Aggregate Planning and S&OP

CHAPTER 13

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 13

GLOBAL COMPANY PROFILE
Frito-Lay

Aggregate Planning Provides a Competitive Advantage at Frito-Lay

Like other organizations throughout the world, Frito-Lay relies on effective aggregate planning to match fluctuating multi-billion-dollar demand to capacity in its 36 North American plants. Planning for the intermediate term (3 to 18 months) is the heart of aggregate planning. Effective aggregate planning combined with tight scheduling, effective maintenance, and efficient employee and facility scheduling are the keys to high plant utilization. High utilization is a critical factor in facilities such as Frito-Lay, where capital investment is substantial.

Frito-Lay has more than three dozen brands of snacks and chips, 15 of which sell more than $100 million annually and 7 of which sell over $1 billion. Its brands include such well-known names as Fritos, Lay's, Doritos, Sun Chips, Cheetos, Tostitos, Flat Earth, and Ruffles. Unique processes using specially designed equipment are required to produce each of these products. Because these specialized processes generate high fixed cost, they must operate at very high volume. But such product-focused facilities benefit by having low variable costs. High utilization and performance above the break-even point require a good match between demand and capacity. Idle equipment is disastrous.

At Frito-Lay's headquarters near Dallas, planners create a total demand profile. They use historical product sales, forecasts of new products, product innovations, product promotions,

Frito-Lay North America

The aggregate plan adjusts for farm location, yield, and quantities for timely delivery of Frito-Lay's unique varieties of potatoes. During harvest times, potatoes go directly to the plant. During non-harvest months, potatoes are stored in climate-controlled environments to maintain quality, texture, and taste.

LEARNING OBJECTIVES

LO 13.1 ***Define*** sales and operations planning 533
LO 13.2 ***Define*** aggregate planning 534
LO 13.3 ***Identify*** optional strategies for developing an aggregate plan 535
LO 13.4 ***Prepare*** a graphical aggregate plan 538
LO 13.5 ***Solve*** an aggregate plan via the transportation method 544
LO 13.6 ***Understand*** and solve a revenue management problem 548

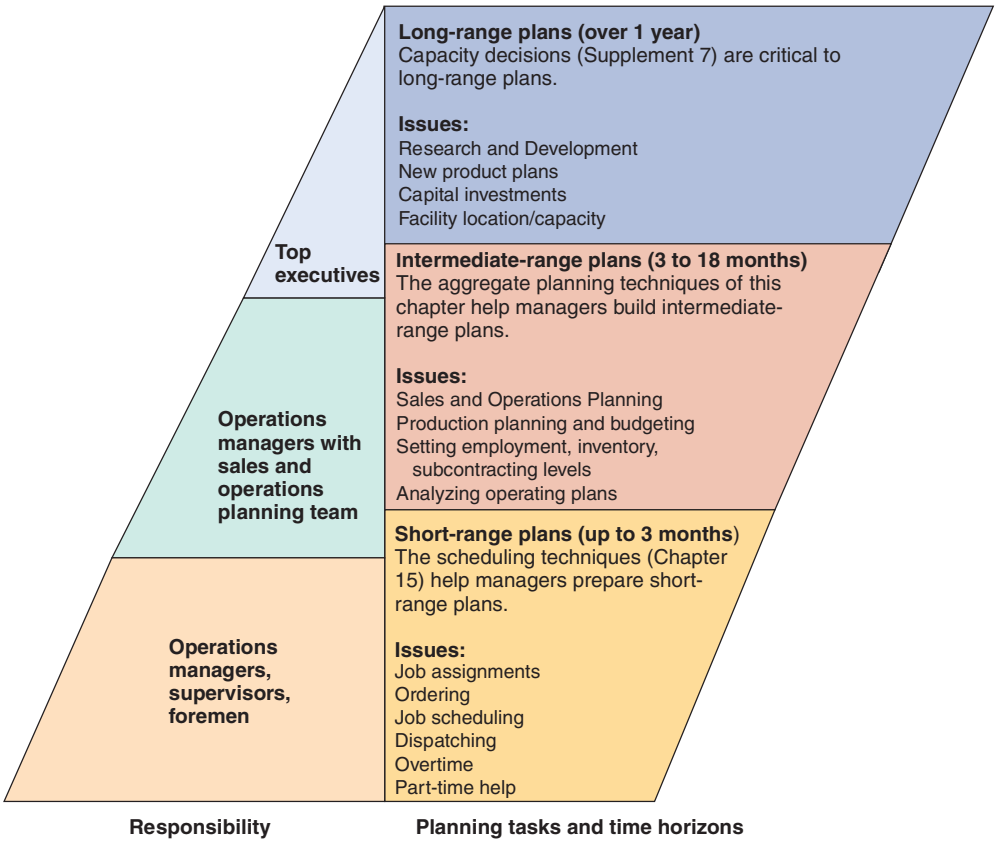
The Planning Process

In Chapter 4, we saw that demand forecasting can address long-, medium-, and short-range decisions. Figure 13.1 illustrates how managers translate these forecasts into long-, intermediate-, and short-range plans. Long-range forecasts, the responsibility of top management, provide data for a firm's multi-year plans. These long-range plans require policies and strategies related to issues such as capacity and capital investment (Supplement 7), facility location (Chapter 8), new products (Chapter 5) and processes (Chapter 7), and supply-chain development (Chapter 11).

Intermediate plans are designed to be consistent with top management's long-range plans and strategy, and work within the resource constraints determined by earlier strategic decisions. The challenge is to have these plans match production to the ever-changing demands of the market. Intermediate plans are the job of the operations manager, working with other functional areas of the firm. In this chapter we deal with intermediate plans, typically measured in months.

Short-range plans are usually for less than 3 months. These plans are also the responsibility of operations personnel. Operations managers work with supervisors and foremen to translate

Figure 13.1
Planning Tasks and Responsibilities



the intermediate plan into short-term plans consisting of weekly, daily, and hourly schedules. Short-term planning techniques are discussed in Chapter 15.

