Short-Term Scheduling

CHAPTER 15

CHAPTER OUTLINE

Alaska Airlines

10 OM STRATEGY DECISIONS

- Design of Goods and Services
- Managing Quality
- Process Strategy
- Location Strategies
- Layout Strategies
- Human Resources
- Supply-Chain Management
- Inventory Management
- *Scheduling*
  - Aggregate/S&OP (Ch. 13)
  - ***Short-Term (Ch. 15)***
- Maintenance

CHAPTER 15

GLOBAL COMPANY PROFILE
Alaska Airlines

Scheduling Flights When Weather Is the Enemy

Seattle–Tacoma International Airport (SEA) is the 15th busiest in the U.S. in passenger traffic. Served by 24 airlines that fly non-stop to 76 domestic and 19 international destinations, it is a weather forecaster's nightmare, raining 5 inches a month in the winter season. But it is also the top-ranked U.S. airport in on-time departures, at 85.8%. Much of the credit goes to Alaska Airlines, which dominates traffic at SEA with over 50% of all domestic flights. Alaska's scheduling is critical to efficiency and passenger service.

4 A.M.
FORECAST: Rain with a chance of light snow for Seattle.

ACTION: Discuss status of planes and possible need for cancellations.

10 A.M.
FORECAST: Freezing rain after 5 P.M.

ACTION: Ready deicing trucks; develop plans to cancel 50% to 80% of flights after 6 P.M.

1:30 P.M.
FORECAST: Rain changing to snow.

ACTION: Cancel half the flights from 6 P.M. to 10 A.M.; notify passengers and reroute planes.

5 P.M.
FORECAST: Less snow than expected.

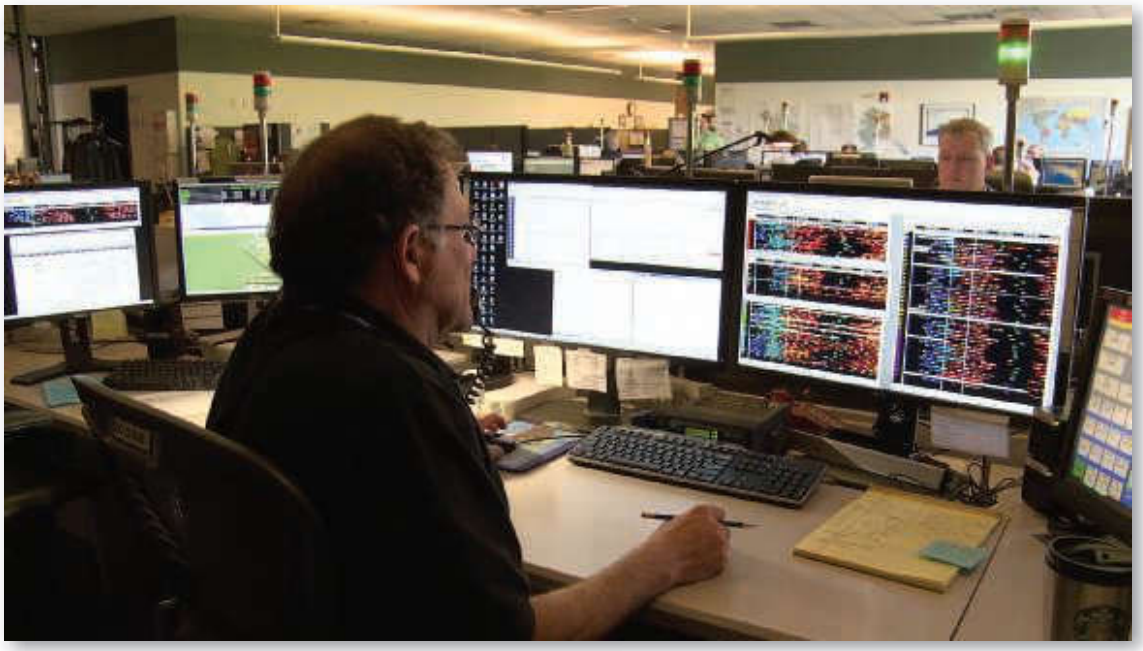
ACTION: Continue calling passengers and arrange alternate flights.

10 P.M.
FORECAST: Snow tapering off.

ACTION: Find hotels for 600 passengers stranded by the storm.

This is typical of what Alaska Air officials had to do one December day when a storm bore down on Seattle.

Managers at airlines, such as Alaska, learn to expect the unexpected. Events that require rapid rescheduling are a regular part of life. Throughout the ordeals of hurricanes, tornadoes, ice storms, snow storms, and more, airlines around the globe struggle to cope with delays, cancellations, and furious passengers. The inevitable schedule changes often create a ripple effect that impacts passengers at dozens of airports.



Alaska Airlines

To improve flight rescheduling efforts, Alaska Air employees monitor numerous screens that display flights in progress, meteorological charts, and weather patterns at its Flight Operations Department in Seattle. Note the many *andon* signal lights used to indicate "status OK" (green), "needs attention" (yellow), or "major issue—emergency" (red).

LEARNING OBJECTIVES

- **LO 15.1** ***Explain*** the relationship between short-term scheduling, capacity planning, aggregate planning, and a master schedule 603
- **LO 15.2** ***Draw*** Gantt loading and scheduling charts 607
- **LO 15.3** ***Apply*** the assignment method for loading jobs 608
- **LO 15.4** ***Name*** and describe each of the priority sequencing rules 613
- **LO 15.5** ***Use*** Johnson's rule 616
- **LO 15.6** ***Define*** finite capacity scheduling 617
- **LO 15.7** ***Use*** the cyclical scheduling technique 620

The Importance of Short-Term Scheduling

Alaska Airlines doesn't just schedule its 150 aircraft every day; it also schedules over 4,500 pilots and flight attendants to accommodate passengers seeking timely arrival at their destinations. This schedule, developed with huge computer programs, plays a major role in meeting customer expectations. Alaska finds competitive advantage with its ability to make last-minute adjustments to demand fluctuations and weather disruptions.

Scheduling decisions for five organizations—an airline, a hospital, a college, a sports arena, and a manufacturer—are shown in Table 15.1. These decisions all deal with the timing of operations.

When manufacturing firms make schedules that match resources to customer demands, scheduling competence focuses on making parts on a just-in-time basis, with low setup times, little work-in-process, and high facility utilization. Efficient scheduling is how manufacturing companies drive down costs and meet promised due dates.

The strategic importance of scheduling is clear:

- Internally effective scheduling means faster movement of goods and services through a facility and greater use of assets. The result is greater capacity per dollar invested, which translates into lower costs.
- Externally good scheduling provides faster throughput, added flexibility, and more dependable delivery, improving customer service.

