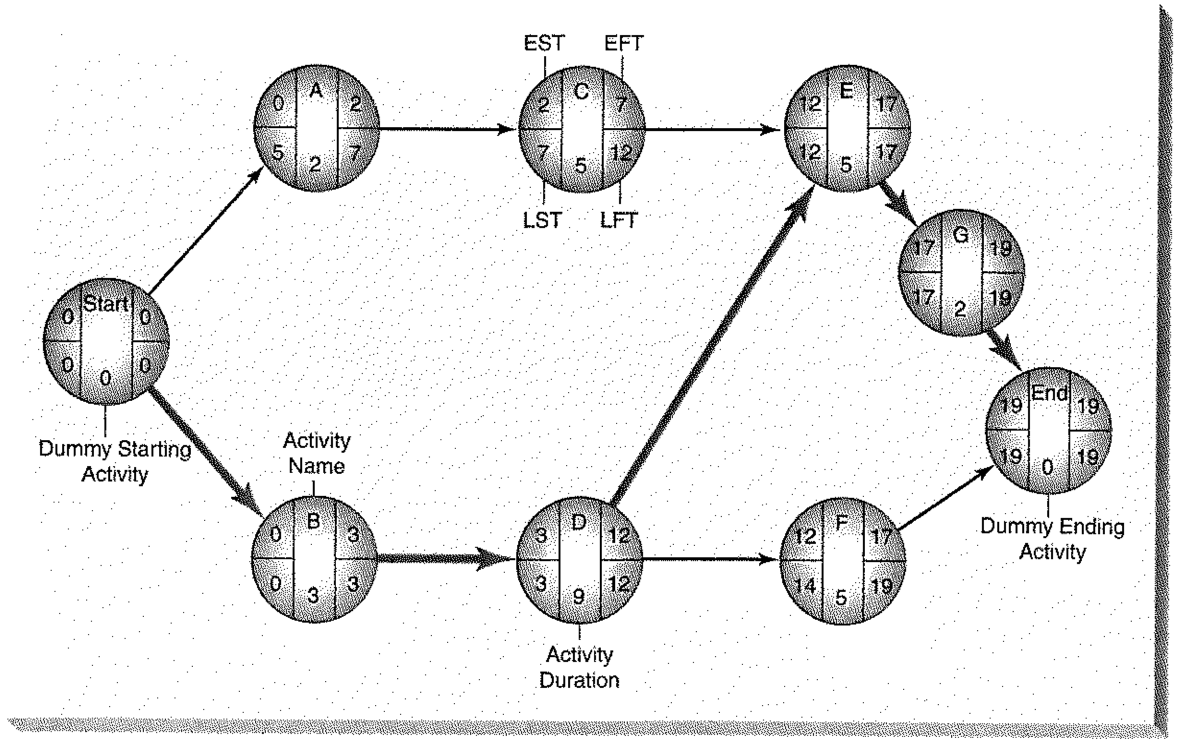
FIGURE 7.20 **Critical Path for Solved Problem 7-2**



successors. Hence, in addition to a dummy unique starting activity (Start), we have included a dummy unique finishing activity (End) for the project.

Figure 7.20 shows the earliest and latest times for all activities. The activities along the critical path are B, D, E, and G. These activities have zero slack. The expected project completion time is 19 weeks. The sum of the variances of the critical activities is 1.333, which implies that the standard deviation of the project completion time is 1.155 weeks. Hence,

$$P(\text{Completion time} \leq 22 \text{ weeks}) = P(Z \leq (21-19)/1.155) = P(Z \leq 1.73) = 0.9582 \text{ (from Appendix C)}$$

DISCUSSION QUESTIONS AND PROBLEMS

Discussion Questions

7-1 What are some of the questions that can be answered with project management?

7-2 What are the major differences between PERT and CPM?

7-3 What is an activity? What is an immediate predecessor?

7-4 Describe how expected activity times and variances can be computed in a PERT analysis.

7-5 Briefly discuss what is meant by critical path analysis. What are critical path activities, and why are they important?

7-6 What are the EST and LST? How are they computed?

7-7 Describe the meaning of slack and discuss how it can be determined.

7-8 How can we determine the probability that a project will be completed by a certain date? What assumptions are made in this computation?

7-9 Briefly describe how project budgets can be monitored.

7-10 What is crashing, and how is it done by hand?

7-11 Why is LP useful in project crashing?