Intermediate planning is initiated by a process known as *sales and operations planning (S&OP)*.

Sales and Operations Planning

Good intermediate planning requires the coordination of demand forecasts with functional areas of a firm and its supply chain. And because each functional part of a firm and the supply chain has its own limitations and constraints, the coordination can be difficult. This coordinated planning effort has evolved into a process known as **sales and operations planning (S&OP)**. As Figure 13.2 shows, S&OP receives input from a variety of sources both internal and external to the firm. Because of the diverse inputs, S&OP is typically done by cross-functional teams that align the competing constraints.

Sales and operations planning (S&OP)
A process of balancing resources and forecasted demand, aligning an organization's competing demands from supply chain to final customer, while linking strategic planning with operations over all planning horizons.

LO 13.1 *Define* sales and operations planning

One of the tasks of S&OP is to determine which plans are feasible in the coming months and which are not. Any limitations, both within the firm and in the supply chain, must be reflected in an intermediate plan that brings day-to-day sales and operational realities together. When the resources appear to be substantially at odds with market expectations, S&OP provides advanced warning to top management. If the plan cannot be implemented in the short run, the planning exercise is useless. And if the plan cannot be supported in the long run, strategic changes need to be made. To keep aggregate plans current and to support its intermediate planning role, S&OP uses rolling forecasts that are frequently updated—often weekly or monthly.

The output of S&OP is called an *aggregate plan*. The **aggregate plan** is concerned with determining the quantity and timing of production for the intermediate future, often from 3 to

Aggregate plan
A plan that includes forecast levels for families of products of finished goods, inventory, shortages, and changes in the workforce.

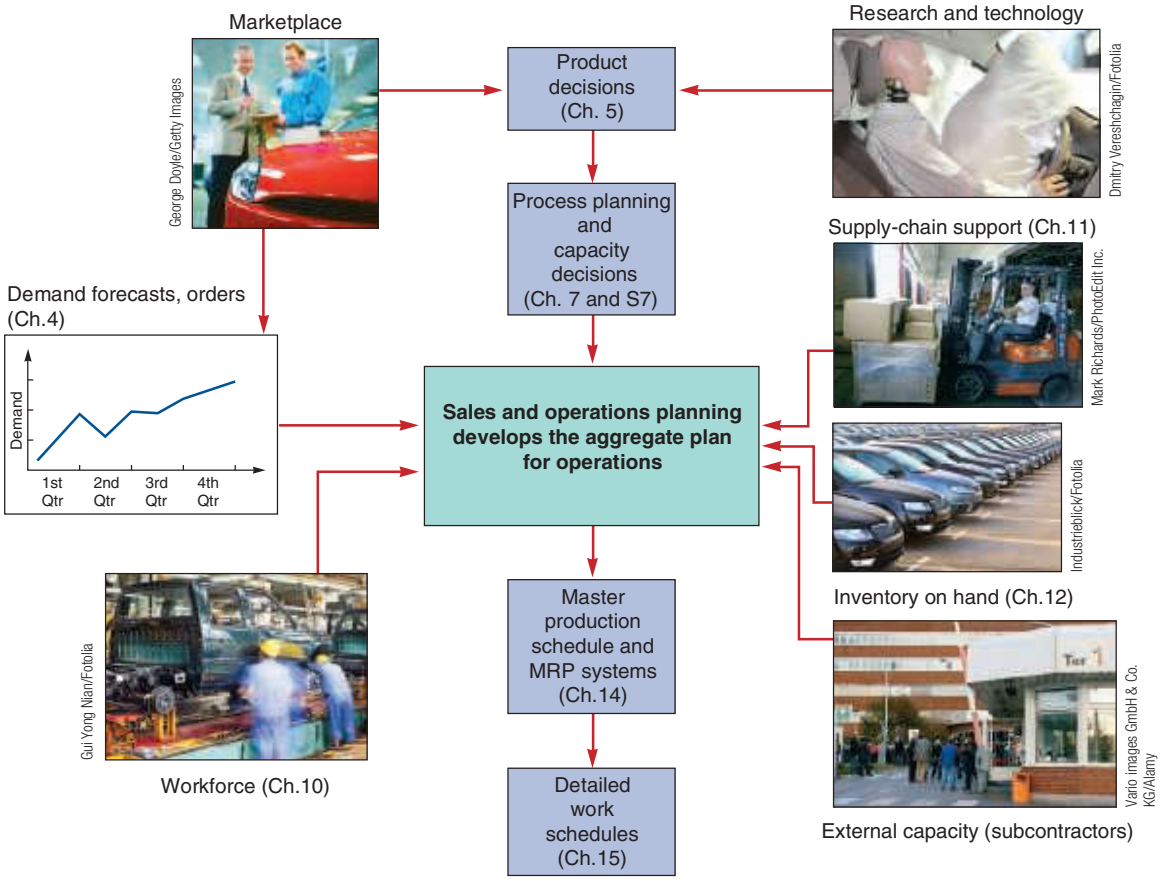


Figure **13.2**

Relationships of S&OP and the Aggregate Plan

18 months ahead. Aggregate plans use information regarding product families or product lines rather than individual products. These plans are concerned with the total, or *aggregate,* of the individual product lines.

Rubbermaid, Office Max, and Rackspace have developed formal systems for S&OP, each with its own planning focus. Rubbermaid may use S&OP with a focus on production decisions; Office Max may focus S&OP on supply chain and inventory decisions; while Rackspace, a data storage firm, tends to have its S&OP focus on its critical and expensive investments in capacity. In *all* cases, though, the decisions must be tied to strategic planning and integrated with *all* areas of the firm over *all* planning horizons. Specifically, S&OP is aimed at (1) the coordination and integration of the internal and external resources necessary for a successful aggregate plan and (2) communication of the plan to those charged with its execution. The added advantage of S&OP and an aggregate plan is that they can be effective tools to engage members of the supply chain in achieving the firm's goals.