STUDENT TIP Scheduling decisions range from years, for capacity planning, to minutes/hours/days, called short-term scheduling. This chapter focuses on the latter.

Scheduling Issues

Figure 15.1 shows that a series of decisions affects scheduling. Schedule decisions begin with planning capacity, which defines the facility and equipment resources available (discussed in Supplement 7). **Capacity plans** are usually made over a period of years as new equipment

TABLE 15.1 Scheduling Decisions

ORGANIZATION	MANAGERS SCHEDULE THE FOLLOWING
Alaska Airlines	Maintenance of aircraft Departure timetables Flight crews, catering, gate, and ticketing personnel
Arnold Palmer Hospital	Operating room use Patient admissions Nursing, security, maintenance staffs Outpatient treatments
University of Alabama	Classrooms and audiovisual equipment Student and instructor schedules Graduate and undergraduate courses
Amway Center	Ushers, ticket takers, food servers, security personnel Delivery of fresh foods and meal preparation Orlando Magic games, concerts, arena football
Lockheed Martin factory	Production of goods Purchases of materials Workers

VIDEO 15.1
From the Eagles to the Magic: Converting the Amway Center

TABLE 15.2 Different Processes Suggest Different Approaches to Scheduling

Process-focused facilities (job shops)
◆ Scheduling to customer orders where changes in both volume and variety of jobs/clients/patients are frequent.
◆ Schedules are often due-date focused, with loading refined by finite loading techniques.
◆ *Examples:* foundries, machine shops, cabinet shops, print shops, many restaurants, and the fashion industry.
Repetitive facilities (assembly lines)
◆ Schedule module production and product assembly based on frequent forecasts.
◆ Finite loading with a focus on generating a forward-looking schedule.
◆ JIT techniques are used to schedule components that feed the assembly line.
◆ *Examples:* assembly lines for washing machines at Whirlpool and automobiles at Ford.
Product-focused facilities (continuous)
◆ Schedule high-volume finished products of limited variety to meet a reasonably stable demand within existing fixed capacity.
◆ Finite loading with a focus on generating a forward-looking schedule that can meet known setup and run times for the limited range of products.
◆ *Examples:* huge paper machines at International Paper, beer in a brewery at Anheuser-Busch, and potato chips at Frito-Lay.

WIP inventory will be high. Therefore, the fewer the number of jobs that are in the system, the lower the inventory.

4. *Minimize customer waiting time:* Evaluated by determining the average number of late periods (e.g., days or hours).

These four criteria are used in this chapter, as they are in industry, to evaluate scheduling performance. In addition, good scheduling techniques should be simple, clear, easily understood, easy to carry out, flexible, and realistic.

Scheduling is further complicated by machine breakdowns, absenteeism, quality problems, shortages, and other factors. Consequently, assignment of a date does not ensure that the work will be performed according to the schedule. Many specialized techniques have been developed to aid in preparing reliable schedules. Table 15.2 provides an overview of approaches to scheduling for three different processes.

In this chapter, we first examine the scheduling of process-focused facilities and then the challenge of scheduling employees in the service sector.

Scheduling Process-Focused Facilities

Process-focused facilities (also known as *intermittent*, or *job-shop, facilities*) are common in high-variety, low-volume manufacturing and service organizations. These facilities produce make-to-order products or services and include everything from auto repair garages and hospitals to beauty salons. The production items themselves differ considerably, as do the talents, material, and equipment required to make them. Scheduling requires that the sequence of work (its routing), time required for each item, and the capacity and availability of each work center be known. The variety of products and unique requirements means that scheduling is often complex. In this section we look at some of the tools available to managers for loading and sequencing work for these facilities.

Loading Jobs

Operations managers assign jobs to work centers so that costs, idle time, or completion times are kept to a minimum. "Loading" work centers takes two forms. One is oriented to capacity; the second is related to assigning specific jobs to work centers.

First, we examine loading from the perspective of capacity via a technique known as *input–output* control. Then, we present two approaches used for loading: *Gantt charts* and the *assignment method* of linear programming.

Sequencing Jobs

Once jobs are *loaded* in a work center, as we just discussed, managers decide the *sequence* in which they are to be completed. **Sequencing** (often called *dispatching*) is accomplished by specifying the priority rules to use to release (dispatch) jobs to each work center.

Sequencing
Determining the order in which jobs should be done at each work center.

Priority Rules for Sequencing Jobs

Priority rules are especially applicable for process-focused facilities such as clinics, print shops, and manufacturing job shops. The most popular priority rules are:

- **FCFS:** first come, first served. Jobs are completed in the order they arrived.
- **SPT:** shortest processing time. Jobs with the shortest processing times are assigned first.
- **EDD:** earliest due date. Earliest due date jobs are assigned first.
- **LPT:** longest processing time. Jobs with the longest processing time are assigned first.

Priority rules
Rules used to determine the sequence of jobs in process-oriented facilities.

Performance Criteria The choice of which priority rule to choose depends in part on how each rule performs on four criteria: the priority rules try to minimize *completion time,* maximize *facility utilization,* minimize *number of jobs in the system*, and minimize *job lateness.* These performance criteria incorporate the concept of **flow time**, which measures the time each job spends waiting plus time being processed. For example, if Job B waits 6 days for Job A to be processed and then takes 2 more days of operation time itself, its flow time would be 6 + 2 = 8 days. The performance criteria are measured as:

Flow time
The time between the release of a job to a work center until the job is finished.

$$\text{Average completion time} = \frac{\text{Sum of total flow time}}{\text{Number of jobs}} \tag{15-1}$$

$$\text{Utilization metric} = \frac{\text{Total job work (processing) time}}{\text{Sum of total flow time}} \tag{15-2}$$

$$\text{Average number of jobs in the system} = \frac{\text{Sum of total flow time}}{\text{Total job work (processing) time}} \tag{15-3}$$

$$\text{Average job lateness} = \frac{\text{Total late days}}{\text{Number of jobs}} \tag{15-4}$$

Computing the lateness of a particular job involves assumptions about the start time during the day and the timing of delivering a completed job. Equation (15-5) assumes that today is a work day, work has not yet begun today, and a job finished by the end of a day can be delivered to the customer that same day.

$$\text{Job lateness} = \text{Max}\{0, \text{yesterday} + \text{flow time} - \text{due date}\} \tag{15-5}$$

For example, suppose that today is day 20 (thus yesterday was day 19). Job A is due tomorrow (day 21) and has a flow time of 1 day. That job would be considered to be completed on time, i.e., not late:

$$\text{Max}\{0, 19 + 1 - 21\} = \text{Max}\{0, -1\} = 0 \text{ days late.}$$

Meanwhile, Job B is due on day 32 and has a flow time of 15 days. The lateness of Job B would be:

$$\text{Max}\{0, 19 + 15 - 32\} = \text{Max}\{0, 2\} = 2 \text{ days late.}$$

We will examine four of the most popular priority rules in Example 5.

