Project Management

CHAPTER 3

CHAPTER OUTLINE

Alaska Airlines

CHAPTER 3

GLOBAL COMPANY PROFILE
Bechtel Group

Project Management Provides a Competitive Advantage for Bechtel

Over a century old, the San Francisco–based Bechtel Group (www.bechtel.com) is the world's premier manager of massive construction and engineering projects. Known for billion-dollar projects, Bechtel is famous for its construction feats on the Hoover Dam, the Boston Central Artery/Tunnel project, the Riyadh, Saudi Arabia Metro, and over 25,000 other projects in 160 countries. With 53,000 employees and revenues over $39 billion, Bechtel is the U.S.'s largest project manager.

Philipus/Alamy

A massive dredge hired by Bechtel removes silt from Iraq's port at Umm Qasr. This paved the way for large-scale deliveries of U.S. food and the return of commercial shipping.

Steve Hebert/Bechtel National, Inc./PRN/Newscom

In addition to major construction projects, Bechtel used its project management skills to provide emergency response to major catastrophes as it did here in the wake of Hurricane Katrina.

Conditions weren't what Bechtel expected when it won a series of billion-dollar contracts from the U.S. government to help reconstruct war-torn Iraq in the last decade. That country's defeat by Allied forces hadn't caused much war damage. Instead, what Bechtel found was a nation that had been crumbling for years. None of the sewage plants in Baghdad worked. Power flicked on and off. Towns and cities had been left to decay. And scavengers were stealing everything from museum artifacts to electric power lines. Bechtel's job was to oversee electric power, sewage, transportation, and airport repairs.

Bechtel's crews travelled under armed escort and slept in trailers surrounded by razor wire. But the company's efforts have paid off. Iraq's main seaport, Umm Qasr, has opened. Electrical generation is back to prewar levels, and Bechtel has refurbished more than 1,200 schools.

With a global procurement program, Bechtel easily tapped the company's network of suppliers and buyers worldwide to help rebuild Iraq's infrastructure.

LEARNING OBJECTIVES

STUDENT TIP
Wherever your career takes you, one of the most useful tools you can have, as a manager, is the ability to manage a project.

The Importance of Project Management

When Bechtel, the subject of the opening Global Company Profile, begins a project, it quickly has to mobilize substantial resources, often consisting of manual workers, construction professionals, cooks, medical personnel, and even security forces. Its project management team develops a supply chain to access materials to build everything from ports to bridges, dams, and monorails. Bechtel is just one example of a firm that faces modern phenomena: growing project complexity and collapsing product/service life cycles. This change stems from awareness of the strategic value of time-based competition and a quality mandate for continuous improvement. Each new product/service introduction is a unique event—a project. In addition, projects are a common part of our everyday life. We may be planning a wedding or a surprise birthday party, remodeling a house, or preparing a semester-long class project.

VIDEO 3.1
Project Management at Hard Rock's Rockfest

Scheduling projects can be a difficult challenge for operations managers. The stakes in project management are high. Cost overruns and unnecessary delays occur due to poor scheduling and poor controls.

Projects that take months or years to complete are usually developed outside the normal production system. Project organizations within the firm may be set up to handle such jobs and are often disbanded when the project is complete. On other occasions, managers find projects just a part of their job. The management of projects involves three phases (see Figure 3.1):

1. *Planning:* This phase includes goal setting, defining the project, and team organization.
2. *Scheduling:* This phase relates people, money, and supplies to specific activities and relates activities to each other.
3. *Controlling:* Here the firm monitors resources, costs, quality, and budgets. It also revises or changes plans and shifts resources to meet time and cost demands.

We begin this chapter with a brief overview of these functions. Three popular techniques to allow managers to plan, schedule, and control—Gantt charts, PERT, and CPM—are also described.

Project Planning

Projects can be defined as a series of related tasks directed toward a major output. In some firms a **project organization** is developed to make sure existing programs continue to run smoothly on a day-to-day basis while new projects are successfully completed.

Project organization
An organization formed to ensure that programs (projects) receive the proper management and attention.

For companies with multiple large projects, such as a construction firm, a project organization is an effective way of assigning the people and physical resources needed. It is a temporary organization structure designed to achieve results by using specialists from throughout the firm.

The project organization may be most helpful when:

1. Work tasks can be defined with a specific goal and deadline.
2. The job is unique or somewhat unfamiliar to the existing organization.
3. The work contains complex interrelated tasks requiring specialized skills.

creating a team for Windows Vista (1.1.2.2), and creating a team for Windows XP (1.1.2.3). There are usually many level-4 activities.

Project Scheduling

Project scheduling involves sequencing and allotting time to all project activities. At this stage, managers decide how long each activity will take and compute the resources needed at each stage of production. Managers may also chart separate schedules for personnel needs by type of skill (management, engineering, or pouring concrete, for example) and material needs.

One popular project scheduling approach is the Gantt chart. **Gantt charts** are low-cost means of helping managers make sure that (1) activities are planned, (2) order of performance is documented, (3) activity time estimates are recorded, and (4) overall project time is developed. As Figure 3.4 shows, Gantt charts are easy to understand. Horizontal bars are drawn for each project activity along a time line. This illustration of a routine servicing of a Delta jetliner during a 40-minute layover shows that Gantt charts also can be used for scheduling repetitive operations. In this case, the chart helps point out potential delays. The *OM in Action* box on Delta provides additional insights.

Gantt charts
Planning charts used to schedule resources and allocate time.

On simple projects, scheduling charts such as these permit managers to observe the progress of each activity and to spot and tackle problem areas. Gantt charts, though, do not adequately illustrate the interrelationships between the activities and the resources.

STUDENT TIP
Gantt charts are simple and visual, making them widely used.

PERT and CPM, the two widely used network techniques that we shall discuss shortly, *do* have the ability to consider precedence relationships and interdependency of activities. On complex projects, the scheduling of which is almost always computerized, PERT and CPM thus have an edge over the simpler Gantt charts. Even on huge projects, though, Gantt charts can be used as summaries of project status and may complement the other network approaches.

LO 3.1 *Use* a Gantt chart for scheduling

To summarize, whatever the approach taken by a project manager, project scheduling serves several purposes:

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.