LO 13.2 *Define* aggregate planning

Besides being representative, timely, and comprehensive, an effective S&OP process needs these four additional features to generate a useful aggregate plan:

- A logical unit for measuring sales and output, such as pounds of Doritos at Frito-Lay, air-conditioning units at GE, or terabytes of storage at Rackspace
- A forecast of demand for a reasonable intermediate planning period in aggregate terms
- A method to determine the relevant costs
- A model that combines forecasts and costs so scheduling decisions can be made for the planning period

In this chapter we describe several techniques that managers use when developing an aggregate plan for both manufacturing and service-sector firms. For manufacturers, an aggregate schedule ties a firm's strategic goals to production plans. For service organizations, an aggregate schedule ties strategic goals to workforce schedules.

The Nature of Aggregate Planning

An S&OP team builds an aggregate plan that satisfies forecasted demand by adjusting production rates, labor levels, inventory levels, overtime work, subcontracting rates, and other controllable variables. The plan can be for Frito-Lay, Whirlpool, hospitals, colleges, or Pearson Education, the company that publishes this textbook. Regardless of the firm, *the objective of aggregate planning is usually to meet forecast demand while minimizing cost over the planning period.* However, other strategic issues may be more important than low cost. These strategies may be to smooth employment, to drive down inventory levels, or to meet a high level of service, regardless of cost.

Let's look at Snapper, which produces many different models of lawn mowers. Snapper makes walk-behind mowers, rear-engine riding mowers, garden tractors, and many more, for a total of 145 models. For each month in the upcoming 3 quarters, the aggregate plan for Snapper might have the following output (in units of production) for Snapper's "family" of mowers:

QUARTER 1			QUARTER 2			QUARTER 3		
Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
150,000	120,000	110,000	100,000	130,000	150,000	180,000	150,000	140,000

Briggs & Stratton Power Products Marketing

S&OP builds an aggregate plan using the total expected demand for all of the family products, such as 145 models at Snapper (a few of which are shown above). Only when the forecasts are assembled in the aggregate plan does the company decide how to meet the total requirement with the available resources. These resource constraints include facility capacity, workforce size, supply-chain limitations, inventory issues, and financial resources.

OM in Action Building the Plan at Snapper

Every bright-red Snapper lawn mower sold anywhere in the world comes from a factory in McDonough, Georgia. Ten years ago, the Snapper line had about 40 models of mowers, leaf blowers, and snow blowers. Today, reflecting the demands of mass customization, the product line is much more complex. Snapper designs, manufactures, and sells 145 models. This means that aggregate planning and the related short-term scheduling have become more complex, too.

In the past, Snapper met demand by carrying a huge inventory for 52 regional distributors and thousands of independent dealerships. It manufactured and shipped tens of thousands of lawn mowers, worth tens of millions of dollars, without quite knowing when they would be sold—a very expensive approach to meeting demand. Some changes were necessary. The new plan's goal is for each distribution center to receive only the minimum inventory necessary to meet demand. Today, operations managers at Snapper evaluate production capacity and use frequent data from the field as inputs to sophisticated software to forecast sales. The new system tracks customer demand and aggregates forecasts for every model in every region of the country. It even adjusts for holidays and weather. And the number of distribution centers has been cut from 52 to 4.

Once evaluation of the aggregate plan against capacity determines the plan to be feasible, Snapper's planners break down the plan into production needs for each model. Production by model is accomplished by building rolling monthly and weekly plans. These plans track the pace at which various units are selling. Then, the final step requires juggling work assignments to various work centers for each shift, such as 265 lawn mowers in an 8-hour shift. That's a new Snapper every 109 seconds.

Sources: Fair Disclosure Wire (January 17, 2008); *The Wall Street Journal* (July 14, 2006); *Fast Company* (January/February 2006); and **www.snapper.com**.

Note that the plan looks at production *in the aggregate* (the family of mowers), not as a product-by-product breakdown. Likewise, an aggregate plan for BMW tells the auto manufacturer how many cars to make but not how many should be two-door vs. four-door or red vs. green. It tells Nucor Steel how many tons of steel to produce but does not differentiate grades of steel. (We extend the discussion of planning at Snapper in the *OM in Action* box "Building the Plan at Snapper.")

In a manufacturing environment, the process of breaking the aggregate plan down into greater detail is called **disaggregation**. Disaggregation results in a **master production schedule**, which provides input to material requirements planning (MRP) systems. The master production schedule addresses the purchasing or production of major parts or components (see Chapter 14). It is *not* a sales forecast. Detailed work schedules for people and priority scheduling for products result as the final step of the production planning system (and are discussed in Chapter 15).

Disaggregation
The process of breaking an aggregate plan into greater detail.

Master production schedule
A timetable that specifies what is to be made and when.

Aggregate Planning Strategies

When generating an aggregate plan, the operations manager must answer several questions:

1. Should inventories be used to absorb changes in demand during the planning period?
2. Should changes be accommodated by varying the size of the workforce?
3. Should part-timers be used, or should overtime and idle time absorb fluctuations?
4. Should subcontractors be used on fluctuating orders so a stable workforce can be maintained?
5. Should prices or other factors be changed to influence demand?

STUDENT TIP
Managers can meet aggregate plans by adjusting either capacity or demand.

All of these are legitimate planning strategies. They involve the manipulation of inventory, production rates, labor levels, capacity, and other controllable variables. We will now examine eight options in more detail. The first five are called *capacity options* because they do not try to change demand but attempt to absorb demand fluctuations. The last three are *demand options* through which firms try to smooth out changes in the demand pattern over the planning period.

LO 13.3 *Identify* optional strategies for developing an aggregate plan

Capacity Options

A firm can choose from the following basic capacity (production) options:

1. *Changing inventory levels:* Managers can increase inventory during periods of low demand to meet high demand in future periods. If this strategy is selected, costs associated with storage, insurance, handling, obsolescence, pilferage, and capital invested will increase.

Level scheduling
Maintaining a constant output rate, production rate, or workforce level over the planning horizon.