Problems

7-12 Sid Davidson is the personnel director of Babson and Willcount, a company that specializes in consulting and research. One of the training programs that Sid is considering for the middle-level managers of Babson and Willcount is leadership training. Sid has listed a number of activities that must be completed before a training program of this nature can be conducted. The activities, their immediate predecessors, and estimated durations appear in the following table:

Activity	Immediate Predecessors	Time (Days)
A	—	2
B	—	5
C	—	1
D	B	10
E	A, D	3
F	C	6
G	E, F	8

(a) Develop a project network for this problem.
(b) Determine the EST, EFT, LST, LFT, and slack for each activity. Also determine the total project completion time and the critical path(s).

7-13 Terry Anderson is responsible for planning a local political campaign. A variety of activities need to be coordinated in order to be prepared for the upcoming election date. The following table describes the relationships between these activities that need to be completed, as well as estimated times:

Activity	Immediate Predecessors	Time (Weeks)
A	—	3
B	—	5
C	A	7
D	A	5
E	B, C	4
F	B	6
G	D, E	2
H	F	3

(a) Develop a project network for this problem.
(b) Determine the EST, EFT, LST, LFT, and slack for each activity. Also determine the total project completion time and the critical path(s).

7-14 Monohan Machinery specializes in developing weed-harvesting equipment that is used to clear small lakes of weeds. George Monohan, president of Monohan Machinery, is convinced that harvesting weeds is far better than using chemicals to kill them. Chemicals cause pollution, and the weeds seem to grow faster after chemicals have been used. George is contemplating the construction of a machine that would harvest weeds on narrow rivers and waterways. The activities that are necessary to build one of these experimental weed-harvesting machines are listed in the following table, along with their immediate predecessors and estimated durations:

Activity	Immediate Predecessors	Time (Days)
A	—	6
B	—	5
C	A	3
D	A	2
E	B	4
F	B	6
G	C, E	10
H	D, F	7

(a) Develop a project network for this problem.
(b) Determine the EST, EFT, LST, LFT, and slack for each activity. Also determine the total project completion time and the critical path(s).

7-15 The Johnstone Advertising Agency is developing a TV advertising campaign for a new client. The following table describes the relationships between the activities that need to be completed:

Activity	Immediate Predecessors	Time (Days)
A	—	4
B	A	6
C	B	12
D	B	11
E	D	9
F	D	8
G	D	10
H	C	5
I	C	7
J	E, F, G	4
K	H, I	9

(a) Develop a project network for this problem.
(b) Determine the EST, EFT, LST, LFT, and slack for each activity. Also determine the total project completion time and the critical path(s).

7-16 Tim Smith is responsible for planning an installation of a computer system. The following table describes the relationships between the activities that need to be completed:

ACTIVITY	IMMEDIATE PREDECESSORS	TIME (DAYS)
A	—	5
B	A	6
C	A	2
D	A	9
E	B	9
F	C, D	3
G	D	7
H	D	4
I	E, F, G	6
J	H	5

(a) Develop a project network for this problem.
(b) Determine the EST, EFT, LST, LFT, and slack for each activity. Also determine the total project completion time and the critical path(s).

7-17 Zuckerman Wiring and Electric is a company that installs wiring and electrical fixtures in residential construction. John Zuckerman has been concerned with the amount of time it takes to complete wiring jobs. Some of his workers are very unreliable. A list of activities and their optimistic, their pessimistic, and their most likely completion times, in days, are given in the following table:

	DAYS			
ACTIVITY	*a*	*m*	*b*	IMMEDIATE PREDECESSORS
A	3	6	8	—
B	2	4	4	—
C	1	2	3	—
D	6	7	8	C
E	2	4	6	B, D
F	6	10	14	A, E
G	1	2	4	A, E
H	3	6	9	F
I	10	11	12	G
J	14	16	20	G
K	2	8	10	H, I

(a) Develop a project network for this problem.
(b) Determine the expected duration and variance for each activity.
(c) Zuckerman would like to determine the EST, EFT, LST, LFT, and slack for each activity. He also wants to determine the total project completion time and critical path(s) for installing electrical wiring and equipment.
(d) What is the probability that Zuckerman will finish the project in 40 days or less?

