

Additional problems 3.24–3.27 are available in MyOMLab.

Problems 3.28–3.33 relate to Cost-Time Trade-Offs and Project Crashing

•• **3.28** Assume that the activities in Problem 3.11 have the following costs to shorten: A, \$300/week; B, \$100/week; C, \$200/week; E, \$100/week; and F, \$400/week. Assume also that you can crash an activity down to 0 weeks in duration and that every week you can shorten the project is worth \$250 to you. What activities would you crash? What is the total crashing cost?

••• **3.29** What is the minimum cost of crashing the following project that Roger Solano manages at Slippery Rock University by 4 days?

ACTIVITY	NORMAL TIME (DAYS)	CRASH TIME (DAYS)	NORMAL COST	CRASH COST	IMMEDIATE PREDECESSOR(S)
A	6	5	\$ 900	\$1,000	—
B	8	6	300	400	—
C	4	3	500	600	—
D	5	3	900	1,200	A
E	8	5	1,000	1,600	C

•• **3.30** Three activities are candidates for crashing on a project network for a large computer installation (all are, of course, critical). Activity details are in the following table:

ACTIVITY	PREDECESSOR	NORMAL TIME	NORMAL COST	CRASH TIME	CRASH COST
A	—	7 days	\$6,000	6 days	\$6,600
B	A	4 days	1,200	2 days	3,000
C	B	11 days	4,000	9 days	6,000

- a) What action would you take to reduce the critical path by 1 day?
- b) Assuming no other paths become critical, what action would you take to reduce the critical path one additional day?
- c) What is the total cost of the 2-day reduction? **Px**

••• **3.31** Development of Version 2.0 of a particular accounting software product is being considered by Jose Noguera’s technology firm in Baton Rouge. The activities necessary for the completion of this project are listed in the following table:

ACTIVITY	NORMAL TIME (WEEKS)	CRASH TIME (WEEKS)	NORMAL COST	CRASH COST	IMMEDIATE PREDECESSOR(S)
A	4	3	\$2,000	\$2,600	—
B	2	1	2,200	2,800	—
C	3	3	500	500	—
D	8	4	2,300	2,600	A
E	6	3	900	1,200	B
F	3	2	3,000	4,200	C
G	4	2	1,400	2,000	D, E

- a) What is the project completion date?
- b) What is the total cost required for completing this project on normal time?
- c) If you wish to reduce the time required to complete this project by 1 week, which activity should be crashed, and how much will this increase the total cost?
- d) What is the maximum time that can be crashed? How much would costs increase? **Px**

••• **3.32** Kimpel Products makes pizza ovens for commercial use. James Kimpel, CEO, is contemplating producing smaller ovens for use in high school and college kitchens. The activities necessary to build an experimental model and related data are given in the following table:

ACTIVITY	NORMAL TIME (WEEKS)	CRASH TIME (WEEKS)	NORMAL COST (\$)	CRASH COST (\$)	IMMEDIATE PREDECESSOR(S)
A	3	2	1,000	1,600	—
B	2	1	2,000	2,700	—
C	1	1	300	300	—
D	7	3	1,300	1,600	A
E	6	3	850	1,000	B
F	2	1	4,000	5,000	C
G	4	2	1,500	2,000	D, E

- a) What is the project completion date?
- b) Crash this project to 10 weeks at the least cost.
- c) Crash this project to 7 weeks (which is the maximum it can be crashed) at the least cost. **Px**

Additional problem 3.33 is available in MyOMLab.

CASE STUDIES

Southwestern University: (A)*

Southwestern University (SWU), a large state college in Stephenville, Texas, 30 miles southwest of the Dallas/Fort Worth metroplex, enrolls close to 20,000 students. In a typical town–gown relationship, the school is a dominant force in the small city, with more students during fall and spring than permanent residents.

A longtime football powerhouse, SWU is a member of the Big Eleven conference and is usually in the top 20 in college football rankings. To bolster its chances of reaching the elusive and long-desired number-one ranking, in 2009, SWU hired the legendary Phil Flamm as its head coach.