Level Strategy A level strategy (or level scheduling) is an aggregate plan in which production is uniform from period to period. Firms like Toyota and Nissan attempt to keep production at uniform levels and may (1) let the finished-goods inventory vary to buffer the difference between demand and production or (2) find alternative work for employees. Their philosophy is that a stable workforce leads to a better-quality product, less turnover and absenteeism, and more employee commitment to corporate goals. Other hidden savings include more experienced employees, easier scheduling and supervision, and fewer dramatic startups and shutdowns. Level scheduling works well when demand is reasonably stable.

Mixed strategy
A planning strategy that uses two or more controllable variables to set a feasible production plan.

For most firms, neither a chase strategy nor a level strategy is likely to prove ideal, so a combination of the eight options (called a mixed strategy) must be investigated to achieve minimum cost. However, because there are a huge number of possible mixed strategies, managers find that aggregate planning can be a challenging task. Finding the one "optimal" plan is not always possible, but as we will see in the next section, a number of techniques have been developed to aid the aggregate planning process.

Methods for Aggregate Planning

In this section, we introduce techniques that operations managers use to develop aggregate plans. They range from the widely used graphical method to the transportation method of linear programming.

Graphical Methods

Graphical techniques
Aggregate planning techniques that work with a few variables at a time to allow planners to compare projected demand with existing capacity.

LO 13.4 *Prepare* a graphical aggregate plan

Graphical techniques are popular because they are easy to understand and use. These plans work with a few variables at a time to allow planners to compare projected demand with existing capacity. They are trial-and-error approaches that do not guarantee an optimal production plan, but they require only limited computations and can be performed by clerical staff. Following are the five steps in the graphical method:

1. Determine the demand in each period.
2. Determine capacity for regular time, overtime, and subcontracting each period.
3. Find labor costs, hiring and layoff costs, and inventory holding costs.
4. Consider company policy that may apply to the workers or to stock levels.
5. Develop alternative plans and examine their total costs.

These steps are illustrated in Examples 1 through 4.

Example 1

GRAPHICAL APPROACH TO AGGREGATE PLANNING FOR A ROOFING SUPPLIER

A Juarez, Mexico, manufacturer of roofing supplies has developed monthly forecasts for a family of products. Data for the 6-month period January to June are presented in Table 13.2. The firm would like to begin development of an aggregate plan.

TABLE 13.2 Monthly Forecasts

MONTH	EXPECTED DEMAND	PRODUCTION DAYS	DEMAND PER DAY (COMPUTED)
Jan.	900	22	41
Feb.	700	18	39
Mar.	800	21	38
Apr.	1,200	21	57
May	1,500	22	68
June	1,100	20	55
	6,200	124	

Try to confirm that the cost of this initial solution is $105,900. The initial solution is not optimal, however. See if you can find the production schedule that yields the least cost (which turns out to be $105,700) using software or by hand.

INSIGHT ▶ The transportation method is flexible when costs are linear but does not work when costs are nonlinear.

LEARNING EXAMPLE ▶ What is the impact on this problem if there is no beginning inventory? [Answer: Total capacity (units) available is reduced by 100 units and the need to subcontract increases by 100 units.]

RELATED PROBLEMS ▶ 13.13–13.18 (13.20–13.22 are available in MyOMLab)

EXCEL OM Data File **Ch13Ex5.xls** can be found in MyOMLab.

The transportation method of linear programming described in the preceding example works well when analyzing the effects of holding inventories, using overtime, and subcontracting. However, it does not work when nonlinear or negative factors are introduced. Thus, when other factors such as hiring and layoffs are introduced, the more general method of linear programming must be used. Similarly, computer simulation models look for a minimum-cost combination of values.

A number of commercial S&OP software packages that incorporate the techniques of this chapter are available to ease the mechanics of aggregate planning. These include Arkieva's S&OP *Workbench* for process industries, Demand Solutions's *S&OP Software,* and Steelwedge's *S&OP Suite.*

Aggregate Planning in Services

Some service organizations conduct aggregate planning in exactly the same way as we did in Examples 1 through 5 in this chapter, but with demand management taking a more active role. Because most services pursue *combinations* of the eight capacity and demand options discussed earlier, they usually formulate mixed aggregate planning strategies. In industries such as banking, trucking, and fast foods, aggregate planning may be easier than in manufacturing.

Controlling the cost of labor in service firms is critical. Successful techniques include:

1. Accurate scheduling of labor-hours to ensure quick response to customer demand
2. An on-call labor resource that can be added or deleted to meet unexpected demand
3. Flexibility of individual worker skills that permits reallocation of available labor
4. Flexibility in rate of output or hours of work to meet changing demand

These options may seem demanding, but they are not unusual in service industries, in which labor is the primary aggregate planning vehicle. For instance:

STUDENT TIP
The major variable in capacity management for services is labor.

- Excess capacity is used to provide study and planning time by real estate and auto salespersons.
- Police and fire departments have provisions for calling in off-duty personnel for major emergencies. Where the emergency is extended, police or fire personnel may work longer hours and extra shifts.
- When business is unexpectedly light, restaurants and retail stores send personnel home early.
- Supermarket stock clerks work cash registers when checkout lines become too lengthy.
- Experienced waitresses increase their pace and efficiency of service as crowds of customers arrive.

Approaches to aggregate planning differ by the type of service provided. Here we discuss five service scenarios.

APPROACH ▶ If we make some assumptions about the workweek and skills, we can provide an aggregate plan for the firm. Assuming a 40-hour workweek and that 100% of each lawyer's hours are billed, about 500 billable hours are available from each lawyer this fiscal quarter.

SOLUTION ▶ We divide hours of billable time (which is the demand) by 500 to provide a count of lawyers needed (lawyers represent the capacity) to cover the estimated demand. Capacity then is shown to be 39, 34, and 30 for the three forecasts, best, likely, and worst, respectively. For example, the best-case scenario of 19,500 total hours, divided by 500 hours per lawyer, equals 39 lawyers needed. Because all 32 lawyers at Klasson and Avalon are qualified to perform basic legal research, this skill has maximum scheduling flexibility (column 6). The most highly skilled (and capacity-constrained) categories are trial work and corporate law. The firm's best-case forecast just barely covers trial work, with 3.6 lawyers needed (see column 5) and 4 qualified (column 6). And corporate law is short 1 full person.