7-18 A plant engineering group needs to set up an assembly line to produce a new product. The following table describes the relationships between the activities that need to be completed for this product to be manufactured:

	DAYS			
ACTIVITY	*a*	*m*	*b*	IMMEDIATE PREDECESSORS
A	3	6	8	—
B	5	8	10	A
C	5	6	8	A
D	1	2	4	B, C
E	7	11	17	D
F	7	9	12	D
G	6	8	9	D
H	3	4	7	F, G
I	3	5	7	E, F, H

(a) Develop a project network for this problem.
(b) Determine the expected duration and variance for each activity.
(c) Determine the EST, EFT, LST, LFT, and slack for each activity. Also determine the total project completion time and the critical path(s).
(d) Determine the probability that the project will be completed in less than 34 days.
(e) Determine the probability that the project will take more than 29 days.

7-19 Tom Schriber, director of personnel of Management Resources, Inc., is in the process of designing a program that the company's customers can use in the job-finding process. Some of the activities include preparing resumés, writing letters, making appointments to see prospective employers, researching companies and industries, and so on. Some of the information on the activities is shown in the table at the top of page 345.

(a) Determine the expected times and variances for each activity.
(b) Construct a project network for this problem.
(c) Determine the EST, EFT, LST, LFT, and slack for each activity. Also determine the critical path and project completion time.
(d) What is the probability that the project will be finished in 70 days?
(e) What is the probability that the project will need at least 75 days?

Table for Problem 7-19

	Days			Immediate
Activity	a	m	b	Predecessors
A	8	10	12	—
B	6	7	9	—
C	3	3	4	—
D	10	20	30	A
E	6	7	8	C
F	9	10	11	B, D, E
G	6	7	10	B, D, E
H	14	15	16	F
I	10	11	13	F
J	6	7	8	G, H
K	4	7	8	I, J
L	1	2	4	G, H

7-20 Laura Thompson needs to plan and manage a local construction project. The following table describes the relationships between the activities that need to be completed:

	Days			Immediate
Activity	a	m	b	Predecessors
A	4	8	13	—
B	4	10	15	A
C	7	14	20	B
D	9	16	19	B
E	6	9	11	B
F	2	4	5	D, E
G	4	7	11	C, F
H	3	5	9	G
I	2	3	4	G, H

(a) Determine the expected times and variances for each activity.
(b) Construct a project network for this problem.
(c) Determine the EST, EFT, LST, LFT, and slack for each activity. Also determine the critical path and project completion time.
(d) What is the probability that the project will be finished in less than 57 days?
(e) What is the probability that the project will need at least 50 days?

7-21 David Stockman is responsible for developing a supervisory training program for his organization. The following table describes the relationships between the activities that need to be completed:

	Days			Immediate
Activity	a	m	b	Predecessors
A	3	7	13	—
B	5	10	17	—
C	3	5	8	A, B
D	5	12	14	C
E	2	5	9	C
F	2	5	15	E
G	5	8	12	F
H	6	10	12	D
I	3	4	8	F, H
J	4	7	10	G, I

(a) Determine the expected times and variances for each activity.
(b) Construct a project network for this problem.
(c) Determine the EST, EFT, LST, LFT, and slack for each activity. Also determine the critical path and project completion time.
(d) What is the probability that the project will be finished in less than 49 days?
(e) What is the probability that the project will need at least 54 days?

7-22 Ed Rose was able to determine that the expected project completion time for the construction of a pleasure yacht is 21 months, and the project variance is 4. What is the probability that the project will

(a) need at least 17 months?
(b) be completed in 20 months?
(c) need at least 23 months?
(d) be completed in 25 months?

7-23 Cirillo Brothers Construction Company has determined that the expected completion time for its most popular model home follows the normal probability distribution with a mean of 25 weeks and a standard deviation of 4 weeks.

(a) What is the probability that the next home will be completed within 30 weeks?
(b) What is the probability that the next home will be completed within 22 weeks?
(c) Find the number of weeks within which Cirillo Brothers is 99% sure the next home will be completed.
(d) Find the number of weeks within which Cirillo Brothers is 85% sure the next home will be completed.

7-24 The General Foundry air pollution project discussed in this chapter has progressed over the past several weeks, and it is now the end of week 8. Lester Harky would like to know the value of the work completed, the amount of any cost overruns or underruns for the project, and the extent to which the project is ahead of schedule or behind schedule by developing a table like the one in Table 7.7 (see page 323). The current project status is shown in the following table:

Activity	Percentage Completed	Actual Cost
A	100	$20,000
B	100	$36,000
C	100	$26,000
D	100	$44,000
E	50	$25,000
F	60	$15,000
G	10	$ 5,000
H	10	$ 1,000

7-25 Fred Ridgeway has been given the responsibility of managing a training and development program. He knows the EST and LST (both in months), and the total costs for each activity. This information is given in the following table:

Activity	EST	LST	t	Total Cost
A	0	0	6	$10,000
B	1	4	2	$14,000
C	3	3	7	$ 5,000
D	4	9	3	$ 6,000
E	6	6	10	$14,000
F	14	15	11	$13,000
G	12	18	2	$ 4,000
H	14	14	11	$ 6,000
I	18	21	6	$18,000
J	18	19	4	$12,000
K	22	22	14	$10,000
L	22	23	8	$16,000
M	18	24	6	$18,000

(a) Using ESTs, determine Fred's total monthly budget.