Example 5

PRIORITY RULES FOR DISPATCHING

Five architectural rendering jobs are waiting to be assigned at Avanti Sethi Architects. Their work (processing) times and due dates are given in the following table. The firm wants to determine the sequence of processing according to (1) FCFS, (2) SPT, (3) EDD, and (4) LPT rules. Jobs were assigned a letter in the order they arrived. Today is day 1, and work begins today.

2. Rules do not look upstream or downstream; idle resources and bottleneck resources in other departments may not be recognized.
3. Rules do not look beyond due dates. For instance, two orders may have the same due date. One order involves restocking a distributor and the other is a custom order that will shut down the customer's factory if not completed. Both may have the same due date, but clearly the custom order is more important.

Despite these limitations, schedulers often use sequencing rules such as SPT, EDD, or critical ratio. They apply these methods at each work center and then modify the sequence to deal with a multitude of real-world variables. They may do this manually or with finite capacity scheduling software.

Finite Capacity Scheduling (FCS)

Finite capacity scheduling (FCS)
Computerized short-term scheduling that overcomes the disadvantage of rule-based systems by providing the user with graphical interactive computing.

Short-term scheduling systems are also called finite capacity scheduling.[2] **Finite capacity scheduling (FCS)** overcomes the disadvantages of systems based exclusively on rules by providing the scheduler with interactive computing and graphic output. In dynamic scheduling environments such as job shops (with high variety, low volume, and shared resources) we expect changes. But changes disrupt schedules. Operations managers are moving toward FCS systems that allow virtually instantaneous change by the operator. Improvements in communication on the shop floor are also enhancing the accuracy and speed of information necessary for effective control in job shops. Computer-controlled machines can monitor events and collect information in near real-time. This means the scheduler can make schedule changes based on up-to-the-minute information. These schedules are often displayed in Gantt chart form. In addition to including priority rule options, many of the current FCS systems also combine an "expert system" or simulation techniques and allow the scheduler to assign costs to various options. The scheduler has the flexibility to handle any situation, including order, labor, or machine changes.

LO 15.6 *Define* finite capacity scheduling

The combining of planning and FCS data, priority rules, models to assist analysis, and Gantt chart output is shown in Figure 15.5.

Finite capacity scheduling allows delivery requirements to be based on today's conditions and today's orders, not according to some predefined rule. The scheduler determines what constitutes a "good" schedule. FCS software packages such as Lekin (shown in Figure 15.6), ProPlanner, Preactor, Asprova, Schedlyzer, and Jobplan are currently used at over 60% of U.S. plants.

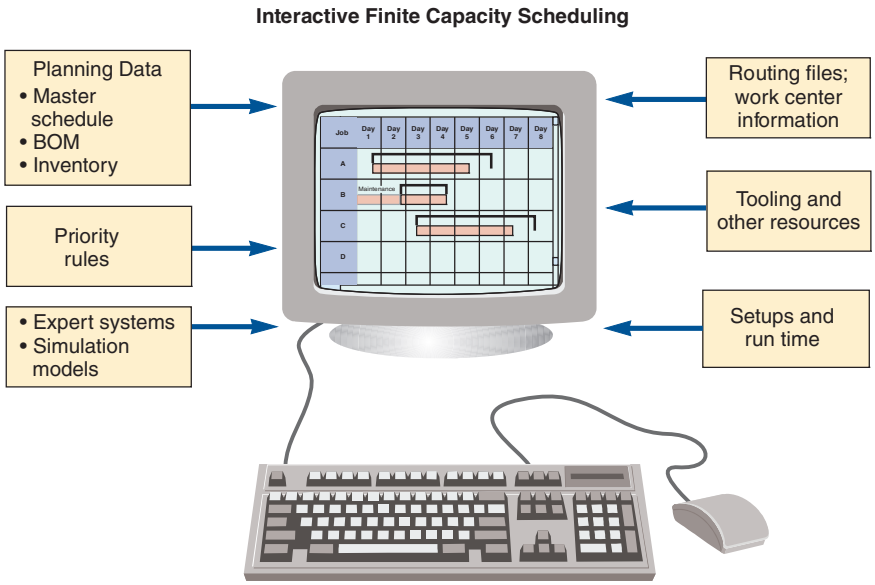
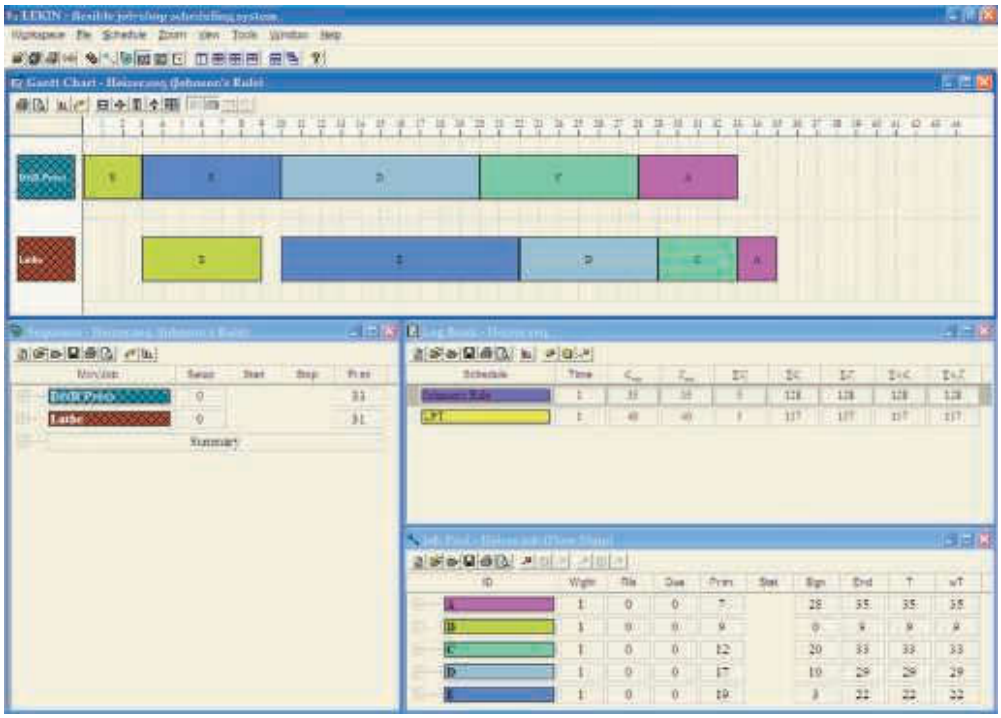


Figure **15.5**
Finite Capacity Scheduling Systems Use Production Data to Generate Gantt Load Charts, and Work-in-Process Data That Can Be Manipulated by the User to Evaluate Schedule Alternatives

Figure 15.6

Finite Capacity Scheduling (FCS) System

This Lekin® finite capacity scheduling software presents a schedule of the five jobs and the two work centers shown in Example 7 (pages 615–616) in Gantt chart form. The software is capable of using a variety of priority rules and many jobs. The Lekin software is available for free at **http://community.stern.nyu.edu/om/software/lekin/download.html** and can solve many of the problems at the end of this chapter.