*This integrated study runs throughout the text. Other issues facing Southwestern’s football expansion include (B) forecasting game attendance (Chapter 4); (C) quality of facilities (Chapter 6); (D) break-even analysis for food services (Supplement 7); (E) location of the new stadium (Chapter 8); (F) inventory planning of football programs (Chapter 12); and (G) scheduling of campus security officers/staff for game days (Chapter 13).

TABLE 3.6 Southwestern University Project

ACTIVITY	DESCRIPTION	PREDECESSOR(S)	TIME ESTIMATES (DAYS)			
			OPTIMISTIC	MOST LIKELY	PESSIMISTIC	CRASH COST/DAY
A	Bonding, insurance, tax structuring	—	20	30	40	\$1,500
B	Foundation, concrete footings for boxes	A	20	65	80	3,500
C	Upgrading skybox stadium seating	A	50	60	100	4,000
D	Upgrading walkways, stairwells, elevators	C	30	50	100	1,900
E	Interior wiring, lathes	B	25	30	35	9,500
F	Inspection approvals	E	0.1	0.1	0.1	0
G	Plumbing	D, F	25	30	35	2,500
H	Painting	G	10	20	30	2,000
I	Hardware/AC/metal workings	H	20	25	60	2,000
J	Tile/carpet/windows	H	8	10	12	6,000
K	Inspection	J	0.1	0.1	0.1	0
L	Final detail work/cleanup	I, K	20	25	60	4,500

One of Flamm's demands on joining SWU had been a new stadium. With attendance increasing, SWU administrators began to face the issue head-on. After 6 months of study, much political arm wrestling, and some serious financial analysis, Dr. Joel Wisner, president of Southwestern University, had reached a decision to expand the capacity at its on-campus stadium.

Adding thousands of seats, including dozens of luxury skyboxes, would not please everyone. The influential Flamm had argued the need for a first-class stadium, one with built-in dormitory rooms for his players and a palatial office appropriate for the coach of a future NCAA champion team. But the decision was made, and *everyone*, including the coach, would learn to live with it.

The job now was to get construction going immediately after the 2015 season ended. This would allow exactly 270 days until the 2016 season opening game. The contractor, Hill Construction (Bob Hill being an alumnus, of course), signed his contract. Bob Hill looked at the tasks his engineers had outlined and looked President Wisner in the eye. "I guarantee the team will be able to take the field on schedule next year," he said with a sense of confidence. "I sure hope so," replied Wisner. "The contract penalty

of \$10,000 per day for running late is nothing compared to what Coach Flamm will do to you if our opening game with Penn State is delayed or canceled." Hill, sweating slightly, did not need to respond. In football-crazy Texas, Hill Construction would be *mud* if the 270-day target was missed.

Back in his office, Hill again reviewed the data (see Table 3.6) and noted that optimistic time estimates can be used as crash times. He then gathered his foremen. "Folks, if we're not 75% sure we'll finish this stadium in less than 270 days, I want this project crashed! Give me the cost figures for a target date of 250 days—also for 240 days. I want to be *early*, not just on time!"

Discussion Questions

1. Develop a network drawing for Hill Construction and determine the critical path. How long is the project expected to take?
2. What is the probability of finishing in 270 days?
3. If it is necessary to crash to 250 or 240 days, how would Hill do so, and at what costs? As noted in the case, assume that optimistic time estimates can be used as crash times.

Project Management at Arnold Palmer Hospital

Video Case

The equivalent of a new kindergarten class is born every day at Orlando's Arnold Palmer Hospital. With more than 13,000 births in the mid-2000s in a hospital that was designed 15 years earlier for a capacity of 6,500 births a year, the newborn intensive care unit was stretched to the limit. Moreover, with continuing strong population growth in central Florida, the hospital was often full. It was clear that new facilities were needed. After much analysis, forecasting, and discussion, the management team decided to build a new 273-bed building across the street from the existing hospital. But the facility had to be built in accordance with the hospital's Guiding Principles and its uniqueness as a health center dedicated to the specialized needs of women and infants. Those