(b) Using LSTs, determine Fred's total monthly budget.

7-26 Fred Ridgeway's project (see Problem 7-25) has progressed over the past several months, and it is now the end of month 16. Fred would like to know the current status of the project with regard to schedule and budget by developing an appropriate table. The relevant data are shown in the following table:

Activity	Percentage Completed	Actual Cost
A	100	$13,000
B	100	$12,000
C	100	$ 6,000
D	100	$ 6,000
E	80	$12,000
F	13	$ 1,000
G	100	$ 4,500
H	20	$ 500

Assume that activities not shown in the table have not yet started and have incurred no cost to date. All activities follow their earliest time schedules.

7-27 Susan Roger needs to coordinate the opening of a new office for her company in the city of Denver. The activity time and relationships for this project, as well as the total budgeted cost for each activity, are shown in the following table:

Activity	Immediate Predecessors	Time (Weeks)	Total Cost
A	—	2	$1,400
B	A	3	$4,800
C	A	4	$4,000
D	B, C	2	$2,800
E	C	3	$2,400
F	D, E	3	$1,500

(a) Develop a weekly budget for this project using the earliest start times.

(b) Develop a weekly budget for this project using the latest start times.

7-28 Susan Roger's project (see Problem 7-27) has progressed over the past several weeks, and it is now the end of week 8. Susan would like to know the current status of the project with regard to schedule and budget by developing an appropriate table. Assume that all activities follow their earliest time schedules. The relevant data are shown in the following table:

Activity	Percentage Completed	Actual Cost
A	100	$1,500
B	100	$4,500
C	100	$4,000
D	70	$2,800
E	70	$2,000
F	0	$ 0

7-29 General Foundry's project crashing data are shown in Table 7.10 on page 327. Crash this project by hand to 11 weeks. What are the final times for each activity after crashing?

7-30 Bowman Builders manufactures steel storage sheds for commercial use. Joe Bowman, president of Bowman Builders, is contemplating producing sheds for home use. The activities necessary to build an experimental model and related data are given in the following table:

Activity	Immediate Predecessors	Normal Time (Weeks)	Normal Cost	Crash Time (Weeks)	Crash Cost
A	—	3	$1,000	2	$1,600
B	—	2	$2,000	1	$2,700
C	—	1	$ 300	1	$ 300
D	A	7	$1,300	3	$1,600
E	B	6	$ 850	3	$1,000
F	C	2	$4,000	1	$5,000
G	D, E	4	$1,500	2	$2,000

Set up and solve an LP model using Excel to crash this project to 10 weeks.

7-31 The following table describes the various activities of a construction project in a chemical plant:

Activity	Immediate Predecessors	Normal Time (Days)	Normal Cost	Crash Time (Days)	Crash Cost
A	—	4	$2,000	2	$2,600
B	A	6	$3,500	5	$4,300
C	A	8	$3,300	6	$3,900
D	B	5	$1,200	4	$1,800
E	C, D	3	$1,700	2	$2,200
F	E	7	$2,200	5	$3,600
G	E	5	$ 900	4	$1,550
H	F, G	4	$1,200	3	$1,700

Set up and solve an LP model using Excel to crash this project to 23 days. What is the total crashing cost?

7-32 A new order filling system needs to be installed as soon as possible. The following activities need to be completed in the order shown here (see Table for Problem 7-32). Also provided is the cost information to reduce the normal activity times.

Set up and solve an LP model using Excel to crash this project to 25 days. What is the total crashing cost?