Screenshot from Lekin® Finite Capacity Scheduling Software. Reprinted with permission.

Scheduling Services

STUDENT TIP Scheduling people to perform services can be even more complex than scheduling machines.

Scheduling service systems differs from scheduling manufacturing systems in several ways:

- In manufacturing, the scheduling emphasis is on machines and materials; in services, it is on staffing levels.
- Inventories can help smooth demand for manufacturers, but many service systems do not maintain inventories.
- Services are labor intensive, and the demand for this labor can be highly variable.
- Legal considerations, such as wage and hour laws and union contracts that limit hours worked per shift, week, or month, constrain scheduling decisions.
- Because services usually schedule people (rather than material), social, fatigue, seniority, and status issues complicate scheduling.

The following examples note the complexity of scheduling services.

VIDEO 15.2
Scheduling at Hard Rock Cafe

Hospitals A hospital is an example of a service facility that may use a scheduling system every bit as complex as one found in a job shop. Hospitals seldom use a machine shop priority system such as first come, first served (FCFS) for treating emergency patients, but they often use FCFS *within* a priority class, a "triage" approach. And they often schedule products (such as surgeries) just like a factory, maintaining excess capacity to meet wide variations in demand.

Banks Cross-training of the workforce in a bank allows loan officers and other managers to provide short-term help for tellers if there is a surge in demand. Banks also employ part-time personnel to provide a variable capacity.

Retail Stores Scheduling optimization systems, such as Workbrain, Cybershift, and Kronos, are used at retailers including Walmart, Payless Shoes, and Target. These systems track individual store sales, transactions, units sold, and customer traffic in 15-minute increments to create work schedules. Walmart's 2.2 million and Target's 350,000 employees used to take thousands of managers' hours to schedule; now staffing is drawn up nationwide in a few hours, and customer checkout experience has improved dramatically.

Starbucks' scheduling software is discussed in the *OM in Action* box on the next page.

Doris needs six full-time employees to meet the staffing needs and one employee to work Saturday.

Notice that capacity (number of employees) equals requirements, provided an employee works overtime on Saturday, or a part-time employee is hired for Saturday.

INSIGHT ▶ Doris has implemented an efficient scheduling system that accommodates 2 consecutive days off for every employee.

LEARNING EXERCISE ▶ If Doris meets the staffing requirement for Saturday with a full-time employee, how does she schedule that employee? [Answer: That employee can have any 2 days off, except Saturday, and capacity will exceed requirements by 1 person each day the employee works (except Saturday).]

RELATED PROBLEMS ▶ 15.26, 15.27

Using the approach in Example 8, Colorado General Hospital saved an average of 10 to 15 hours a month and found these added advantages: (1) no computer was needed, (2) the nurses were happy with the schedule, (3) the cycles could be changed seasonally to accommodate avid skiers, and (4) recruiting was easier because of predictability and flexibility. This approach yields an optimum, although there may be multiple optimal solutions.

Other cyclical scheduling techniques have been developed to aid service scheduling. Some approaches use linear programming: This is how Hard Rock Cafe schedules its services (see the Video Case Study at the end of this chapter). There is a natural bias in scheduling to use tools that are understood and yield solutions that are accepted.

Summary

Scheduling involves the timing of operations to achieve the efficient movement of units through a system. This chapter addressed the issues of short-term scheduling in process-focused and service environments. We saw that process-focused facilities are production systems in which products are made to order and that scheduling tasks in them can become complex. Several aspects and approaches to scheduling, loading, and sequencing of jobs were introduced. These ranged from Gantt charts and the assignment method of scheduling to a series of priority rules, the critical-ratio rule, Johnson's rule for sequencing, and finite capacity scheduling.

Service systems generally differ from manufacturing systems. This leads to the use of first-come, first-served rules and appointment and reservation systems, as well as linear programming for matching capacity to demand in service environments.

Key Terms

Loading (p. 604)
Input–output control (p. 606)
ConWIP cards (p. 606)
Gantt charts (p. 607)
Assignment method (p. 608)
Sequencing (p. 611)
Priority rules (p. 611)
Flow time (p. 611)
Critical ratio (CR) (p. 614)
Johnson's rule (p. 615)
Finite capacity scheduling (FCS) (p. 617)

Ethical Dilemma

Scheduling people to work second and third shifts (evening and "graveyard") is a problem in almost every 24-hour company. Medical and ergonomic data indicate the body does not respond well to significant shifts in its natural circadian rhythm of sleep. There are also significant long-run health issues with frequent changes in work and sleep cycles.

Consider yourself the manager of a nonunion steel mill that must operate 24-hour days, and where the physical demands are such that 8-hour days are preferable to 10- or 12-hour days.

Your empowered employees have decided that they want to work weekly rotating shifts. That is, they want a repeating work cycle of 1 week, 7 A.M. to 3 P.M., followed by a second week from 3 P.M. to 11 P.M., and the third week from 11 P.M. to 7 P.M. You are sure this is not a good idea in terms of both productivity and the long-term health of the employees. If you do not accept their decision, you undermine the work empowerment program, generate a morale issue, and perhaps, more significantly, generate few more votes for a union. What is the ethical position and what do you do?

Marcel Mooij/Shutterstock

Discussion Questions

1. What is the overall objective of scheduling?
2. List the four criteria for determining the effectiveness of a *scheduling* decision. How do these criteria relate to the four criteria for *sequencing* decisions?
3. Describe what is meant by "loading" work centers. What are the two ways work centers can be loaded? What are two techniques used in loading?
4. Name five priority sequencing rules. Explain how each works to assign jobs.
5. What are the advantages and disadvantages of the shortest processing time (SPT) rule?
6. What is a due date?
7. Explain the terms *flow time* and *lateness*.
8. Which shop-floor scheduling rule would you prefer to apply if you were the leader of the only team of experts charged with defusing several time bombs scattered throughout your building? You can see the bombs; they are of different types. You can tell how long each one will take to defuse. Discuss.
9. When is Johnson's rule best applied in job-shop scheduling?
10. State the four effectiveness measures for dispatching rules.
11. What are the steps of the assignment method of linear programming?
12. What are the advantages to finite capacity scheduling?
13. What is input–output control?