Guiding Principles are: *Family-centered focus, a healing environment where privacy and dignity are respected, sanctuary of caring that includes warm, serene surroundings with natural lighting, sincere and dedicated staff providing the highest quality care, and patient-centered flow and function.*

The vice president of business development, Karl Hodges, wanted a hospital that was designed from the inside out by the people who understood the Guiding Principles, who knew most about the current system, and who were going to use the new system, namely, the doctors and nurses. Hodges and his staff spent 13 months discussing expansion needs with this group, as well as with patients and the community, before developing a proposal

TABLE 3.7 Expansion Planning and Arnold Palmer Hospital Construction Activities and Times^a

ACTIVITY	SCHEDULED TIME	PRECEDENCE ACTIVITY(IES)
1. Proposal and review	1 month	—
2. Establish master schedule	2 weeks	1
3. Architect selection process	5 weeks	1
4. Survey whole campus and its needs	1 month	1
5. Conceptual architect's plans	6 weeks	3
6. Cost estimating	2 months	2, 4, 5
7. Deliver plans to board for consideration/decision	1 month	6
8. Surveys/regulatory review	6 weeks	6
9. Construction manager selection	9 weeks	6
10. State review of need for more hospital beds ("Certificate of Need")	3.5 months	7, 8
11. Design drawings	4 months	10
12. Construction documents	5 months	9, 11
13. Site preparation/demolish existing building	9 weeks	11
14. Construction start/building pad	2 months	12, 13
15. Relocate utilities	6 weeks	12
16. Deep foundations	2 months	14
17. Building structure in place	9 months	16
18. Exterior skin/roofing	4 months	17
19. Interior buildout	12 months	17
20. Building inspections	5 weeks	15, 19
21. Occupancy	1 month	20

^aThis list of activities is abbreviated for purposes of this case study. For simplification, assume each week = .25 months (i.e., 2 weeks = .5 month, 6 weeks = 1.5 months, etc.).

for the new facility. An administrative team created 35 user groups, which held over 1,000 planning meetings (lasting from 45 minutes to a whole day). They even created a "Supreme Court" to deal with conflicting views on the multifaceted issues facing the new hospital.

Funding and regulatory issues added substantial complexity to this major expansion, and Hodges was very concerned that the project stay on time and within budget. Tom Hyatt, director of facility development, was given the task of onsite manager of the \$100 million project, in addition to overseeing ongoing renovations, expansions, and other projects. The activities in the multi-year project for the new building at Arnold Palmer are shown in Table 3.7.

Discussion Questions*

1. Develop the network for planning and construction of the new hospital at Arnold Palmer.
2. What is the critical path, and how long is the project expected to take?
3. Why is the construction of this 11-story building any more complex than construction of an equivalent office building?
4. What percent of the whole project duration was spent in planning that occurred prior to the proposal and reviews? Prior to the actual building construction? Why?

*You may wish to view the video accompanying this case before addressing these questions.

Managing Hard Rock's Rockfest



At the Hard Rock Cafe, like many organizations, project management is a key planning tool. With Hard Rock's constant growth in hotels and cafes, remodeling of existing cafes, scheduling for Hard Rock Live concert and event venues, and planning the annual Rockfest, managers rely on project management techniques and software to maintain schedule and budget performance.

"Without Microsoft Project," says Hard Rock Vice-President Chris Tomasso, "there is no way to keep so many people on the same page." Tomasso is in charge of the Rockfest event, which is attended by well over 100,000 enthusiastic fans. The challenge is pulling it off within a tight 9-month planning horizon. As the event approaches, Tomasso devotes greater energy to its

activities. For the first 3 months, Tomasso updates his Microsoft Project charts monthly. Then at the 6-month mark, he updates his progress weekly. At the 9-month mark, he checks and corrects his schedule twice a week.

Early in the project management process, Tomasso identifies 10 major tasks (called level-2 activities in a work breakdown structure, or WBS):[†] talent booking, ticketing, marketing/PR, online promotion, television, show production, travel, sponsorships, operations, and merchandising. Using a WBS, each of these is further divided into a series of subtasks. Table 3.8 identifies 26 of the major activities and subactivities, their immediate predecessors, and time estimates. Tomasso enters all these into the Microsoft Project software.[‡] Tomasso alters the Microsoft Project document and the time line as the

project progresses. “It’s okay to change it as long as you keep on track,” he states.