Table for Problem 7-32

Activity	Immediate Predecessors	Normal Time (Days)	Normal Cost	Crash Time (Days)	Crash Cost
A	—	7	$2,000	5	$ 3,500
B	A	10	$3,000	8	$ 4,700
C	A	8	$3,400	7	$ 3,700
D	C	6	$1,600	4	$ 2,600
E	C	7	$1,900	4	$ 4,000
F	D, E	5	$1,200	3	$ 2,800
G	B, C	11	$8,200	8	$10,900
H	F, G	4	$2,600	3	$ 3,800

7-33 Software Development Specialists (SDS) is involved with developing software for customers in the banking industry. SDS breaks a large programming project into teams that perform the necessary steps. Team A is responsible for going from general systems design all the way through to actual systems testing. This involves 18 separate activities. Team B is then responsible for the final installation.

To determine cost and time factors, optimistic, most likely, and pessimistic time estimates have been made for all of the 18 activities involved for team A. The first step that this team performs is general systems design. The optimistic, most likely, and pessimistic times are 3 weeks, 4 weeks, and 5 weeks. Following this, a number of activities can begin. Activity 2 is involved with procedures design. Optimistic, most likely, and pessimistic times for completing this activity are 4, 5, and 7 weeks. Activity 3 is developing detailed report designs. Optimistic, most likely, and pessimistic time estimates are 6, 8, and 9 weeks. Activity 4, detailed forms design, has optimistic, most likely, and pessimistic time estimates of 2, 3, and 5 weeks.

Activities 5 and 6 involve writing detailed program specifications and developing file specifications. The three time estimates for activity 5 are 6, 7, and 9 weeks, and the three time estimates for activity 6 are 3, 4, and 5 weeks. Activity 7 involves specifying system test data. Before this is done, activity 6, involving file specifications, must be completed. The time estimates for activity 7 are 2, 4, and 5 weeks. Activity 8 involves reviewing forms. Before activity 8 can be conducted, detailed forms design must be completed. The time estimates for activity 8 are 3, 4, and 6 weeks. The next activity, activity 9, is reviewing the detailed report design. This requires that the detailed report design, activity 3, be completed first. The time estimates for activity 9 are 1, 2, and 4 weeks, respectively.

Activity 10 involves reviewing procedures design. Time estimates are 1, 3, and 4 weeks. Of course, procedures design must be done before activity 10 can be started. Activity 11 involves the system design checkpoint review. A number of activities must be completed before this is done. These activities include reviewing the forms, reviewing the detailed report design, reviewing the procedures design, writing detailed program specs, and specifying system test data. The optimistic, most likely, and pessimistic time estimates for activity 11 are 3, 4, and 6 weeks. Performing program logic design is activity 12. This can be started only after the system design checkpoint review is completed. The time estimates for activity 12 are 4, 6, and 7 weeks.

Activity 13, coding the programs, is done only after the program logic design is completed. The time estimates for this activity are 6, 8, and 10 weeks. Activity 14 is involved in developing test programs. Activity 13 is the immediate predecessor. Time estimates for activity 14 are 3, 4, and 6 weeks. Developing a system test plan is activity 15. A number of activities must be completed before activity 15 can be started. These activities include specifying system test data, writing detailed program specifications, and reviewing procedure designs, the detailed report design, and forms. The time estimates for activity 15 are 3, 4, and 5 weeks.

Activity 16, creating system test data, has time estimates of 2, 4, and 6 weeks. Activity 15 must be done before activity 16 can be started. Activity 17 is reviewing program test results. The immediate predecessor to activity 17 is to test the programs (activity 14). The three time estimates for activity 17 are 2, 3, and 4 weeks.

The final activity is conducting system tests. This is activity 18. Before activity 18 can be started, activities 16 and 17 must be complete. The three time estimates for conducting these system tests are 3, 5, and 6 weeks.

How long will it take for team A to complete its programming assignment?

7-34 Bender Construction Co. is involved in constructing municipal buildings and other structures that are used primarily by city and state municipalities. This requires developing legal documents, drafting feasibility studies, obtaining bond ratings, and so forth. Recently, Bender was given a request to submit a proposal for the construction of a municipal building. The first step is to develop legal documents and to perform all steps necessary before the construction contract is signed. This requires more than 20 separate activities that must be completed. These activities, their immediate predecessors, and optimistic (a), most likely (m), and pessimistic (b) time estimates are given in the following table:

Table for Problem 7-34

	Weeks Required				
Activity	a	m	b	Description of Activity	Immediate Predecessors
1	1	4	5	Draft legal documents	—
2	2	3	4	Prepare financial statements	—
3	3	4	5	Draft history	—
4	7	8	9	Draft demand portion of feasibility study	—
5	4	4	5	Review and approval of legal documents	1
6	1	2	4	Review and approval of history	3
7	4	5	6	Review feasibility study	4
8	1	2	4	Draft final financial portion of feasibility study	7
9	3	4	4	Draft facts relevant to the bond transaction	5
10	1	1	2	Review and approve financial statements	2
11	18	20	26	Receive firm price of project	—
12	1	2	3	Review and complete financial portion of feasibility study	8
13	1	1	2	Complete draft statement	6, 9, 10, 11, 12
14	0.10	0.14	0.16	Send all materials to bond rating services	13
15	0.20	0.30	0.40	Print statement and distributed it to all interested parties	14
16	1	1	2	Make presentation to bond rating services	14
17	1	2	3	Receive bond rating	16
18	3	5	7	Market bonds	15, 17
19	0.10	0.10	0.20	Execute purchase contract	18
20	0.10	0.14	0.16	Authorize and complete final statement	19
21	2	3	6	Purchase contract	19
22	0.10	0.10	0.20	Make bond proceeds available	20
23	0	0.20	0.20	Sign construction contract	21, 22

Determine the total project completion time for this preliminary step, the critical path, and slack time for all activities involved.

7-35 Getting a degree from a college or university can be a long and difficult task. Certain courses must be completed before other courses may be taken. Develop a network diagram in which every activity is a particular course that you must take for your degree program. The immediate predecessors will be course prerequisites. Don't forget to include all university, college, and departmental course requirements. Then try to group these courses into semesters or quarters for your particular school. How long do you think it will take you to graduate? Which courses, if not taken in the proper sequence, could delay your graduation?

7-36 Dream Team Productions is in the final design phases of its new film, *Killer Worms*, to be released next summer. Market Wise, the firm hired to coordinate the release of *Killer Worms* toys, has identified 16 activities to be completed before the release of the film. These activities, their immediate predecessors, and optimistic (a), most likely (m), and pessimistic (b) time estimates are given in the following table:

		Weeks Required		
Activity	Immediate Predecessors	a	m	b
A	—	1	2	4
B	—	3	3.5	4
C	—	10	12	13
D	—	4	5	7
E	—	2	4	5
F	A	6	7	8
G	B	2	4	5.5
H	C	5	7.7	9
I	C	9.9	10	12
J	C	2	4	5
K	D	2	4	6
L	E	2	4	6
M	F, G, H	5	6	6.5
N	J, K, L	1	1.1	2
O	I, M	5	7	8
P	N	5	7	9

(a) How many weeks in advance of the film release should Market Wise start its marketing campaign? What are the critical paths?

(b) If activities I and J were not necessary, what impact would this have on the critical path and the number of weeks needed to complete the marketing campaign?

7-37 Sager Products has been in the business of manufacturing and marketing toys for toddlers for the past two decades. Jim Sager, president of the firm, is considering the development of a new manufacturing line to allow it to produce high-quality plastic toys at reasonable prices. The development process is long and complex. Jim estimates that there are five phases involved and multiple activities for each phase.

Phase 1 of the development process involves the completion of four activities. These activities have no immediate predecessors. Activity A has an optimistic completion time of 2 weeks, a probable completion time of 3 weeks, and a pessimistic completion time of 4 weeks. Activity B has estimated completion times of 5, 6, and 8 weeks; these represent optimistic, probable, and pessimistic time estimates. Similarly, activity C has estimated completion times of 1 week, 1 week, and 2 weeks; and activity D has expected completion times of 8 weeks, 9 weeks, and 11 weeks.

Phase 2 involves six separate activities. Activity E has activity A as an immediate predecessor. Time estimates are 1 week, 1 week, and 4 weeks. Activity F and activity G both have activity B as their immediate predecessor. For activity F, the time estimates are 3 weeks, 3 weeks, and 4 weeks. For activity G, the time estimates are 1 week, 2 weeks, and 2 weeks. The only immediate predecessor for activity H is activity C. Time estimates for activity H are 5 weeks, 5 weeks, and 6 weeks. Activity D must be performed before activity I and activity J can be started. Activity I has estimated completion times of 9 weeks, 10 weeks, and 11 weeks. Activity J has estimated completion times of 1 week, 2 weeks, and 2 weeks.