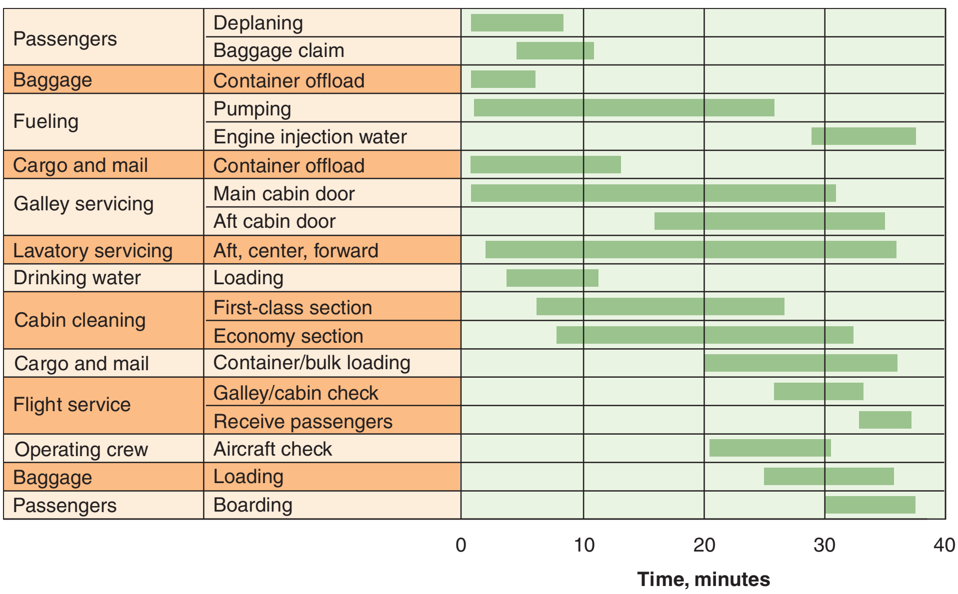


Figure 3.4
Gantt Chart of Service Activities for a Delta Jet during a 40-Minute Layover
Delta saves $50 million a year with this turnaround time, which is a reduction from its traditional 60-minute routine.

OM in Action Delta's Ground Crew Orchestrates a Smooth Takeoff

Flight 574's engines screech its arrival as the jet lumbers down Richmond's taxiway with 140 passengers arriving from Atlanta. In 40 minutes, the plane is to be airborne again.

However, before this jet can depart, there is business to attend to: passengers, luggage, and cargo to unload and load; thousands of gallons of jet fuel and countless drinks to restock; cabin and restrooms to clean; toilet holding tanks to drain; and engines, wings, and landing gear to inspect.

The 10-person ground crew knows that a miscue anywhere—a broken cargo loader, lost baggage, misdirected passengers—can mean a late departure and trigger a chain reaction of headaches from Richmond to Atlanta to every destination of a connecting flight.

Carla Sutera, the operations manager for Delta's Richmond International Airport, views the turnaround operation like a pit boss awaiting a race car. Trained crews are in place for Flight 574 with baggage carts and tractors, hydraulic cargo loaders, a truck to load food and drinks, another to lift the cleanup crew, another to put fuel on, and a fourth to take water off. The "pit crew" usually performs so smoothly that most passengers never suspect the proportions of the effort. Gantt charts, such as the one in Figure 3.4, aid Delta and other airlines with the staffing and scheduling that are needed for this task.


Jeff Topping/Getty Images

Sources: Knight Ridder Tribune Business News (July 16, 2005) and (November 21, 2002).

Project Controlling

VIDEO 3.2
Project Management at Arnold Palmer Hospital

The control of projects, like the control of any management system, involves close monitoring of resources, costs, quality, and budgets. Control also means using a feedback loop to revise the project plan and having the ability to shift resources to where they are needed most. Computerized PERT/CPM reports and charts are widely available today from scores of competing software firms. Some of the more popular of these programs are Oracle Primavera (by Oracle), MindView (by Match Ware), HP Project (by Hewlett-Packard), Fast Track (by AEC Software), and Microsoft Project (by Microsoft Corp.), which we illustrate in this chapter.

STUDENT TIP
To use project management software, you first need to understand the next two sections in this chapter.

These programs produce a broad variety of reports, including (1) detailed cost breakdowns, (2) labor requirements, (3) cost and hour summaries, (4) raw material and expenditure forecasts, (5) variance reports, (6) time analysis reports, and (7) work status reports.


Courtesy Arnold Palmer Medical Center


Courtesy Arnold Palmer Medical Center

Construction of the new 11-story building at Arnold Palmer Hospital in Orlando, Florida, was an enormous project for the hospital administration. The photo on the left shows the first six floors under construction. The photo on the right shows the building as completed two years later. Prior to beginning actual construction, regulatory and funding issues added, as they do with most projects, substantial time to the overall project. Cities have zoning and parking issues; the EPA has drainage and waste issues; and regulatory authorities have their own requirements, as do issuers of bonds. The $100 million, 4-year project at Arnold Palmer Hospital is discussed in the Video Case Study at the end of this chapter.

OM in Action Agile Project Management at Mastek

Agile project management has changed the way that Mastek Corp., in Mumbai, India, develops its educational software products. On a traditional well-defined project, managers are actively involved in directing work and telling their team what needs to be done—a style often referred to as a step-by-step *waterfall* style of project management.

Agile project management is different. In the early stages, the project manager creates a high-level plan, based on outline requirements and a high-level view of the solution. From that point, the end project is created iteratively and incrementally, with each increment building on the output of steps preceding it.

The principles of agile are essentially communication and transparency. Instead of waiting for something to be delivered, with limited understanding of the desired end result, there are numerous checkpoints and feedback loops to track progress.

Agile provides Mastek the ability to keep costs under control. Without agile, the cost of quality increases. "It's much harder to correct mistakes when a software product is nearing its final phase of development," says a company executive. "It's much better to develop it as you go along. I think agile project management would help any software developer."

Sources: AMPG International (2015) and **www.cprime.com** (2012).

Controlling projects can be difficult. The stakes are high; cost overruns and unnecessary delays can occur due to poor planning, scheduling, and controls. Some projects are "well-defined," whereas others may be "ill-defined." Projects typically only become well-defined after detailed extensive initial planning and careful definition of required inputs, resources, processes, and outputs. Well-established projects where constraints are known (e.g., buildings and roads) and engineered products (e.g., airplanes and cars) with well-defined specifications and drawings may fall into this category. Well-defined projects are assumed to have changes small enough to be managed without substantially revising plans. They use what is called a *waterfall* approach, where the project progresses smoothly, in a step-by-step manner, through each phase to completion.