The day of the rock concert itself is not the end of the project planning. “It’s nothing but surprises. A band not being able to get to the venue because of traffic jams is a surprise, but an ‘anticipated’ surprise. We had a helicopter on stand-by ready to fly the band in,” says Tomasso.

On completion of Rockfest in July, Tomasso and his team have a 3-month reprieve before starting the project planning process again.

[†]The level-1 activity is the Rockfest concert itself.

[‡]There are actually 127 activities used by Tomasso; the list is abbreviated for this case study.

TABLE 3.8 Some of the Major Activities and Subactivities in the Rockfest Plan

ACTIVITY	DESCRIPTION	PREDECESSOR(S)	TIME (WEEKS)
A	Finalize site and building contracts	—	7
B	Select local promoter	A	3
C	Hire production manager	A	3
D	Design promotional Web site	B	5
E	Set TV deal	D	6
F	Hire director	E	4
G	Plan for TV camera placement	F	2
H	Target headline entertainers	B	4
I	Target support entertainers	H	4
J	Travel accommodations for talent	I	10
K	Set venue capacity	C	2
L	Ticketmaster contract	D, K	3
M	On-site ticketing	L	8
N	Sound and staging	C	6
O	Passes and stage credentials	G, R	7
P	Travel accommodations for staff	B	20
Q	Hire sponsor coordinator	B	4
R	Finalize sponsors	Q	4
S	Define/place signage for sponsors	R, X	3
T	Hire operations manager	A	4
U	Develop site plan	T	6
V	Hire security director	T	7
W	Set police/fire security plan	V	4
X	Power, plumbing, AC, toilet services	U	8
Y	Secure merchandise deals	B	6
Z	Online merchandise sales	Y	6

Discussion Questions[§]

1. Identify the critical path and its activities for Rockfest. How long does the project take?
2. Which activities have a slack time of 8 weeks or more?
3. Identify five major challenges a project manager faces in events such as this one.
4. Why is a work breakdown structure useful in a project such as this? Take the 26 activities and break them into what you think should be level-2, level-3, and level-4 tasks.

[§]You may wish to view the video accompanying this case before addressing these questions.

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- **Additional Case Study:** Visit [MyOMLab](#) for this free case study:
Shale Oil Company: This oil refinery must shut down for maintenance of a major piece of equipment.

Endnotes

1. This formula is based on the statistical concept that from one end of the beta distribution to the other is 6 standard deviations (± 3 standard deviations from the mean). Because $(b - a)$ is 6 standard deviations, the variance is $[(b - a)/6]^2$.
2. *Source:* Adapted from James A. D. Stoner, *Management*, 6th ed. (Upper Saddle River, NJ: Pearson).