Phase 3 is the most difficult and complex of the entire development project. It also consists of six separate activities. Activity K has three time estimates of 2 weeks, 2 weeks, and 3 weeks. The immediate predecessor for this activity is activity E. The immediate predecessor for activity L is activity F. The time estimates for activity L are 3 weeks, 4 weeks, and 6 weeks. Activity M has 2 weeks, 2 weeks, and 4 weeks for the estimates of the optimistic, probable, and pessimistic time estimates. The immediate predecessor for activity M is activity G. Activities N and O both have activity I as their immediate predecessor. Activity N has 8 weeks, 9 weeks, and 11 weeks for its three time estimates. Activity O has 1 week, 1 week, and 3 weeks as its time estimates. Finally, activity P has time estimates of 4 weeks, 4 weeks, and 8 weeks. Activity J is the only immediate predecessor.

Phase 4 involves five activities. Activity Q requires activity K to be completed before it can be started. The three time estimates for activity Q are 6 weeks, 6 weeks, and 7 weeks. Activity R requires that both activity L and activity M be completed first. The three time estimates for activity R are 1, 2, and 4 weeks. Activity S requires activity N to be completed first. Its time estimates are 6 weeks, 6 weeks, and 7 weeks. Activity T requires that activity O be completed. The time estimates for activity T are 3 weeks, 3 weeks, and 4 weeks. The final activity for phase 4 is activity U. The time estimates for this activity are 1 week, 2 weeks, and 3 weeks. Activity P must be completed before activity U can be started.

Phase 5 is the final phase of the development project. It consists of only two activities. Activity V requires that activity Q and activity R be completed before it can be started. Time estimates for this activity are 9 weeks, 10 weeks, and 11 weeks. Activity W is the final activity of the process. It requires three activities to be completed before it can be started: activities S, T, and U. The estimated completion times for activity W are 2 weeks, 4 weeks, and 5 weeks.

(a) Given this information, determine the expected completion time for the entire process. Also determine which activities are along the critical path.
(b) Jim hopes that the total project will take less than 40 weeks. Is this likely to occur?
(c) Jim has just determined that activities D and I have already been completed and that no additional work is required on these activities. What is the impact of this change on the activities along the critical path?

CASE STUDY

Haygood Brothers Construction Company

George and Harry Haygood are building contractors who specialize in the construction of private home dwellings, storage warehouses, and small businesses (less than 20,000 sq. ft. of floor space). Both George and Harry entered a carpenter union's apprenticeship program in the early 1990s and, upon completion of the apprenticeship, became skilled craftsmen in 1996. Before going into business for themselves, they worked for several local building contractors in the Detroit area.

Typically, Haygood Brothers submits competitive bids for the construction of proposed dwellings. Whenever its bids are accepted, various aspects of the construction (e.g., electrical wiring, plumbing, brick laying, painting) are subcontracted. George and Harry, however, perform all carpentry work. In addition, they plan and schedule all construction operations, frequently arrange interim financing, and supervise all construction activities.

The philosophy under which Haygood Brothers has always operated can be simply stated: "Time is money." Delays in construction increase the costs of interim financing and postpone the initiation of their building projects. Consequently, Haygood Brothers deals with all bottlenecks promptly and avoids all delays whenever possible. To minimize the time consumed in a construction project, Haygood Brothers uses PERT.

TABLE 7.11

Project Data for Haygood Brothers Construction Co.

ACTIVITY	IMMEDIATE PREDECESSORS	TIME (DAYS) a	m	b
A	—	4	5	6
B	A	2	5	8
C	B	5	7	9
D	B	4	5	6
E	C	2	4	6
F	E	3	5	9
G	E	4	5	6
H	E	3	4	7
I	E	5	7	9
J	D, I	10	11	12
K	F, G, H, J	4	6	8
L	F, G, H, J	7	8	9
M	L	4	5	10
N	K	5	7	9
O	N	5	6	7
P	M, O	2	3	4

First, all construction activities and events are itemized and properly arranged (in parallel and sequential combinations) in a network. Then time estimates for each activity are made, the expected time for completing each activity is determined, and the critical (longest) path is calculated. Finally, earliest times, latest times, and slack values are computed. Having made these calculations, George and Harry can place their resources in the critical areas to minimize the time of completing the project.

The following are the activities that constitute an upcoming project (home dwelling) for Haygood Brothers:

1. Arrange financing (A)
2. Let subcontracts (B)
3. Set and pour foundations (C)
4. Plumbing (D)
5. Framing (E)
6. Roofing (F)
7. Electrical wiring (G)
8. Installation of windows and doors (H)
9. Ductwork and insulation (including heating and cooling units) (I)
10. Sheetrock, paneling, and paper hanging (J)
11. Installation of cabinets (K)
12. Bricking (L)
13. Outside trim (M)
14. Inside trim (including fixtures) (N)
15. Painting (O)
16. Flooring (P)

The immediate predecessors and optimistic (a), most likely (m), and pessimistic (b) time estimates are shown in Table 7.11.