But many projects, such as software development (e.g., 3-D games) and new technology (e.g., landing the Mars land rover) are ill-defined. These projects require what is known as an *agile* style of management with collaboration and constant feedback to adjust to the many unknowns of the evolving technology and project specifications. The *OM in Action* box "Agile Project Management at Mastek" provides such an example. Most projects fall somewhere between waterfall and agile.

Project Management Techniques: PERT and CPM

Program evaluation and review technique (PERT) and the **critical path method (CPM)** were both developed in the 1950s to help managers schedule, monitor, and control large and complex projects. CPM arrived first, as a tool developed to assist in the building and maintenance of chemical plants at duPont. Independently, PERT was developed in 1958 for the U.S. Navy.

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 time factor per activity.

The Framework of PERT and CPM

PERT and CPM both follow six basic steps:

1. Define the project and prepare the work breakdown structure.
2. Develop the relationships among the activities. Decide which activities must precede and which must follow others.
3. Draw the network connecting all the activities.
4. Assign time and/or cost estimates to each activity.
5. Compute the *longest* time path through the network. This is called the **critical path**.
6. Use the network to help plan, schedule, monitor, and control the project.

Critical path
The computed *longest* time path(s) through a network.

Step 5, finding the critical path, is a major part of controlling a project. The activities on the critical path represent tasks that will delay the entire project if they are not completed on time. Managers can gain the flexibility needed to complete critical tasks by identifying

Activity-on-Arrow Example

In an AOA project network we can represent activities by arrows. A node represents an *event*, which marks the start or completion time of an activity. We usually identify an event (node) by a number.

Example 3

ACTIVITY-ON-ARROW FOR MILWAUKEE PAPER

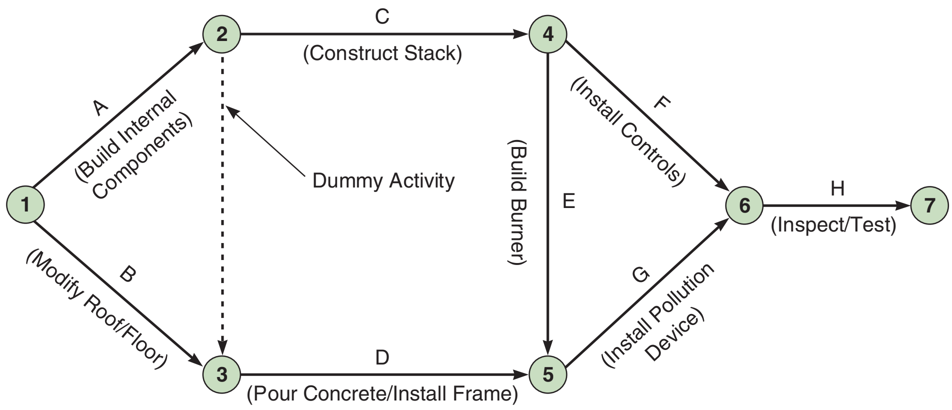
Draw the complete AOA project network for Milwaukee Paper's problem.

APPROACH ▶ Using the data from Table 3.1 in Example 1, draw one activity at a time, starting with A.

SOLUTION ▶ We see that activity A starts at event 1 and ends at event 2. Likewise, activity B starts at event 1 and ends at event 3. Activity C, whose only immediate predecessor is activity A, starts at node 2 and ends at node 4. Activity D, however, has two predecessors (i.e., A and B). Hence, we need both activities A and B to end at event 3, so that activity D can start at that event. However, we cannot have multiple activities with common starting and ending nodes in an AOA network. To overcome this difficulty, in such cases, we may need to add a dummy line (activity) to enforce the precedence relationship. The dummy activity, shown in Figure 3.8 as a dashed line, is inserted between events 2 and 3 to make the diagram reflect the precedence between A and D. The remainder of the AOA project network for Milwaukee Paper's example is also shown.

Figure **3.8**

Complete AOA Network (with Dummy Activity) for Milwaukee Paper



STUDENT TIP The dummy activity consumes no time, but note how it changes precedence. Now activity D cannot begin until *both* B and the dummy are complete.

INSIGHT ▶ Dummy activities are common in AOA networks. They do not really exist in the project and take zero time.

LEARNING EXERCISE ▶ A new activity, *EPA Approval*, follows activity H. Add it to Figure 3.8. [Answer: Insert an arrowed line from node 7, which ends at a new node 8, and is labeled I (EPA Approval).]

RELATED PROBLEMS ▶ 3.4b, 3.6, 3.7

Determining the Project Schedule

Look back at Figure 3.7 (in Example 2) for a moment to see Milwaukee Paper's completed AON project network. Once this project network has been drawn to show all the activities and their precedence relationships, the next step is to determine the project schedule. That is, we need to identify the planned starting and ending time for each activity.

Let us assume Milwaukee Paper estimates the time required for each activity, in weeks, as shown in Table 3.2. The table indicates that the total time for all eight of the company's activities is 25 weeks. However, because several activities can take place simultaneously, it is clear that the total project completion time may be less than 25 weeks. To find out just how long the project will take, we perform the **critical path analysis** for the network.

Critical path analysis
A process that helps determine a project schedule.

Tim Coggin/Alamy

To plan, monitor, and control the huge number of details involved in sponsoring a rock festival attended by more than 100,000 fans, managers use Microsoft Project and the tools discussed in this chapter. The *Video Case Study* "Managing Hard Rock's Rockfest," at the end of the chapter, provides more details of the management task.

Variability in Activity Times

In identifying all earliest and latest times so far, and the associated critical path(s), we have adopted the CPM approach of assuming that all activity times are known and fixed constants. That is, there is no variability in activity times. However, in practice, it is likely that activity completion times vary depending on various factors.

For example, building internal components (activity A) for Milwaukee Paper Manufacturing is estimated to finish in 2 weeks. Clearly, supply-chain issues such as late arrival of materials, absence of key personnel, and so on could delay this activity. Suppose activity A actually ends up taking 3 weeks. Because A is on the critical path, the entire project will now be delayed by 1 week to 16 weeks. If we had anticipated completion of this project in 15 weeks, we would obviously miss our Earth Day deadline.

Although some activities may be relatively less prone to delays, others could be extremely susceptible to delays. For example, activity B (modify roof and floor) could be heavily dependent on weather conditions. A spell of bad weather could significantly affect its completion time.

This means that we cannot ignore the impact of variability in activity times when deciding the schedule for a project. PERT addresses this issue.