Using Software for Short-Term Scheduling

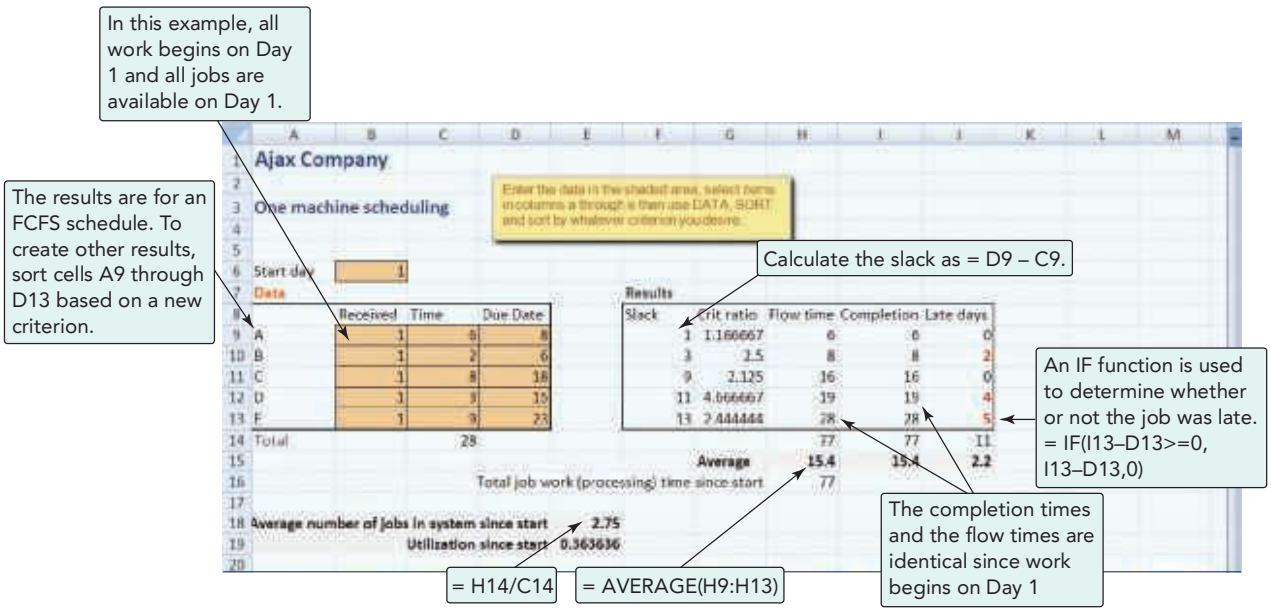
In addition to the commercial software we noted in this chapter, short-term scheduling problems can be solved with the Excel OM software that comes free with this text. POM for Windows also includes a scheduling module. The use of each of these programs is explained next.

USING EXCEL OM

Excel OM has two modules that help solve short-term scheduling problems: Assignment and Job Shop Scheduling. The Assignment module is illustrated in Programs 15.1 and 15.2. The input screen, using the Example 4 data, appears first, as Program 15.1. Once the data are all entered, we choose the **Data tab** command, followed by the **Solver** command. Excel's Solver uses linear programming to optimize assignment problems. (So select Simplex LP.) The constraints are also shown in Program 15.1. We then select the **Solve** command; the solution appears in Program 15.2.

Excel OM's Job Shop Scheduling module is illustrated in Program 15.3. Program 15.3 uses Example 5's data. Because jobs are listed in the sequence in which they arrived (see column A), the results are for the FCFS rule. Program 15.3 also shows some of the formulas (columns F, G, H, I, J) used in the calculations.

To solve with the SPT rule, we need four intermediate steps: (1) Select (that is, highlight) the data in columns A, B, C for all jobs; (2) invoke the **Data** command; (3) invoke the **Sort** command; and (4) sort by **Time** (column C) in *ascending* order. To solve for EDD, Step 4 changes to sort by **Due Date** (column D) in *ascending* order. Finally, for an LPT solution, Step 4 becomes sort by **Due Date** (column D) in *descending* order.



Program **15.3**

Excel OM's Job Shop Scheduling Module Applied to Example 5's Data

P USING POM FOR WINDOWS

POM for Windows can handle both categories of scheduling problems we see in this chapter. Its Assignment module is used to solve the traditional one-to-one assignment problem of people to tasks, machines to jobs, and so on. Its Job Shop Scheduling module can solve a one- or two-machine job-shop problem. Available priority rules include SPT, FCFS, EDD, and LPT. Each can be examined in turn once the data are all entered. Refer to Appendix IV for specifics regarding POM for Windows.

Solved Problems

Virtual Office Hours help is available in MyOMLab.

SOLVED PROBLEM 15.1

King Finance Corporation, headquartered in New York, wants to assign three recently hired college graduates, Julie Jones, Al Smith, and Pat Wilson, to regional offices. However, the firm also has an opening in New York and would send one of the three there if it were more economical than a move to Omaha, Dallas, or Miami. It will cost $1,000 to relocate Jones to New York, $800 to relocate Smith there, and $1,500 to move Wilson. What is the optimal assignment of personnel to offices?

HIREE \ OFFICE	OMAHA	MIAMI	DALLAS
Jones	$800	$1,100	$1,200
Smith	$500	$1,600	$1,300
Wilson	$500	$1,000	$2,300

SOLUTION

a) The cost table has a fourth column to represent New York. To "balance" the problem, we add a "dummy" row (person) with a zero relocation cost to each city.

HIREE \ OFFICE	OMAHA	MIAMI	DALLAS	NEW YORK
Jones	$800	$1,100	$1,200	$1,000
Smith	$500	$1,600	$1,300	$ 800
Wilson	$500	$1,000	$2,300	$1,500
Dummy	0	0	0	0

b) Subtract the smallest number in each row and cover all zeros (column subtraction of each column's zero will give the same numbers and therefore is not necessary):

HIREE \ OFFICE	OMAHA	MIAMI	DALLAS	NEW YORK
Jones	0	300	400	200
Smith	0	1,100	800	300
Wilson	0	500	1,800	1,000
Dummy	~~0~~	~~0~~	~~0~~	~~0~~

Problems

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

Problems 15.1–15.14 relate to Loading Jobs

•• **15.1** Ron Satterfield's excavation company uses both Gantt scheduling charts and Gantt load charts.

a) Today, which is the end of day 7, Ron is reviewing the Gantt chart depicting these schedules:
- Job #151 was scheduled to begin on day 3 and to take 6 days. As of now, it is 1 day ahead of schedule.
- Job #177 was scheduled to begin on day 1 and take 4 days. It is currently on time.
- Job #179 was scheduled to start on day 7 and take 2 days. It actually got started on day 6 and is progressing according to plan.
- Job #211 was scheduled to begin on day 5, but missing equipment delayed it until day 6. It is progressing as expected and should take 3 days.
- Job #215 was scheduled to begin on day 4 and take 5 days. It got started on time but has since fallen behind 2 days.