Chapter 3 *Rapid Review*

Main Heading	Review Material	MyOMLab
THE IMPORTANCE OF PROJECT MANAGEMENT (p. 62)	<p>The management of projects involves three phases:</p> <ol style="list-style-type: none"> 1. <i>Planning</i>—This phase includes goal setting, defining the project, and team organization. 2. <i>Scheduling</i>—This phase relates people, money, and supplies to specific activities and relates activities to each other. 3. <i>Controlling</i>—Here the firm monitors resources, costs, quality, and budgets. It also revises or changes plans and shifts resources to meet time and cost demands. 	<p>Concept Questions: 1.1–1.4</p> <p>VIDEO 3.1 Project Management at Hard Rock’s Rockfest</p>
PROJECT PLANNING (pp. 62–65)	<p>Projects can be defined as a series of related tasks directed toward a major output.</p> <ul style="list-style-type: none"> ■ Project organization—An organization formed to ensure that programs (projects) receive the proper management and attention. ■ Work breakdown structure (WBS)—Defines a project by dividing it into more and more detailed components. 	<p>Concept Questions: 2.1–2.4</p> <p>Problems: 3.1–3.2</p>
PROJECT SCHEDULING (pp. 65–66)	<ul style="list-style-type: none"> ■ Gantt charts—Planning charts used to schedule resources and allocate time. <p>Project scheduling serves several purposes:</p> <ol style="list-style-type: none"> 1. It shows the relationship of each activity to others and to the whole project. 2. It identifies the precedence relationships among activities. 3. It encourages the setting of realistic time and cost estimates for each activity. 4. It helps make better use of people, money, and material resources by identifying critical bottlenecks in the project. 	<p>Concept Questions: 3.1–3.4</p> <p>Problem: 3.3</p>
PROJECT CONTROLLING (pp. 66–67)	<p>Computerized programs produce a broad variety of PERT/CPM reports, including (1) detailed cost breakdowns for each task, (2) total program labor curves, (3) cost distribution tables, (4) functional cost and hour summaries, (5) raw material and expenditure forecasts, (6) variance reports, (7) time analysis reports, and (8) work status reports.</p>	<p>Concept Questions: 4.1–4.2</p> <p>VIDEO 3.2 Project Management at Arnold Palmer Hospital</p>
PROJECT MANAGEMENT TECHNIQUES: PERT AND CPM (pp. 67–71)	<ul style="list-style-type: none"> ■ Program evaluation and review technique (PERT)—A project management technique that employs three time estimates for each activity. ■ Critical path method (CPM)—A project management technique that uses only one estimate per activity. ■ Critical path—The computed <i>longest</i> time path(s) through a network. <p>PERT and CPM both follow six basic steps.</p> <p>The activities on the critical path will delay the entire project if they are not completed on time.</p> <ul style="list-style-type: none"> ■ Activity-on-node (AON)—A network diagram in which nodes designate activities. ■ Activity-on-arrow (AOA)—A network diagram in which arrows designate activities. <p>In an AOA network, the nodes represent the starting and finishing times of an activity and are also called <i>events</i>.</p> <ul style="list-style-type: none"> ■ Dummy activity—An activity having no time that is inserted into a network to maintain the logic of the network. <p>A dummy ending activity can be added to the end of an AON diagram for a project that has multiple ending activities.</p>	<p>Concept Questions: 5.1–5.4</p> <p>Problems: 3.4–3.14</p> <p>Virtual Office Hours for Solved Problems: 3.1, 3.2</p>
DETERMINING THE PROJECT SCHEDULE (pp. 71–77)	<ul style="list-style-type: none"> ■ Critical path analysis—A process that helps determine a project schedule. <p>To find the critical path, we calculate two distinct starting and ending times for each activity:</p> <ul style="list-style-type: none"> ■ <i>Earliest start (ES)</i> = Earliest time at which an activity can start, assuming that all predecessors have been completed ■ <i>Earliest finish (EF)</i> = Earliest time at which an activity can be finished ■ <i>Latest start (LS)</i> = Latest time at which an activity can start, without delaying the completion time of the entire project ■ <i>Latest finish (LF)</i> = Latest time by which an activity has to finish so as to not delay the completion time of the entire project ■ Forward pass—A process that identifies all the early start and early finish times. $ES = \text{Max} \{EF \text{ of all immediate predecessors}\} \quad (3-1)$ $EF = ES + \text{Activity time} \quad (3-2)$ ■ Backward pass—A process that identifies all the late start and late finish times. $LF = \text{Min} \{LS \text{ of all immediate following activities}\} \quad (3-3)$ $LS = LF - \text{Activity time} \quad (3-4)$ 	<p>Concept Questions: 6.1–6.4</p> <p>Problems: 3.15, 3.16</p>