STUDENT TIP

PERT's ability to handle three time estimates for each activity enables us to compute the probability that we can complete the project by a target date.

Three Time Estimates in PERT

In PERT, we employ a probability distribution based on three time estimates for each activity, as follows:

Optimistic time (a) = time an activity will take if everything goes as planned. In estimating this value, there should be only a small probability (say, 1/100) that the activity time will be $< a$.

Pessimistic time (b) = time an activity will take assuming very unfavorable conditions. In estimating this value, there should also be only a small probability (also 1/100) that the activity time will be $> b$.

Most likely time (m) = most realistic estimate of the time required to complete an activity.

Optimistic time
The "best" activity completion time that could be obtained in a PERT network.

Pessimistic time
The "worst" activity time that could be expected in a PERT network.

Most likely time
The most probable time to complete an activity in a PERT network.

When using PERT, we often assume that activity time estimates follow the beta probability distribution (see Figure 3.11). This continuous distribution is often appropriate for determining the expected value and variance for activity completion times.

Example 8). In fact, the pessimistic completion time for D is 6 weeks. This means that if D ends up taking its pessimistic time to finish, the project will not finish in 15 weeks, even though D is not a critical activity.

For this reason, when we find probabilities of project completion times, it may be necessary for us to not focus only on the critical path(s). Indeed, some research has suggested that expending project resources to reduce the variability of activities not on the critical path can be an effective element in project management. We may need also to compute these probabilities for noncritical paths, especially those that have relatively large variances. It is possible for a noncritical path to have a smaller probability of completion within a due date, when compared with the critical path. Determining the variance and probability of completion for a noncritical path is done in the same manner as Examples 9 and 10.

What Project Management Has Provided So Far Project management techniques have thus far been able to provide Julie Ann Williams with several valuable pieces of management information:

1. The project's expected completion date is 15 weeks.
2. There is a 71.57% chance that the equipment will be in place within the 16-week deadline. PERT analysis can easily find the probability of finishing by any date Williams is interested in.
3. Five activities (A, C, E, G, and H) are on the critical path. If any one of these is delayed for any reason, the entire project will be delayed.
4. Three activities (B, D, F) are not critical and have some slack time built in. This means that Williams can borrow from their resources, and, if necessary, she may be able to speed up the whole project.
5. A detailed schedule of activity starting and ending dates, slack, and critical path activities has been made available (see Table 3.3 in Example 6).

Cost-Time Trade-Offs and Project Crashing

While managing a project, it is not uncommon for a project manager to be faced with either (or both) of the following situations: (1) the project is behind schedule, and (2) the scheduled project completion time has been moved forward. In either situation, some or all of the remaining activities need to be speeded up (usually by adding resources) to finish the project by the desired due date. The process by which we shorten the duration of a project in the cheapest manner possible is called project **crashing**.

Crashing
Shortening activity time in a network to reduce time on the critical path so total completion time is reduced.

CPM is a technique in which each activity has a *normal* or *standard* time that we use in our computations. Associated with this normal time is the *normal* cost of the activity. However, another time in project management is the *crash time*, which is defined as the shortest duration required to complete an activity. Associated with this crash time is the *crash cost* of the activity. Usually, we can shorten an activity by adding extra resources (e.g., equipment, people) to it. Hence, it is logical for the crash cost of an activity to be higher than its normal cost.

The amount by which an activity can be shortened (i.e., the difference between its normal time and crash time) depends on the activity in question. We may not be able to shorten some activities at all. For example, if a casting needs to be heat-treated in the furnace for 48 hours, adding more resources does not help shorten the time. In contrast, we may be able to shorten some activities significantly (e.g., frame a house in 3 days instead of 10 days by using three times as many workers).

Likewise, the cost of crashing (or shortening) an activity depends on the nature of the activity. Managers are usually interested in speeding up a project at the least additional cost. Hence, when choosing which activities to crash, and by how much, we need to ensure the following:

- The amount by which an activity is crashed is, in fact, permissible
- Taken together, the shortened activity durations will enable us to finish the project by the due date
- The total cost of crashing is as small as possible

But we spot that activity G is common to both paths. That is, by crashing activity G, we will simultaneously reduce the completion time of both paths. Even though the $1,500 crash cost for activity G is higher than that for activities C and D, we would still prefer crashing G because the total crashing cost will now be only $1,500 (compared with the $2,000 if we crash C and D).

INSIGHT ▶ To crash the project down to 13 weeks, Williams should crash activity A by 1 week and activity G by 1 week. The total additional cost will be $2,250 (= $750 + $1,500). This is important because many contracts for projects include bonuses or penalties for early or late finishes.

LEARNING EXERCISE ▶ Say the crash cost for activity B is $31,000 instead of $34,000. How does this change the answer? [Answer: no change.]

RELATED PROBLEMS ▶ 3.28–3.32 (3.33 is available in MyOMLab)

EXCEL OM Data File **Ch03Ex12.xls** can be found in MyOMLab.

A Critique of PERT and CPM

As a critique of our discussions of PERT, here are some of its features about which operations managers need to be aware:

Advantages

1. Especially useful when scheduling and controlling large projects.
2. Straightforward concept and not mathematically complex.
3. Graphical networks help highlight relationships among project activities.
4. Critical path and slack time analyses help pinpoint activities that need to be closely watched.
5. Project documentation and graphs point out who is responsible for various activities.
6. Applicable to a wide variety of projects.
7. Useful in monitoring not only schedules but costs as well.

OM in Action — Behind the Tour de France

The large behind-the-scenes operations that support a football World Cup or Formula One racing team are well-known, but a Tour de France team also needs major support. “A Tour de France team is like a large traveling circus,” says the coach of the Belkin team. “The public only sees the riders, but they could not function without the unseen support staff.” The base to the team’s cycling pyramid includes everything from osteopaths to mechanics, from logistics staff to PR people. Their project management skills require substantial know-how, as well as the ability to guarantee that riders are in peak physical, nutritional, and psychological condition. This can mean deciding which snack bars to give the cyclists before, during, and after race stages, while ensuring there are scientifically based cooling regimens in place for the riders. The team’s huge truck, coach, three vans, and five cars resemble the sort of traveling convoy more associated with an international music act. Here are just some of the supplies the project management team for Belkin handles:

- 11 mattresses
- 36 aero suits, 45 bib shorts, 54 race jerseys, 250 podium caps
- 63 bikes
- 140 wheels, 220 tires
- 250 feeding bags, 3,000 water bottles
- 2,190 nutrition gels, 3,800 nutrition bars

Marc Pagani Photography/Shutterstock

- 10 jars of peanut butter, 10 boxes of chocolate sprinkles, 20 bags of wine gums, 20 jars of jam
- 80 kg of nuts, raisins, apricots, and figs, plus 50 kg of cereals

The project management behind a world-tour team is complex: These top teams often compete in two to three races simultaneously, in different countries and sometimes on different continents. Each team has 25–35 riders (9 compete in any single race), coming from different parts of the world, going to different races at different times, each with his own physique and strengths. They have customized bikes, uniforms, and food preferences. The support staff can include another 30 people.