Overtime may be used to cover the excess this quarter, but as business expands, it may be necessary to hire or develop talent in both of these areas. Available staff adequately covers real estate and criminal practice, as long as other needs do not use their excess capacity. With its current legal staff of 32, Klasson and Avalon's best-case forecast will increase the workload by $[(39 - 32)/32 =]$ 21.8% (assuming no new hires). This represents 1 extra day of work per lawyer per week. The worst-case scenario will result in about a 6% underutilization of talent. For both of these scenarios, the firm has determined that available staff will provide adequate service.

INSIGHT ▶ While our definitions of demand and capacity are different than for a manufacturing firm, aggregate planning is as appropriate, useful, and necessary in a service environment as in manufacturing.

LEARNING EXERCISE ▶ If the criminal law best-case forecast increases to 4,500 hours, what happens to the number of lawyers needed? [Answer: The demand for lawyers increases to 41.]

RELATED PROBLEMS ▶ 13.24, 13.25

Source: Based on Glenn Bassett, *Operations Management for Service Industries* (Westport, CT: Quorum Books): 110.

Airline Industry

Airlines and auto-rental firms also have unique aggregate scheduling problems. Consider an airline that has its headquarters in New York, two hub sites in cities such as Atlanta and Dallas, and 150 offices in airports throughout the country. This planning is considerably more complex than aggregate planning for a single site or even for a number of independent sites.

Aggregate planning consists of schedules for (1) number of flights into and out of each hub; (2) number of flights on all routes; (3) number of passengers to be serviced on all flights; (4) number of air personnel and ground personnel required at each hub and airport; and (5) determining the seats to be allocated to various fare classes. Techniques for determining seat allocation are called revenue (or yield) management, our next topic.

Revenue Management

STUDENT TIP
Revenue management changes the focus of aggregate planning from capacity management to demand management.

Most operations models, like most business models, assume that firms charge all customers the same price for a product. In fact, many firms work hard at charging different prices. The idea is to match capacity and demand by charging different prices based on the customer's willingness to pay. The management challenge is to identify those differences and price accordingly. The technique for multiple price points is called revenue management.

Revenue (or yield) management is the aggregate planning process of allocating the company's scarce resources to customers at prices that will maximize revenue. Popular use of the technique dates to the 1980s, when American Airlines's reservation system (called SABRE) allowed the airline to alter ticket prices, in real time and on any route, based on demand information. If it looked like demand for expensive seats was low, more discounted seats were offered. If demand for full-fare seats was high, the number of discounted seats was reduced.

Revenue (or yield) management
Capacity decisions that determine the allocation of resources to maximize revenue or yield.

Industries traditionally associated with revenue management include hotels, airlines, and rental cars. They are able to apply variable pricing for their product and control product use or availability (number of airline seats or hotel rooms sold at economy rates). Others, such as movie theaters, arenas, or performing arts centers have less pricing flexibility but still use time (evening or matinee) and location (orchestra, side, or balcony) to manage revenue. In both cases, management has control over the amount of the resource used—both the quantity and the duration of the resource.

The manager's job is more difficult in facilities such as restaurants and on golf courses because the duration and the use of the resource is less controllable. However, with imagination, managers are using excess capacity even for these industries. For instance, the golf course may sell less desirable tee times at a reduced rate, and the restaurant may have an "early bird" special to generate business before the usual dinner hour.

To make revenue management work, the company needs to manage three issues:

1. *Multiple pricing structures:* These structures must be feasible and appear logical (and preferably fair) to the customer. Such justification may take various forms, for example, first-class seats on an airline or the preferred starting time at a golf course. (See the Ethical Dilemma at the end of this chapter.)
2. *Forecasts of the use and duration of the use:* How many economy seats should be available? How much will customers pay for a room with an ocean view?
3. *Changes in demand:* This means managing the increased use as more capacity is sold. It also means dealing with issues that occur because the pricing structure may not seem logical and fair to all customers. Finally, it means managing new issues, such as overbooking because the forecast was not perfect.

Precise pricing through revenue management has substantial potential, and several firms sell software available to address the issue. These include NCR's *Teradata,* SPS, *DemandTec,* and Oracle with *Profit Logic*.

Summary

Sales and operations planning (S&OP) can be a strong vehicle for coordinating the functional areas of a firm as well as for communication with supply-chain partners. The output of S&OP is an *aggregate plan.* An aggregate plan provides both manufacturing and service firms the ability to respond to changing customer demands and produce with a winning strategy.

Aggregate schedules set levels of inventory, production, subcontracting, and employment over an intermediate time range, usually 3 to 18 months. This chapter describes two aggregate planning techniques: the popular graphical approach and the transportation method of linear programming.

The aggregate plan is an important responsibility of an operations manager and a key to efficient use of existing resources. It leads to the more detailed master production schedule, which becomes the basis for disaggregation, detail scheduling, and MRP systems.

Restaurants, airlines, and hotels are all service systems that employ aggregate plans. They also have an opportunity to implement revenue management.

Regardless of the industry or planning method, the S&OP process builds an aggregate plan that a firm can implement and suppliers endorse.

Key Terms

Sales and operations planning (S&OP) (p. 533)
Aggregate plan (p. 533)
Disaggregation (p. 535)
Master production schedule (p. 535)
Chase strategy (p. 537)
Level scheduling (p. 538)
Mixed strategy (p. 538)
Graphical techniques (p. 538)
Transportation method of linear programming (p. 543)
Revenue (or yield) management (p. 547)

Ethical Dilemma

Airline passengers today stand in numerous lines, are crowded into small seats on mostly full airplanes, and often spend time on taxiways because of air-traffic problems or lack of open gates. But what gripes travelers almost as much as these annoyances is finding out that the person sitting next to them paid a much lower fare than they did for their seat. This concept of *revenue management* results in ticket pricing that can range from free to thousands of dollars on the same plane. Figure 13.7 illustrates what passengers recently paid for various seats on an 11:35 A.M. flight from Minneapolis to Anaheim, California, on an Airbus A320.