Draw the Gantt scheduling chart for the activities above.

b) Ron now wants to use a Gantt load chart to see how much work is scheduled in each of his three work teams: Able, Baker, and Charlie. Five jobs constitute the current workload for these three work teams: Job #250, requiring 48 hours and #275 requiring 32 hours for Work Team Able; Jobs #210 and #280, requiring 16 and 24 hours, respectively, for Team Baker; and Job #225, requiring 40 hours, for Team Charlie.

Prepare the Gantt load chart for these activities.

•• **15.2** First Printing and Copy Center has 4 more jobs to be scheduled, in addition to those shown in Example 3 in the chapter. Production scheduling personnel are reviewing the Gantt chart at the end of day 4.
- Job D was scheduled to begin early on day 2 and to end on the middle of day 9. As of now (the review point after day 4), it is 2 days ahead of schedule.
- Job E should begin on day 1 and end on day 3. It is on time.
- Job F was to begin on day 3, but maintenance forced a delay of 1½ days. The job should now take 5 full days. It is now on schedule.
- Job G is a day behind schedule. It started at the beginning of day 2 and should require 6 days to complete.

Develop a Gantt schedule chart for First Printing and Copy Center.

• **15.3** The Green Cab Company has a taxi waiting at each of four cabstands in Evanston, Illinois. Four customers have called and requested service. The distances, in miles, from the waiting taxis to the customers are given in the following table. Find the optimal assignment of taxis to customers so as to minimize total driving distances to the customers.

	CUSTOMER			
CAB SITE	A	B	C	D
Stand 1	7	3	4	8
Stand 2	5	4	6	5
Stand 3	6	7	9	6
Stand 4	8	6	7	4

PX

• **15.4** J.C. Howard's medical testing company in Kansas wishes to assign a set of jobs to a set of machines. The following table provides the production data of each machine when performing the specific job:

	MACHINE			
JOB	A	B	C	D
1	7	9	8	10
2	10	9	7	6
3	11	5	9	6
4	9	11	5	8

a) Determine the assignment of jobs to machines that will *maximize* total production.

b) What is the total production of your assignments? PX

• **15.5** The Johnny Ho Manufacturing Company in Columbus, Ohio, is putting out four new electronic components. Each of Ho's four plants has the capacity to add one more product to its current line of electronic parts. The unit-manufacturing costs for producing the different parts at the four plants are shown in the accompanying table. How should Ho assign the new products to the plants to minimize manufacturing costs?

ELECTRONIC COMPONENT	PLANT			
	1	2	3	4
C53	$0.10	$0.12	$0.13	$0.11
C81	0.05	0.06	0.04	0.08
D5	0.32	0.40	0.31	0.30
D44	0.17	0.14	0.19	0.15

PX

• **15.6** Jamison Day Consultants has been entrusted with the task of evaluating a business plan that has been divided into four sections—marketing, finance, operations, and human resources. Chris, Steve, Juana, and Rebecca form the evaluation team. Each of them has expertise in a certain field and tends to finish that section faster. The estimated times taken by each team member for each section have been outlined in the table below. Further information states that each of these individuals is paid $60/hour.

a) Assign each member to a different section such that Jamison Consultants's overall cost is minimized.

b) What is the total cost of these assignments?

Times Taken by Team Members for Different Sections (minutes)

	MARKETING	FINANCE	OPERATIONS	HR
Chris	80	120	125	140
Steve	20	115	145	160
Juana	40	100	85	45
Rebecca	65	35	25	75

PX

•• **15.7** The Baton Rouge Police Department has five detective squads available for assignment to five open crime cases. The chief of detectives, Jose Noguera, wishes to assign the squads so that the total time to conclude the cases is minimized. The average number of days, based on past performance, for each squad to complete each case is as follows:

	CASE				
SQUAD	A	B	C	D	E
1	14	7	3	7	27
2	20	7	12	6	30
3	10	3	4	5	21
4	8	12	7	12	21
5	13	25	24	26	8

CASE STUDIES

Old Oregon Wood Store

In 2015, George Wright started the Old Oregon Wood Store to manufacture Old Oregon tables. Each table is carefully constructed by hand using the highest-quality oak. Old Oregon tables can support more than 500 pounds, and since the start of the Old Oregon Wood Store, not one table has been returned because of faulty workmanship or structural problems. In addition to being rugged, each table is beautifully finished using a urethane varnish that George developed over 20 years of working with wood-finishing materials.

The manufacturing process consists of four steps: preparation, assembly, finishing, and packaging. Each step is performed by one person. In addition to overseeing the entire operation, George does all of the finishing. Tom Surowski performs the preparation step, which involves cutting and forming the basic components of the tables. Leon Davis is in charge of the assembly, and Cathy Stark performs the packaging.

Although each person is responsible for only one step in the manufacturing process, everyone can perform any one of the steps. It is George's policy that occasionally everyone should complete several tables on his or her own without any help or assistance. A small competition is used to see who can complete an entire table in the least amount of time. George maintains average total and intermediate completion times. The data are shown in Figure 15.7.

It takes Cathy longer than the other employees to construct an Old Oregon table. In addition to being slower than the other employees, Cathy is also unhappy about her current responsibility of packaging, which leaves her idle most of the day. Her first preference is finishing, and her second preference is preparation.

In addition to quality, George is concerned with costs and efficiency. When one of the employees misses a day, it causes major scheduling problems. In some cases, George assigns another employee overtime to complete the necessary work. At other times, George simply waits until the employee returns to work to complete his or her step in the manufacturing process. Both solutions cause problems. Overtime is expensive, and waiting causes delays and sometimes stops the entire manufacturing process.

To overcome some of these problems, Randy Lane was hired. Randy's major duties are to perform miscellaneous jobs and to help out if one of the employees is absent. George has given Randy training in all phases of the manufacturing process, and he is pleased with the speed at which Randy has been able to learn how to completely assemble Old Oregon tables. Randy's average total and intermediate completion times are given in Figure 15.8.