Sources: BBC News (July 6, 2014) and *The Operations Room* (June 24,2013).

Limitations

1. Project activities have to be clearly defined, independent, and stable in their relationships.
2. Precedence relationships must be specified and networked together.
3. Time estimates tend to be subjective and are subject to fudging by managers who fear the dangers of being overly optimistic or not pessimistic enough.
4. There is the inherent danger of placing too much emphasis on the longest, or critical, path. Near-critical paths need to be monitored closely as well.

Using Microsoft Project to Manage Projects

The approaches discussed so far are effective for managing small projects. However, for large or complex projects, specialized project management software is much preferred. In this section, we provide a brief introduction to the most popular example of such specialized software, Microsoft Project. A time-limited version of Microsoft Project may be requested with this text.

Microsoft Project is extremely useful in drawing project networks, identifying the project schedule, and managing project costs and other resources.

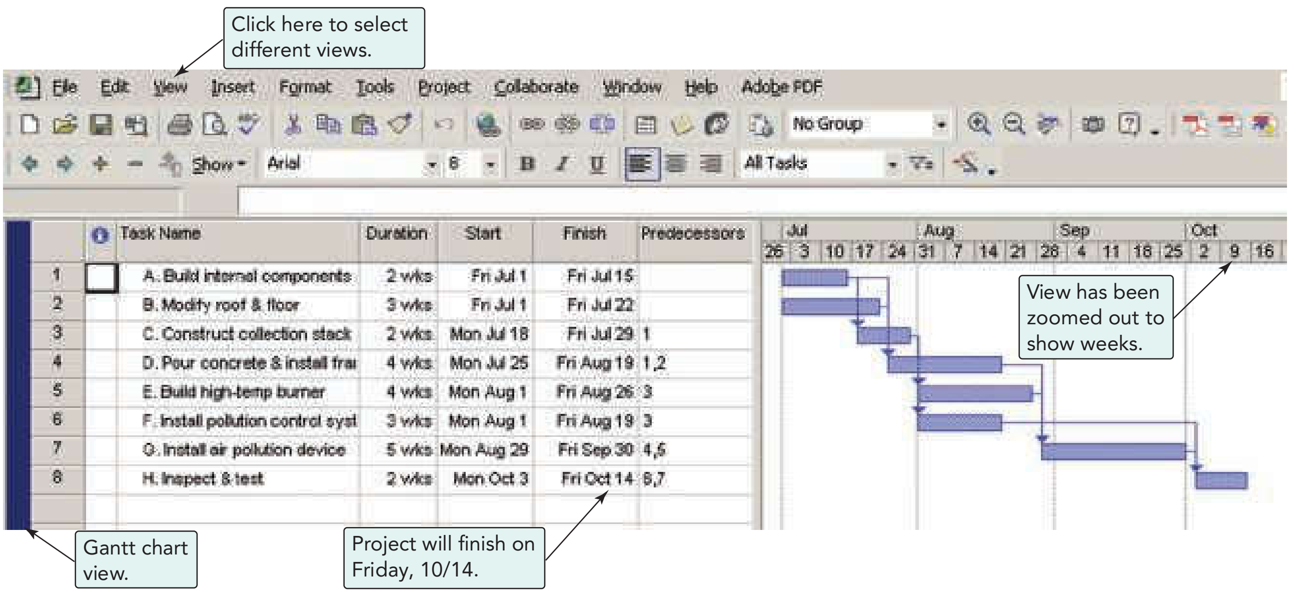
Milwaukee Paper Co. Activities

ACTIVITY	TIME (WKS)	PREDECESSORS
A	2	—
B	3	—
C	2	A
D	4	A, B
E	4	C
F	3	C
G	5	D, E
H	2	F, G

Entering Data Let us again consider the Milwaukee Paper Manufacturing project. Recall that this project has eight activities (repeated in the margin). The first step is to define the activities and their precedence relationships. To do so, we select **File|New** to open a blank project. We type the project start date (as July 1), then enter all activity information (see Program 3.1). For each activity (or task, as Microsoft Project calls it), we fill in the name and duration. The description of the activity is also placed in the ***Task Name*** column in Program 3.1. As we enter activities and durations, the software automatically inserts start and finish dates.

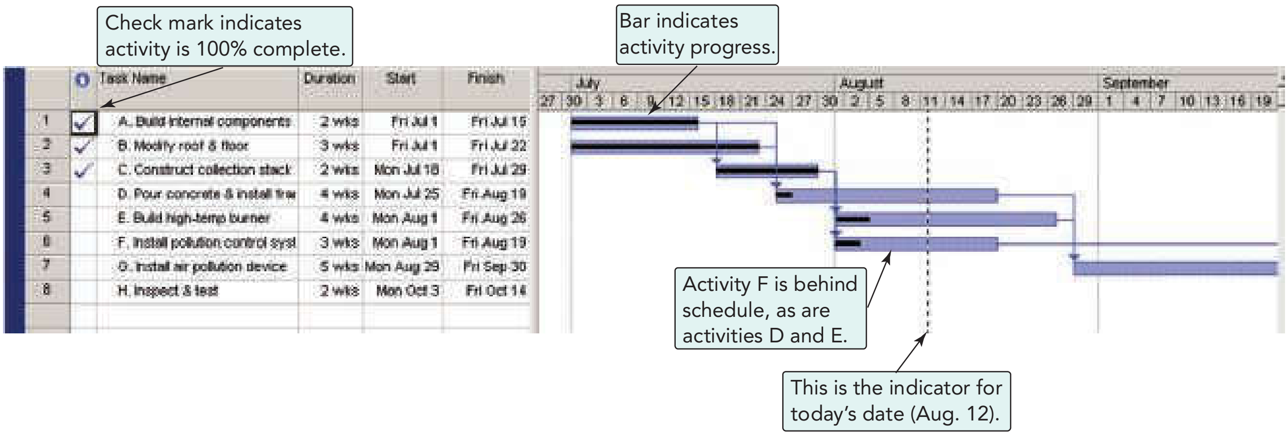
The next step is to define precedence relationships between these activities. To do so, we enter the relevant activity numbers (e.g., 1, 2) in the ***Predecessors*** column.