Discussion Questions

1. What is the time length of the critical path? What is the significance of the critical path?
2. Compute the amount of time that the completion of each activity can be delayed without affecting the overall project.
3. The project was begun August 1. What is the probability that the project can be completed by September 30? (*Note:* Scheduled completion time = 60 days.)

Source: Professor Jerry Kinard, Western Carolina University; and Brian Kinard, Mississippi State University.

CASE STUDY

Family Planning Research Center of Nigeria

Dr. Adinombe Watage, deputy director of the Family Planning Research Center in Nigeria's Over-the-River Province, was assigned the task of organizing and training five teams of field workers to perform educational and outreach activities as part of a large project to demonstrate acceptance of a new method of birth control. These workers already had training in family planning education but must receive specific training regarding the new method of contraception. Two types of materials must also be prepared: (1) those for use in training the workers and (2) those for distribution in the field. Training faculty must be brought in, and arrangements must be made for transportation and accommodations for the participants.

Dr. Watage first called a meeting of this office staff. Together they identified the activities that must be carried out, their necessary sequences, and the time they would require. Their results are displayed in Table 7.12.

TABLE 7.12

Project Data for Family Planning Research Center

ACTIVITY	IMMEDIATE PREDECESSORS	TIME (DAYS)	STAFFING NEEDED
A. Identify faculty and their schedules	—	5	2
B. Arrange transport to base	—	7	3
C. Identify and collect training materials	—	5	2
D. Arrange accommodations	A	3	1
E. Identify team	A	7	4
F. Bring in team	B, E	2	1
G. Transport faculty to base	A, B	3	2
H. Print program material	C	10	6
I. Have program material delivered	H	7	3
J. Conduct training program	D, F, G, I	15	0
K. Perform fieldwork training	J	30	0

TABLE 7.13

Cost Data for Family Planning Research Center

ACTIVITY	NORMAL		CRASH	
	TIME	COST	TIME	COST
A. Identify faculty and their schedules	5	$ 400	2	$ 700
B. Arrange transport to base	7	$ 1,000	4	$ 1,450
C. Identify and collect training materials	5	$ 400	3	$ 500
D. Arrange accommodations	3	$ 2,500	1	$ 3,000
E. Identify team	7	$ 400	4	$ 850
F. Bring in team	2	$ 1,000	1	$ 2,000
G. Transport faculty to base	3	$ 1,500	2	$ 2,000
H. Print program material	10	$ 3,000	5	$ 4,000
I. Have program material delivered	7	$ 200	2	$ 600
J. Conduct training program	15	$ 5,000	10	$ 7,000
K. Perform fieldwork training	30	$10,000	20	$14,000

Louis Odaga, the chief clerk, noted that the project had to be completed in 60 days. Whipping out his solar-powered calculator, he added up the time needed. It came to 94 days. "An impossible task, then," he noted. "No," Dr. Watage replied, "some of these tasks can go forward in parallel." "Be careful, though," warned Mr. Oglagadu, the chief nurse, "there aren't that many of us to go around. There are only 10 of us in this office."

"I can check whether we have enough heads and hands once I have tentatively scheduled the activities," Dr. Watage responded. "If the schedule is too tight, I have permission from the Pathminder Fund to spend some funds to speed it up, just so long as I can prove that it can be done at the least cost necessary. Can you help me prove that? Here are the costs for the activities with the elapsed time that we planned and the costs and times if we shorten them to an absolute minimum." Those data are given in Table 7.13.

Discussion Questions

1. Some of the tasks in this project can be done in parallel. Prepare a diagram showing the required network of tasks and define the critical path. What is the length of the project without crashing?
2. At this point, can the project be done given the personnel constraint of 10 persons?
3. If the critical path is longer than 60 days, what is the least amount that Dr. Watage can spend and still achieve this schedule objective? Assume that crash costs are linear over time.

Source: "Family Planning Research Center of Nigeria" by Curtis P. McLaughlin.

INTERNET CASE STUDIES

See our Internet home page at www.prenhall.com/balakrishnan for these additional case studies:

- Alpha Beta Gamma Record
- Bay Community Hospital
- Shale Oil Company
- Southwestern University

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