Make the case for, and then against, this pricing system. Does the general public seem to accept revenue management? What would happen if you overheard the person in front of you in line getting a better room rate at a Hilton Hotel? How do customers manipulate the airline systems to get better fares?

Sales	Fare	Seats
First class	$817	1
Full fare	792	4
Corporate discount	491	5
21-day advance	273	20
Deep discounts	190	33
Frequent flyer program	0	7
Connections	—	53
Empty	—	27

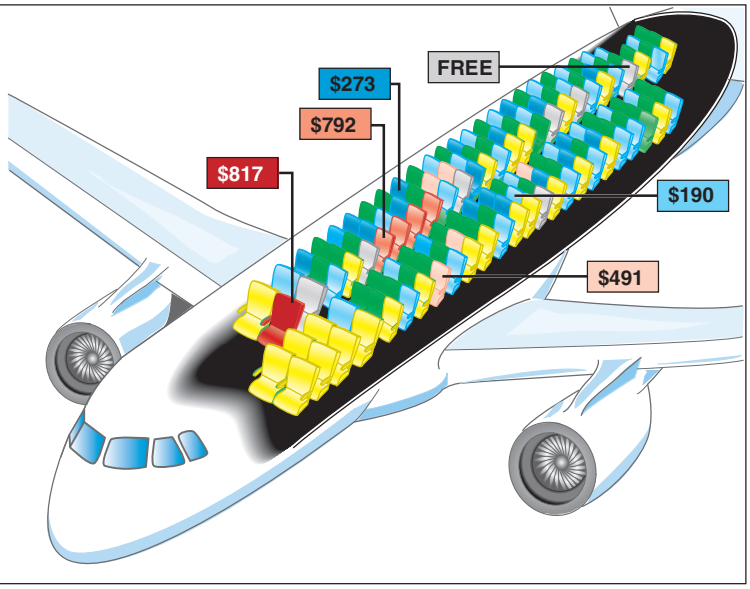


Figure 13.7

Revenue Management Seat Costs on a Typical Flight

Discussion Questions

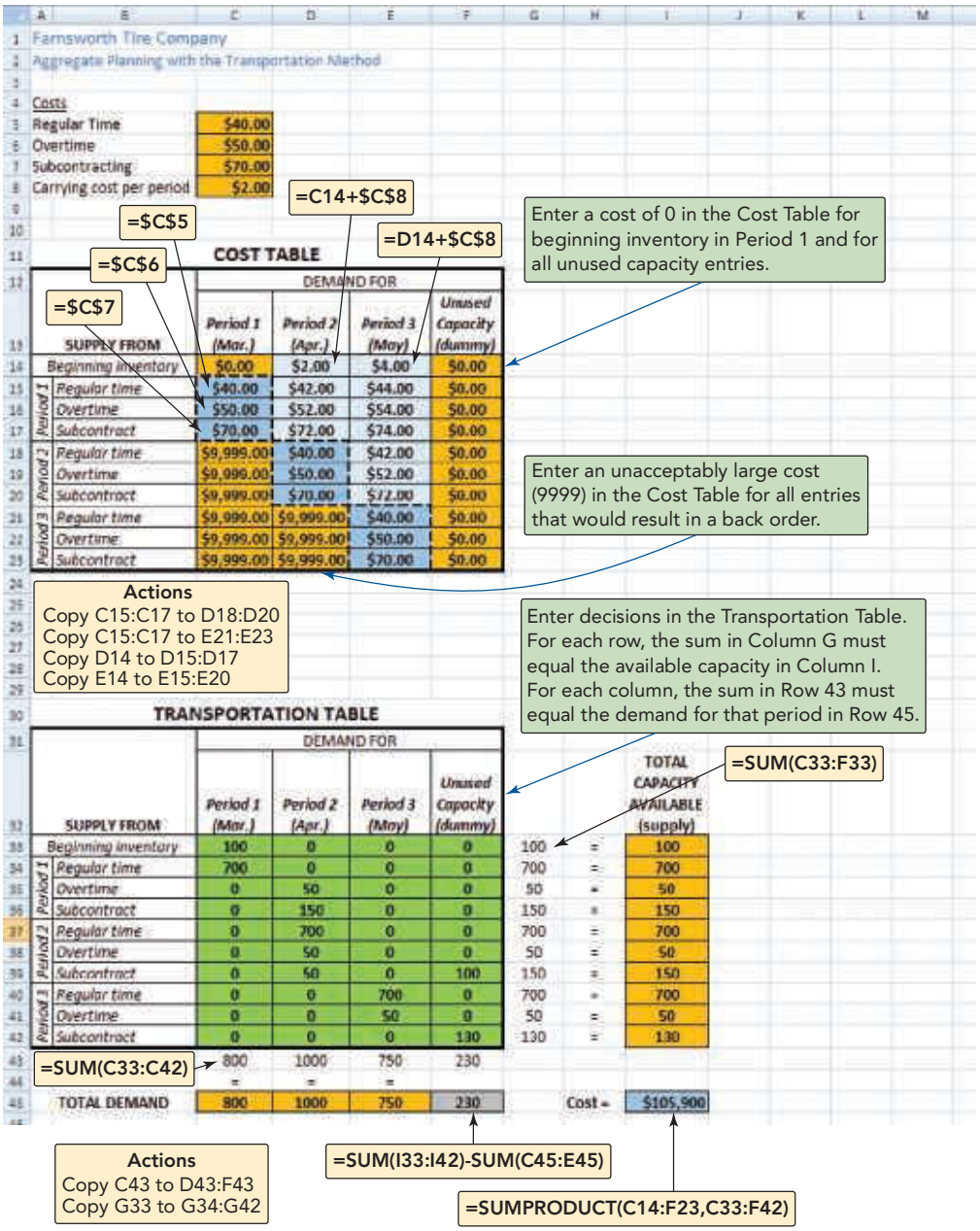
1. Define *sales* and *operations planning*.
2. Why are S&OP teams typically cross-functional?
3. Define *aggregate planning*.
4. Explain what the term *aggregate* in "aggregate planning" means.
5. List the strategic objectives of aggregate planning. Which one of these is most often addressed by the quantitative techniques of aggregate planning? Which one of these is generally the most important?
6. Define *chase strategy*.
7. What is level scheduling? What is the basic philosophy underlying it?
8. Define *mixed strategy*. Why would a firm use a mixed strategy instead of a simple pure strategy?
9. What are the advantages and disadvantages of varying the size of the workforce to meet demand requirements each period?
10. How does aggregate planning in service differ from aggregate planning in manufacturing?
11. What is the relationship between the aggregate plan and the master production schedule?
12. Why are graphical aggregate planning methods useful?
13. What are major limitations of using the transportation method for aggregate planning?
14. How does revenue management impact an aggregate plan?