Viewing the Project Schedule When all links have been defined, the complete project schedule can be viewed as a Gantt chart. We can also select **View|Network Diagram** to view the schedule as a project network (shown in Program 3.2). The critical path is shown in red on the



Program **3.1**

Gantt Chart in Microsoft Project for Milwaukee Paper Manufacturing



Program **3.3**

Tracking Project Progress in Microsoft Project

of today's line indicate that they have been completed. For example, Program 3.3 shows that activities A, B, and C are on schedule. In contrast, activities D, E, and F appear to be behind schedule. These activities need to be investigated further to determine the reason for the delay. This type of easy *visual* information is what makes such software so useful in practice for project management.

We encourage you to load the copy of Microsoft Project that may be ordered with your text and to create a project network for work you are currently doing.

Summary

PERT, CPM, and other scheduling techniques have proven to be valuable tools in controlling large and complex projects. Managers use such techniques to segment projects into discrete activities (work breakdown structures), indentifying specific resources and time requirements for each. With PERT and CPM, managers can understand the status of each activity, including its earliest start, latest start, earliest finish, and latest finish (ES, LS, EF, and LF) times. By controlling the trade-off between ES and LS, managers can identify the activities that have slack and can address resource allocation, perhaps by smoothing resources. Effective project management also allows managers to focus on the activities that are critical to timely project completion. By understanding the project's critical path, they know where crashing makes the most economic sense.

Good project management also allows firms to efficiently create products and services for global markets and to respond effectively to global competition. Microsoft Project, illustrated in this chapter, is one of a wide variety of software packages available to help managers handle network modeling problems.

The models described in this chapter require good management practices, detailed work breakdown structures, clear responsibilities assigned to activities, and straightforward and timely reporting systems. All are critical parts of project management.

Key Terms

Project organization (p. 62)
Work breakdown structure (WBS) (p. 64)
Gantt charts (p. 65)
Program evaluation and review technique (PERT) (p. 67)
Critical path method (CPM) (p. 67)
Critical path (p. 67)
Activity-on-node (AON) (p. 68)
Activity-on-arrow (AOA) (p. 68)
Dummy activity (p. 70)
Critical path analysis (p. 71)
Forward pass (p. 72)
Backward pass (p. 74)
Slack time (p. 75)
Optimistic time (p. 77)
Pessimistic time (p. 77)
Most likely time (p. 77)
Crashing (p. 82)

Ethical Dilemma

Two examples of massively mismanaged projects are TAURUS and the "Big Dig." The first, formally called the London Stock Exchange Automation Project, cost $575 million before it was finally abandoned. Although most IT projects have a reputation for cost overruns, delays, and underperformance, TAURUS set a new standard.

But even TAURUS paled next to the biggest, most expensive public works project in U.S. history—Boston's 15-year-long Central Artery/Tunnel Project. Called the Big Dig, this was perhaps the poorest and most felonious case of project mismanagement in decades. From a starting $2 billion budget to a final price tag of $15 billion, the Big Dig cost more than the Panama Canal, Hoover Dam, or Interstate 95, the 1,919-mile highway between Maine and Florida.

Read about one of these two projects (or another of your choice) and explain why it faced such problems. How and why do project managers allow such massive endeavors to fall into such a state? What do you think are the causes?

Discussion Questions

1. Give an example of a situation in which project management is needed.
2. Explain the purpose of project organization.
3. What are the three phases involved in the management of a large project?
4. What are some of the questions that can be answered with PERT and CPM?
5. Define *work breakdown structure*. How is it used?
6. What is the use of Gantt charts in project management?
7. What is the difference between an activity-on-arrow (AOA) network and an activity-on-node (AON) network? Which is primarily used in this chapter?
8. What is the significance of the critical path?
9. What would a project manager have to do to crash an activity?
10. Describe how expected activity times and variances can be computed in a PERT network.
11. Define *earliest start, earliest finish, latest finish*, and *latest start* times.
12. Students are sometimes confused by the concept of critical path, and want to believe that it is the *shortest* path through a network. Convincingly explain why this is not so.
13. What are dummy activities? Why are they used in activity-on-arrow (AOA) project networks?
14. What are the three time estimates used with PERT?
15. Would a project manager ever consider crashing a noncritical activity in a project network? Explain convincingly.
16. How is the variance of the total project computed in PERT?
17. Describe the meaning of slack, and discuss how it can be determined.
18. How can we determine the probability that a project will be completed by a certain date? What assumptions are made in this computation?
19. Name some of the widely used project management software programs.
20. What is the difference between the *waterfall* approach and *agile* project management?

Using Software to Solve Project Management Problems

In addition to the Microsoft Project software illustrated earlier, both Excel OM and POM for Windows are available to readers of this text as project management tools.

USING EXCEL OM

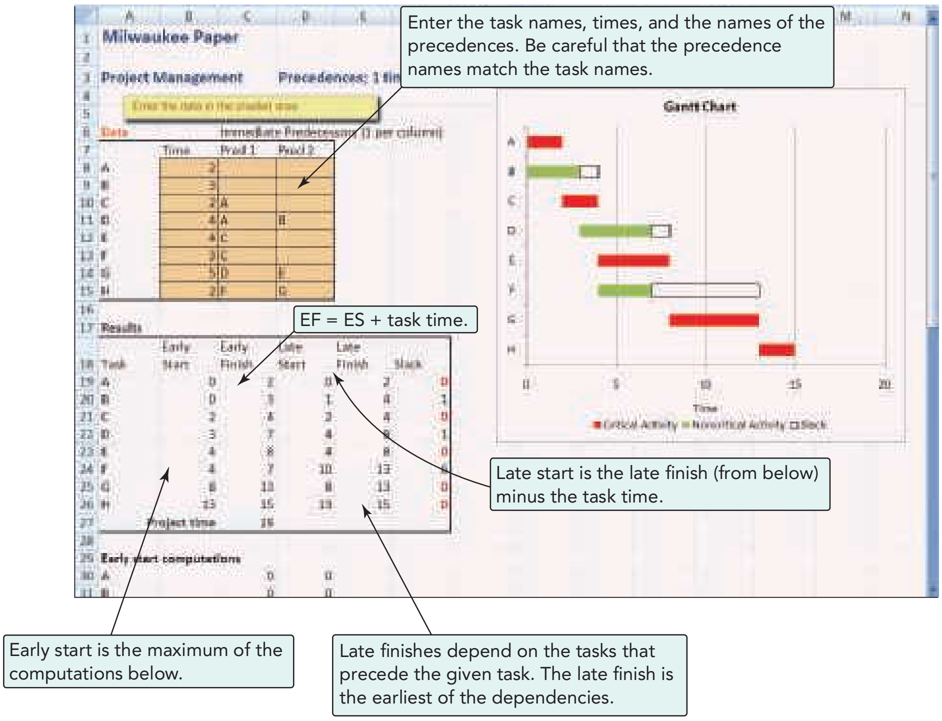
Excel OM has a Project Scheduling module. Program 3.4 uses the data from the Milwaukee Paper Manufacturing example in this chapter (see Examples 4 and 5). The PERT/CPM analysis also handles activities with three time estimates.