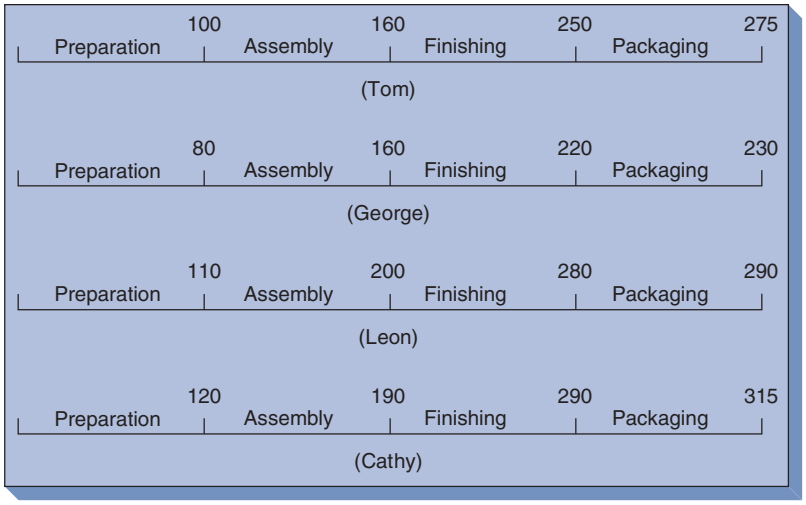


Figure 15.7
Manufacturing Time in Minutes

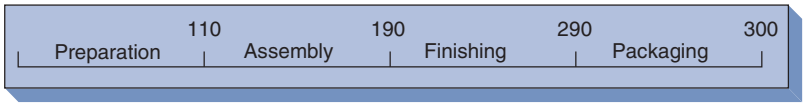


Figure 15.8
Randy's Completion Times in Minutes

Discussion Questions

1. What is the fastest way to manufacture Old Oregon tables using the original crew? How many could be made per day?
2. Would production rates and quantities change significantly if George would allow Randy to perform one of the four functions and make one of the original crew the backup person?
3. What is the fastest time to manufacture a table with the original crew if Cathy is moved to either preparation or finishing?
4. Whoever performs the packaging function is severely underutilized. Can you find a better way of utilizing the four- or five-person crew than either giving each a single job or allowing each to manufacture an entire table? How many tables could be manufactured per day with this scheme?

TABLE 15.3 *Continued*

TIME ALLOWED	TASKS	CREW AND TIME REQUIRED
2 hr	**Chair Crew** *Starts after Seating Unit Crew finishes*	12
	Get chair carts from storage	
	Position chair carts on floor	
	Position chairs behind goals, courtside, and scorer tables	
	Clean, sweep, and place carts in order	
45 min	**End-of-Shift Activities** *Starts after Chair Crew finishes*	12
	Perform checklist items	
	Ensure that steps and stairways and railings are in place and tight	
	Check all seats are in upright position and locked in place	
	Report any damaged seats or armrests in need of repair	
	Verify exact number of chairs behind goals, courtside, and scorer tables	
15 min	**Check Out** *Starts after End-of-Shift Activities*	16
	Check for next conversion date and time and inform crew	
	Report any injuries Punch out all employees before leaving **8:00 AM** Floor ready for Magic practice	

Discussion Questions*

1. Make a Gantt chart to help Charlie organize his crew to perform the concert-to-basketball conversion. *Note*: Do not include the teardown of the concert stage and equipment, as that is the responsibility of the concert crew.
2. What time will the floor be ready?
3. Does Charlie have any extra personnel or a shortage of personnel? If so how many?

*You may wish to view the video that accompanies this case before answering the questions.

Scheduling at Hard Rock Cafe

Video Case 

Whether it's scheduling nurses at Mayo Clinic, pilots at Southwest Airlines, classrooms at UCLA, or servers at a Hard Rock Cafe, it's clear that good scheduling is important. Proper schedules use an organization's assets (1) more effectively, by serving customers promptly, and (2) more efficiently, by lowering costs.

Hard Rock Cafe at Universal Studios, Orlando, is the world's largest restaurant, with 1,100 seats on two main levels. With typical turnover of employees in the restaurant industry at 80% to 100% per year, Hard Rock General Manager Ken Hoffman takes scheduling very seriously. Hoffman wants his 160 servers to be effective, but he also wants to treat them fairly. He has done so with scheduling software and flexibility that has increased productivity while contributing to turnover that is half the industry average. His goal is to find the fine balance that gives employees financially productive daily work shifts while setting the schedule tight enough so as to not overstaff between lunch and dinner.

The weekly schedule begins with a sales forecast. "First, we examine last year's sales at the cafe for the same day of the week," says Hoffman. "Then we adjust our forecast for this year based on a variety of closely watched factors. For example, we call the Orlando Convention Bureau every week to see what major groups will be in town. Then we send two researchers out to check on the occupancy of nearby hotels. We watch closely to see what concerts are scheduled at Hard Rock Live—the 3,000-seat concert stage next door. From the forecast, we calculate how many people we need to have on duty each day for the kitchen, the bar, as hosts, and for table service."

Once Hard Rock determines the number of staff needed, servers submit request forms, which are fed into the software's linear programming mathematical model. Individuals are given priority rankings from 1 to 9, based on their seniority and how important they are to fill each day's schedule. Schedules are then posted by day and by workstation. Trades are handled between employees, who understand the value of each specific shift and station.

Hard Rock employees like the system, as does the general manager, since sales per labor-hour are rising and turnover is dropping.

Discussion Questions*

1. Name and justify several factors that Hoffman could use in forecasting weekly sales.
2. What can be done to lower turnover in large restaurants?
3. Why is seniority important in scheduling servers?
4. How does the schedule impact productivity?

*You may wish to view the video that accompanies this case before answering the questions.

- **Additional Case Study:** Visit MyOMLab for this free case study:
  Payroll Planning, Inc.: Describes setting a schedule for handling the accounting for dozens of client firms.

Endnotes

1. Opportunity costs are those profits forgone or not obtained.
2. Finite capacity scheduling (FCS) systems go by a number of names, including finite scheduling and advance planning systems (APS). The name manufacturing execution systems (MES) may also be used, but MES tends to suggest an emphasis on the reporting system from shop operations back to the scheduling activity.