Using Software for Aggregate Planning

This section illustrates the use of Excel, Excel OM, and POM for Windows in aggregate planning.

CREATING YOUR OWN EXCEL SPREADSHEETS

Program 13.1 illustrates how you can make an Excel model to solve Example 5, which uses the transportation method for aggregate planning.



Program 13.1

Using Excel for Aggregate Planning Via the Transportation Method, with Data from Example 5

Excel comes with an Add-In called Solver that offers the ability to analyze linear programs such as the transportation problem. To ensure that Solver always loads when Excel is loaded, go to: **File→Options→Add-Ins**. Next to **Manage:** at the bottom, make sure that **Excel Add-ins** is selected, and click on the **<Go...>** button. Check **Solver Add-in**, and click **<OK>**. Once in Excel, the Solver dialog box will appear by clicking on: **Data→Analysis: Solver**. The following screen shot shows how to use Solver to find the optimal (very best) solution to Example 4. Click on **<Solve>**, and the solution will automatically appear in the Transportation Table, yielding a cost of $105,700.

Solved Problems

Virtual Office Hours help is available in MyOMLab.

SOLVED PROBLEM 13.1

The roofing manufacturer described in Examples 1 to 4 of this chapter wishes to consider yet a fourth planning strategy (plan 4). This one maintains a constant workforce of eight people and uses overtime whenever necessary to meet demand. Use the information found in Table 13.3 on page 540. Again, assume beginning and ending inventories are equal to zero.

SOLUTION

Employ eight workers and use overtime when necessary. Note that carrying costs will be encountered in this plan.

MONTH	PRODUCTION DAYS	PRODUCTION AT 40 UNITS PER DAY	BEGINNING-OF-MONTH INVENTORY	FORECAST DEMAND THIS MONTH	OVERTIME PRODUCTION NEEDED	ENDING INVENTORY
Jan.	22	880	—	900	20 units	0 units
Feb.	18	720	0	700	0 units	20 units
Mar.	21	840	20	800	0 units	60 units
Apr.	21	840	60	1,200	300 units	0 units
May	22	880	0	1,500	620 units	0 units
June	20	800	0	1,100	300 units	0 units
					1,240 units	80 units

$$\text{Carrying cost totals} = 80 \text{ units} \times \$5/\text{unit/month} = \$400$$

Regular pay:

$$8 \text{ workers} \times \$80/\text{day} \times 124 \text{ days} = \$79{,}360$$

Overtime pay:
To produce 1,240 units at overtime rate requires $1{,}240 \times 1.6$ hours/unit $= 1{,}984$ hours.

$$\text{Overtime cost} = \$17/\text{hour} \times 1{,}984 \text{ hours} = \$33{,}728$$

Plan 4

COSTS (WORKFORCE OF 8 PLUS OVERTIME)		
Carrying cost	$ 400	(80 units carried × $5/unit)
Regular labor	79,360	(8 workers × $80/day × 124 days)
Overtime	33,728	(1,984 hours × $17/hour)
Hiring or firing	0	
Subcontracting	0	
Total costs	$113,488	

Plan 2, at $105,152, is still preferable.

SOLVED PROBLEM 13.2

A Dover, Delaware, plant has developed the accompanying supply, demand, cost, and inventory data. The firm has a constant workforce and meets all its demand. Allocate production capacity to satisfy demand at a minimum cost. What is the cost of this plan?

Demand Forecast

PERIOD	DEMAND (UNITS)
1	450
2	550
3	750

Supply Capacity Available (units)

PERIOD	REGULAR TIME	OVERTIME	SUBCONTRACT
1	300	50	200
2	400	50	200
3	450	50	200

Other data

Initial inventory	50 units
Regular-time cost per unit	$50
Overtime cost per unit	$65
Subcontract cost per unit	$80
Carrying cost per unit per period	$ 1
Back order cost per unit per period	$ 4

SOLUTION

SUPPLY FROM		DEMAND FOR: Period 1	Period 2	Period 3	Unused Capacity (dummy)	TOTAL CAPACITY AVAILABLE (supply)
Beginning inventory		0 50	1	2	0	50
Period 1	*Regular time*	50 300	51	52	0	300
	Overtime	65 50	66	67	0	50
	Subcontract	80 50	81	82	0 150	200
Period 2	*Regular time*	54	50 400	51	0	400
	Overtime	69	65 50	66	0	50
	Subcontract	84	80 100	81 50	0 50	200
Period 3	*Regular time*	58	54	50 450	0	450
	Overtime	73	69	65 50	0	50
	Subcontract	88	84	80 200	0	200
TOTAL DEMAND		450	550	750	200	1,950

Cost of plan:

Period 1: 50($0) + 300($50) + 50($65) + 50($80) = $22,250
Period 2: 400($50) + 50($65) + 100($80) = $31,250
Period 3: 50($81) + 450($50) + 50($65) + 200($80) = $45,800*
Total cost $99,300

*Includes 50 units of subcontract and carrying cost.