USING POM FOR WINDOWS

POM for Window's Project Scheduling module can also find the expected project completion time for a CPM and PERT network with either one or three time estimates. POM for Windows also performs project crashing. For further details refer to Appendix IV.

Program **3.4**

Excel OM's Use of Milwaukee Paper Manufacturing's Data from Examples 4 and 5



Solved Problems

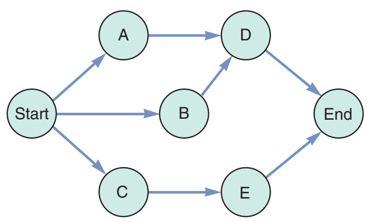
Virtual Office Hours help is available in MyOMLab.

SOLVED PROBLEM 3.1

Construct an AON network based on the following:

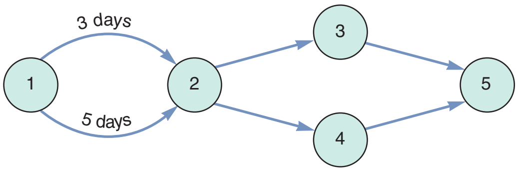
ACTIVITY	IMMEDIATE PREDECESSOR(S)
A	—
B	—
C	—
D	A, B
E	C

SOLUTION



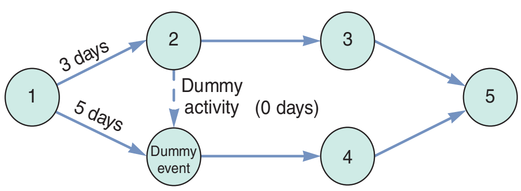
SOLVED PROBLEM 3.2

Insert a dummy activity and event to correct the following AOA network:



SOLUTION

Because we cannot have two activities starting and ending at the same node, we add the following dummy activity and dummy event to obtain the correct AOA network:



Next, crash cost/month must be computed for each activity:

ACTIVITY	NORMAL TIME–CRASH TIME	CRASH COST–NORMAL COST	CRASH COST/MONTH	CRITICAL PATH?
A	2	$400	$200/month	No
B	2	500	250/month	Yes
C	1	300	300/month	No
D	2	600	300/month	Yes
E	1	200	200/month	Yes

Finally, we will select that activity on the critical path with the smallest crash cost/month. This is activity E. Thus, we can reduce the total project completion date by 1 month for an additional cost of $200. We still need to reduce the project completion date by 2 more months. This reduction can be achieved at least cost along the critical path by reducing activity B by 2 months for an additional cost of $500. Neither reduction has an effect on noncritical activities. This solution is summarized in the following table:

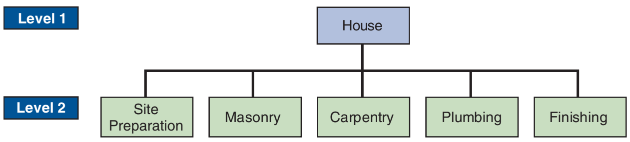
ACTIVITY	MONTHS REDUCED	COST
E	1	$200
B	2	500
		Total: $700

Problems

Note: Px means the problem may be solved with POM for Windows and/or Excel OM.

Problems 3.1–3.2 relate to Project Planning

• **3.1** The work breakdown structure (WBS) for building a house (levels 1 and 2) is shown below:



a) Add two level-3 activities to each of the level-2 activities to provide more detail to the WBS.
b) Select one of your level-3 activities and add two level-4 activities below it.

• • **3.2** James Lawson has decided to run for a seat as Congressman from the House of Representatives, District 34, in Florida. He views his 8-month campaign for office as a major project and wishes to create a work breakdown structure (WBS) to help control the detailed scheduling. So far, he has developed the following pieces of the WBS:

LEVEL	LEVEL ID NO.	ACTIVITY
1	1.0	Develop political campaign
2	1.1	Fund-raising plan
3	1.1.1	______________
3	1.1.2	______________
3	1.1.3	______________
2	1.2	Develop a position on major issues
3	1.2.1	______________
3	1.2.2	______________
3	1.2.3	______________
2	1.3	Staffing for campaign
3	1.3.1	______________
3	1.3.2	______________
3	1.3.3	______________
3	1.3.4	______________
2	1.4	Paperwork compliance for candidacy
3	1.4.1	______________
3	1.4.2	______________
2	1.5	Ethical plan/issues
3	1.5.1	______________

Help Lawson by providing details where the blank lines appear. Are there any other major (level-2) activities to create? If so, add an ID no. 1.6 and insert them.

Problem 3.3 relates to Project Scheduling

• • **3.3** The City Commission of Nashville has decided to build a botanical garden and picnic area in the heart of the city for the recreation of its citizens. The precedence table for all the activities required to construct this area successfully is given. Draw the Gantt chart for the whole construction activity.

CODE	ACTIVITY	DESCRIPTION	TIME (IN HOURS)	IMMEDIATE PREDECESSOR(S)
A	Planning	Find location; determine resource requirements	20	None
B	Purchasing	Requisition of lumber and sand	60	Planning
C	Excavation	Dig and grade	100	Planning
D	Sawing	Saw lumber into appropriate sizes	30	Purchasing
E	Placement	Position lumber in correct locations	20	Sawing, excavation
F	Assembly	Nail lumber together	10	Placement
G	Infill	Put sand in and under the equipment	20	Assembly
H	Outfill	Put dirt around the equipment	10	Assembly
I	Decoration	Put grass all over the garden, landscape, paint	30	Infill, outfill

Problems 3.4–3.14 relate to Project Management Techniques

• • **3.4** Refer to the table in Problem 3.3.

a) Draw the AON network for the construction activity.
b) Draw the AOA network for the construction activity.