Main Heading	Review Material	
	<p>■ Slack time—Free time for an activity.</p> $\text{Slack} = \text{LS} - \text{ES} \quad \text{or} \quad \text{Slack} = \text{LF} - \text{EF} \quad (3-5)$ <p>The activities with zero slack are called <i>critical activities</i> and are said to be on the critical path.</p> <p>The critical path is a continuous path through the project network that starts at the first activity in the project, terminates at the last activity in the project, and includes only critical activities.</p>	Virtual Office Hours for Solved Problem: 3.3 ACTIVE MODEL 3.1
VARIABILITY IN ACTIVITY TIMES (pp. 77–82)	<p>■ Optimistic time (<i>a</i>)—The “best” activity completion time that could be obtained in a PERT network.</p> <p>■ Pessimistic time (<i>b</i>)—The “worst” activity time that could be expected in a PERT network.</p> <p>■ Most likely time (<i>m</i>)—The most probable time to complete an activity in a PERT network.</p> <p>When using PERT, we often assume that activity time estimates follow the beta distribution.</p> $\text{Expected activity time } t = (a + 4m + b)/6 \quad (3-6)$ $\text{Variance of activity completion time} = [(b - a)/6]^2 \quad (3-7)$ $\sigma_p^2 = \text{Project variance} = \Sigma (\text{variances of activities on critical path}) \quad (3-8)$ $Z = (\text{Due date} - \text{Expected date of completion})/\sigma_p \quad (3-9)$ $\text{Due date} = \text{Expected completion time} + (Z \times \sigma_p) \quad (3-10)$	Concept Questions: 7.1–7.4 Problems: 3.17–3.27 Virtual Office Hours for Solved Problems: 3.4, 3.5, 3.6
COST-TIME TRADE-OFFS AND PROJECT CRASHING (pp. 82–85)	<p>■ Crashing—Shortening activity time in a network to reduce time on the critical path so total completion time is reduced.</p> $\text{Crash cost per period} = \frac{(\text{Crash cost} - \text{Normal cost})}{(\text{Normal time} - \text{Crash time})} \quad (3-11)$	Concept Questions: 8.1–8.4 Problems: 3.28–3.33 Virtual Office Hours for Solved Problem: 3.7
A CRITIQUE OF PERT AND CPM (pp. 85–86)	<p>As with every technique for problem solving, PERT and CPM have a number of advantages as well as several limitations.</p>	Concept Questions: 9.1–9.4
USING MICROSOFT PROJECT TO MANAGE PROJECTS (pp. 86–88)	<p>Microsoft Project, the most popular example of specialized project management software, is extremely useful in drawing project networks, identifying the project schedule, and managing project costs and other resources.</p>	Concept Questions: 10.1–10.4

Self Test

■ **Before taking the self-test**, refer to the learning objectives listed at the beginning of the chapter and the key terms listed at the end of the chapter.

- LO 3.1** Which of the following statements regarding Gantt charts is true?
- Gantt charts give a timeline and precedence relationships for each activity of a project.
 - Gantt charts use the four standard spines: Methods, Materials, Manpower, and Machinery.
 - Gantt charts are visual devices that show the duration of activities in a project.
 - Gantt charts are expensive.
 - All of the above are true.
- LO 3.2** Which of the following is true about AOA and AON networks?
- In AOA, arrows represent activities.
 - In AON, nodes represent activities.
 - Activities consume time and resources.
 - Nodes are also called *events* in AOA.
 - All of the above.
- LO 3.3** Slack time equals:
- $\text{ES} + t$.
 - $\text{LS} - \text{ES}$.
 - zero.
 - $\text{EF} - \text{ES}$.
- LO 3.4** The critical path of a network is the:
- shortest-time path through the network.
 - path with the fewest activities.
 - path with the most activities.
 - longest-time path through the network.
- LO 3.5** PERT analysis computes the variance of the total project completion time as:
- the sum of the variances of all activities in the project.
 - the sum of the variances of all activities on the critical path.
 - the sum of the variances of all activities not on the critical path.
 - the variance of the final activity of the project.
- LO 3.6** The crash cost per period:
- is the difference in costs divided by the difference in times (crash and normal).
 - is considered to be linear in the range between normal and crash.
 - needs to be determined so that the smallest cost values on the critical path can be considered for time reduction first.
 - all of the above.

Answers: LO 3.1. c; LO 3.2. e; LO 3.3. b; LO 3.4. d; LO 3.5. b; LO 3.6. d.