bottleneck" activity., since it is on every possible path through the network. Experiment with A, M, and B for this activity and note the effect on expected completion time and "probability of on-time completion" for this project.

Brief Case 2. Table 7.4 below is the network representation of a major skyscraper construction project.

ACTIVITY	PREDECESSOR	A	M	B
A	-	3	7	12
B	-	4	8	11
C	-	1	2	9
D	A	11	21	25
E	A, C	6	7	8
F	B	16	19	30
G	A, C	1	2	4
H	A, C	2	6	9
I	A, C	17	30	36
J	E	17	19	20
K	D, G	3	4	12
L	H	4	6	8
M	K, H	2	2	2
N	F, I, J, L, M	1	2	15
O	N	3	6	10
P	N	4	11	12
Q	O	1	2	3
R	P	6	9	15
S	R	3	7	12
T	Q, S	16	20	35
U	P	10	15	20

Table 7.4 Skyscraper construction Project

a. Using WINQSB's PERT_CPM module, analyze the network. How long does it take to complete the project? What is the probability of completing this project in 730 days?

b. For obvious reasons, activity N is called a "bottleneck" activity, since the thirteen activity A-M must all be completed before work can be begun on this activity. What are the managerial implications of dealing with a "bottleneck" activity?

c. Is the project represented by Table 7.4 a "tight" project, in the sense that several paths are close to being critical?

Brief Case 3. Model a project of interest to you as a PERT-type network, and analyze it using a program like WINQSB. Some suggestions follow: The project of getting a degree; planning a skiing or backpacking trip; climbing a mountain; making a complete Thanksgiving dinner; executing an offensive play in football; moving to a new house or apartment; changing jobs, etc.

References

Herzberg, Frederick, "One More Time: How Do You Motivate Employees?" *Harvard Business Review* (February 1968): pp. 51-62.