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?

••• **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?

••• **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.

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).

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.

- **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)	The management of projects involves three phases: 1. *Planning*—This phase includes goal setting, defining the project, and team organization. 2. *Scheduling*—This phase relates people, money, and supplies to specific activities and relates activities to each other. 3. *Controlling*—Here the firm monitors resources, costs, quality, and budgets. It also revises or changes plans and shifts resources to meet time and cost demands.	Concept Questions: 1.1–1.4 **VIDEO 3.1** Project Management at Hard Rock's Rockfest
PROJECT PLANNING (pp. 62–65)	Projects can be defined as a series of related tasks directed toward a major output. ■ **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.	Concept Questions: 2.1–2.4 Problems: 3.1–3.2
PROJECT SCHEDULING (pp. 65–66)	■ **Gantt charts**—Planning charts used to schedule resources and allocate time. Project scheduling serves several purposes: 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.	Concept Questions: 3.1–3.4 Problem: 3.3
PROJECT CONTROLLING (pp. 66–67)	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.	Concept Questions: 4.1–4.2 **VIDEO 3.2** Project Management at Arnold Palmer Hospital
PROJECT MANAGEMENT TECHNIQUES: PERT AND CPM (pp. 67–71)	■ **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 *longest* time path(s) through a network. PERT and CPM both follow six basic steps. The activities on the critical path will delay the entire project if they are not completed on time. ■ **Activity-on-node (AON)**—A network diagram in which nodes designate activities. ■ **Activity-on-arrow (AOA)**—A network diagram in which arrows designate activities. In an AOA network, the nodes represent the starting and finishing times of an activity and are also called *events*. ■ **Dummy activity**—An activity having no time that is inserted into a network to maintain the logic of the network. A dummy ending activity can be added to the end of an AON diagram for a project that has multiple ending activities.	Concept Questions: 5.1–5.4 Problems: 3.4–3.14 Virtual Office Hours for Solved Problems: 3.1, 3.2
DETERMINING THE PROJECT SCHEDULE (pp. 71–77)	■ **Critical path analysis**—A process that helps determine a project schedule. To find the critical path, we calculate two distinct starting and ending times for each activity: ■ *Earliest start (ES)* = Earliest time at which an activity can start, assuming that all predecessors have been completed ■ *Earliest finish (EF)* = Earliest time at which an activity can be finished ■ *Latest start (LS)* = Latest time at which an activity can start, without delaying the completion time of the entire project ■ *Latest finish (LF)* = 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. $ES = \text{Max}\{\text{EF of all immediate predecessors}\}$ (3-1) $EF = ES + \text{Activity time}$ (3-2) ■ **Backward pass**—A process that identifies all the late start and late finish times. $LF = \text{Min}\{\text{LS of all immediate following activities}\}$ (3-3) $LS = LF - \text{Activity time}$ (3-4)	Concept Questions: 6.1–6.4 Problems: 3.15, 3.16

Chapter 3 ***Rapid Review*** *continued*

Main Heading	Review Material	MyOMLab
	■ **Slack time**—Free time for an activity. Slack = LS − ES or Slack = LF − EF (3-5) The activities with zero slack are called *critical activities* and are said to be on the critical path. 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.	Virtual Office Hours for Solved Problem: 3.3 **ACTIVE MODEL 3.1**
VARIABILITY IN ACTIVITY TIMES (pp. 77–82)	■ **Optimistic time** (a)—The "best" activity completion time that could be obtained in a PERT network. ■ **Pessimistic time** (b)—The "worst" activity time that could be expected in a PERT network. ■ **Most likely time** (m)—The most probable time to complete an activity in a PERT network. When using PERT, we often assume that activity time estimates follow the beta distribution. Expected activity time $t = (a + 4m + b)/6$ (3-6) Variance of activity completion time $= [(b - a)/6]^2$ (3-7) σ_p^2 = Project variance = Σ (variances of activities on critical path) (3-8) Z = (Due date − Expected date of completion)$/\sigma_p$ (3-9) Due date = Expected completion time + $(Z \times \sigma_p)$ (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)	■ **Crashing**—Shortening activity time in a network to reduce time on the critical path so total completion time is reduced. $\text{Crash cost per period} = \dfrac{(\text{Crash cost} - \text{Normal cost})}{(\text{Normal time} - \text{Crash time})}$ (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)	As with every technique for problem solving, PERT and CPM have a number of advantages as well as several limitations.	Concept Questions: 9.1–9.4
USING MICROSOFT PROJECT TO MANAGE PROJECTS (pp. 86–88)	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.	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?
- **a)** Gantt charts give a timeline and precedence relationships for each activity of a project.
- **b)** Gantt charts use the four standard spines: Methods, Materials, Manpower, and Machinery.
- **c)** Gantt charts are visual devices that show the duration of activities in a project.
- **d)** Gantt charts are expensive.
- **e)** All of the above are true.

LO 3.2 Which of the following is true about AOA and AON networks?
- **a)** In AOA, arrows represent activities.
- **b)** In AON, nodes represent activities.
- **c)** Activities consume time and resources.
- **d)** Nodes are also called *events* in AOA.
- **e)** All of the above.

LO 3.3 Slack time equals:
- **a)** ES + t.
- **b)** LS − ES.
- **c)** zero.
- **d)** EF − ES.

LO 3.4 The critical path of a network is the:
- **a)** shortest-time path through the network.
- **b)** path with the fewest activities.
- **c)** path with the most activities.
- **d)** longest-time path through the network.

LO 3.5 PERT analysis computes the variance of the total project completion time as:
- **a)** the sum of the variances of all activities in the project.
- **b)** the sum of the variances of all activities on the critical path.
- **c)** the sum of the variances of all activities not on the critical path.
- **d)** the variance of the final activity of the project.

LO 3.6 The crash cost per period:
- **a)** is the difference in costs divided by the difference in times (crash and normal).
- **b)** is considered to be linear in the range between normal and crash.
- **c)** needs to be determined so that the smallest cost values on the critical path can be considered for time reduction first.
- **d)** 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.