Chapter 15 *Rapid* Review

Main Heading	Review Material	MyOMLab
THE IMPORTANCE OF SHORT-TERM SCHEDULING (p. 602)	The strategic importance of scheduling is clear: ■ Effective scheduling means *faster movement* of goods and services through a facility. This means greater use of assets and hence greater capacity per dollar invested, which, in turn, *lowers cost*. ■ Added capacity, faster throughput, and the related flexibility mean better customer service through *faster delivery*. ■ Good scheduling contributes to realistic commitments, hence *dependable delivery*.	Concept Questions: 1.1–1.2
SCHEDULING ISSUES (pp. 602–605)	*The objective of scheduling is to allocate and prioritize demand (generated by either forecasts or customer orders) to available facilities.* ■ Forward scheduling—Begins the schedule as soon as the requirements are known. ■ Backward scheduling—Begins with the due date by scheduling the final operation first and the other job steps in reverse order. ■ Loading—The assigning of jobs to work or processing centers. The four scheduling criteria are (1) *minimize completion time*, (2) *maximize utilization*, (3) *minimize work-in-process (WIP) inventory*, and (4) *minimize customer waiting time*.	Concept Questions: 2.1–2.4 **VIDEO 15.1** From the Eagles to the Magic: Converting the Amway Center
SCHEDULING PROCESS-FOCUSED FACILITIES (p. 605)	A process-focused facility is a high-variety, low-volume system commonly found in manufacturing and services. It is also called an intermittent, or job shop, facility.	Concept Questions: 3.1–3.4
LOADING JOBS (pp. 605–610)	■ **Input–output control**—A system that allows operations personnel to manage facility work flows by tracking work added to a work center and its work completed. ■ **ConWIP cards**—Cards that control the amount of work in a work center, aiding input/output control. ConWIP is an acronym for *constant work-in-process.* A ConWIP card travels with a job (or batch) through the work center. When the job is finished, the card is released and returned to the initial workstation, authorizing the entry of a new batch into the work center. ■ **Gantt charts**—Planning charts used to schedule resources and allocate time. The Gantt *load chart* shows the loading and idle times of several departments, machines, or facilities. It displays the relative workloads in the system so that the manager knows what adjustments are appropriate. The Gantt *schedule chart* is used to monitor jobs in progress (and is also used for project scheduling). It indicates which jobs are on schedule and which are ahead of or behind schedule. ■ **Assignment method**—A special class of linear programming models that involves assigning tasks or jobs to resources. In assignment problems, only one job (or worker) is assigned to one machine (or project). The assignment method involves adding and subtracting appropriate numbers in the table to find the lowest *opportunity cost* for each assignment.	Concept Questions: 4.1–4.4 Problems: 15.1–15.14 Virtual Office Hours for Solved Problem: 15.1
SEQUENCING JOBS (pp. 611–617)	■ **Sequencing**—Determining the order in which jobs should be done at each work center. ■ **Priority rules**—Rules used to determine the sequence of jobs in process-oriented facilities. ■ First come, first served (FCFS)—Jobs are completed in the order in which they arrived. ■ Shortest processing time (SPT)—Jobs with the shortest processing times are assigned first. ■ Earliest due date—Earliest due date jobs are performed first. ■ Longest processing time (LPT)—Jobs with the longest processing time are completed first. $$\text{Average completion time} = \frac{\text{Sum of total flow time}}{\text{Number of jobs}} \quad (15\text{-}1)$$ $$\text{Utilization metric} = \frac{\text{Total job work (processing) time}}{\text{Sum of total flow time}} \quad (15\text{-}2)$$	Concept Questions: 5.1–5.4 Problems: 15.15–15.25 Virtual Office Hours for Solved Problems: 15.2–15.5 **ACTIVE MODEL 15.1**

Chapter 15 Rapid Review *continued*

Main Heading	Review Material	MyOMLab
	$$\text{Average number of jobs in the system} = \frac{\text{Sum of total flow time}}{\text{Total job work (processing) time}} \quad (15\text{-}3)$$ $$\text{Average job lateness} = \frac{\text{Total late days}}{\text{Number of jobs}} \quad (15\text{-}4)$$ $$\text{Job lateness} = \text{Max}\{0, \text{yesterday} + \text{flow time} - \text{due date}\} \quad (15\text{-}5)$$ SPT is the best technique for minimizing job flow and average number of jobs in the system. FCFS performs about average on most criteria, and it appears fair to customers. EDD minimizes maximum tardiness. ■ **Flow time**—The time each job spends waiting plus the time being processed. ■ **Critical ratio (CR)**—A sequencing rule that is an index number computed by dividing the time remaining until due date by the work time remaining: $$\text{CR} = \frac{\text{Time remaining}}{\text{Workdays remaining}} = \frac{\text{Due date} - \text{Today's date}}{\text{Work (lead) time remaining}} \quad (15\text{-}6)$$ As opposed to the priority rules, the critical ratio is dynamic and easily updated. It tends to perform better than FCFS, SPT, EDD, or LPT on the average job-lateness criterion. ■ **Johnson's rule**—An approach that minimizes processing time for sequencing a group of jobs through two work centers while minimizing total idle time in the work centers. Rule-based scheduling systems have the following limitations: (1) Scheduling is dynamic, (2) rules do not look upstream or downstream, and (3) rules do not look beyond due dates.	
FINITE CAPACITY SCHEDULING (FCS) (pp. 617–618)	■ **Finite capacity scheduling (FCS)**—Computerized short-term scheduling that overcomes the disadvantage of rule-based systems by providing the user with graphical interactive computing.	Concept Questions: 6.1–6.2
SCHEDULING SERVICES (pp. 618–621)	Cyclical scheduling with inconsistent staffing needs is often the case in services. The objective focuses on developing a schedule with the minimum number of workers. In these cases, each employee is assigned to a shift and has time off.	Concept Questions: 7.1–7.4 **VIDEO 15.2** Scheduling at Hard Rock Cafe Problems: 15.26–15.27

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 15.1 Which of the following decisions covers the longest time period?
a) Short-term scheduling
b) Capacity planning
c) Aggregate planning
d) A master schedule

LO 15.2 A visual aid used in loading and scheduling jobs is a:
a) Gantt chart.
b) planning file.
c) bottleneck.
d) load-schedule matrix.
e) level material chart.

LO 15.3 The assignment method involves adding and subtracting appropriate numbers in the table to find the lowest _____ for each assignment.
a) profit
b) number of steps
c) number of allocations
d) range per row
e) opportunity cost

LO 15.4 The most popular priority rules include:
a) FCFS. **b)** EDD.
c) SPT. **d)** all of the above.

LO 15.5 The job that should be scheduled last when using Johnson's rule is the job with the:
a) largest total processing time on both machines.
b) smallest total processing time on both machines.
c) longest activity time if it lies with the first machine.
d) longest activity time if it lies with the second machine.
e) shortest activity time if it lies with the second machine.

LO 15.6 What is computerized short-term scheduling that overcomes the disadvantage of rule-based systems by providing the user with graphical interactive computing?
a) LPT **b)** FCS
c) CSS **d)** FCFS
e) GIC

LO 15.7 Cyclical scheduling is used to schedule:
a) jobs. **b)** machines.
c) shipments. **d)** employees.

Answers: LO 15.1. b; LO 15.2. a; LO 15.3. e; LO 15.4. d; LO 15.5. e; LO 15.6. b; LO 15.7. d.