Problems

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

Problems 13.1–13.23 relate to Methods for Aggregate Planning

• **13.1** Prepare a graph of the monthly forecasts and average forecast demand for Chicago Paint Corp., a manufacturer of specialized paint for artists.

MONTH	PRODUCTION DAYS	DEMAND FORECAST
January	22	1,000
February	18	1,100
March	22	1,200
April	21	1,300
May	22	1,350
June	21	1,350
July	21	1,300
August	22	1,200
September	21	1,100
October	22	1,100
November	20	1,050
December	20	900

•• **13.2** Develop another plan for the Mexican roofing manufacturer described in Examples 1 to 4 (pages 538–542) and Solved Problem 13.1 (page 554).

a) For this plan, plan 5, the firm wants to maintain a constant workforce of six, using subcontracting to meet remaining demand. Is this plan preferable?
b) The same roofing manufacturer in Examples 1 to 4 and Solved Problem 13.1 has yet a sixth plan. A constant workforce of seven is selected, with the remainder of demand filled by subcontracting.
c) Is this better than plans 1–5? PX

••• **13.3** The president of Hill Enterprises, Terri Hill, projects the firm's aggregate demand requirements over the next 8 months as follows:

Jan.	1,400	May	2,200
Feb.	1,600	June	2,200
Mar.	1,800	July	1,800
Apr.	1,800	Aug.	1,800

c) If overtime costs per unit rise from $1,300 to $1,400, will your answer to (a) change? What if overtime costs then fall to $1,200?

Additional problems **13.20–13.23** *are available in* MyOMLab.

Problems 13.24–13.25 relate to Aggregate Planning in Services

••• **13.24** Forrester and Cohen is a small accounting firm, managed by Joseph Cohen since the retirement in December of his partner Brad Forrester. Cohen and his 3 CPAs can together bill 640 hours per month. When Cohen or another accountant bills more than 160 hours per month, he or she gets an additional "overtime" pay of $62.50 for each of the extra hours: this is above and beyond the $5,000 salary each draws during the month. (Cohen draws the same base pay as his employees.) Cohen strongly discourages any CPA from working (billing) more than 240 hours in any given month. The demand for billable hours for the firm over the next 6 months is estimated below:

MONTH	ESTIMATE OF BILLABLE HOURS
Jan.	600
Feb.	500
Mar.	1,000
Apr.	1,200
May	650
June	590

Cohen has an agreement with Forrester, his former partner, to help out during the busy tax season, if needed, for an hourly fee of $125. Cohen will not even consider laying off one of his colleagues in the case of a slow economy. He could, however, hire another CPA at the same salary, as business dictates.

a) Develop an aggregate plan for the 6-month period.
b) Compute the cost of Cohen's plan of using overtime and Forrester.
c) Should the firm remain as is, with a total of 4 CPAs?

•• **13.25** Refer to the CPA firm in Problem 13.24. In planning for next year, Cohen estimates that billable hours will increase by 10% in each of the 6 months. He therefore proceeds to hire a fifth CPA. The same regular time, overtime, and outside consultant (i.e., Forrester) costs still apply.

a) Develop the new aggregate plan and compute its costs.
b) Comment on the staffing level with five accountants. Was it a good decision to hire the additional accountant?

Problem 13.26 relates to Revenue Management

•• **13.26** Southeastern Airlines's daily flight from Atlanta to Charlotte uses a Boeing 737, with all-coach seating for 120 people. In the past, the airline has priced every seat at $140 for the one-way flight. An average of 80 passengers are on each flight. The variable cost of a filled seat is $25. Aysajan Eziz, the new operations manager, has decided to try a yield revenue approach, with seats priced at $80 for early bookings and at $190 for bookings within 1 week of the flight. He estimates that the airline will sell 65 seats at the lower price and 35 at the higher price. Variable cost will not change. Which approach is preferable to Mr. Eziz?

CASE STUDIES

Andrew-Carter, Inc.

Andrew-Carter, Inc. (A-C), is a major Canadian producer and distributor of outdoor lighting fixtures. Its products are distributed throughout South and North America and have been in high demand for several years. The company operates three plants to manufacture fixtures and distribute them to five distribution centers (warehouses).

During the present global slowdown, A-C has seen a major drop in demand for its products, largely because the housing market has declined. Based on the forecast of interest rates, the head of operations feels that demand for housing and thus for A-C's products will remain depressed for the foreseeable future. A-C is considering closing one of its plants, as it is now operating with a forecast excess capacity of 34,000 units per week. The forecast weekly demands for the coming year are as follows:

Warehouse 1	9,000 units
Warehouse 2	13,000
Warehouse 3	11,000
Warehouse 4	15,000
Warehouse 5	8,000

Plant capacities, in units per week, are as follows:

Plant 1, regular time	27,000 units
Plant 1, on overtime	7,000
Plant 2, regular time	20,000
Plant 2, on overtime	5,000
Plant 3, regular time	25,000
Plant 3, on overtime	6,000

If A-C shuts down any plants, its weekly costs will change, because fixed costs will be lower for a nonoperating plant. Table 13.9 shows production costs at each plant, both variable at regular time and overtime, and fixed when operating and shut down. Table 13.10 shows distribution costs from each plant to each distribution center.

Discussion Questions

1. Evaluate the various configurations of operating and closed plants that will meet weekly demand. Determine which configuration minimizes total costs.
2. Discuss the implications of closing a plant.

TABLE 13.9 Andrew-Carter, Inc., Variable Costs and Fixed Production Costs per Week

		FIXED COST PER WEEK	
PLANT	VARIABLE COST (PER UNIT)	OPERATING	NOT OPERATING
1, regular time	$2.80	$14,000	$6,000
1, overtime	3.52	——	——
2, regular time	2.78	12,000	5,000
2, overtime	3.48	——	——
3, regular time	2.72	15,000	7,500
3, overtime	3.42	——	——

TABLE 13.10 Andrew-Carter, Inc., Distribution Costs per Unit

	TO DISTRIBUTION CENTERS				
FROM PLANTS	W1	W2	W3	W4	W5
1	$.50	$.44	$.49	$.46	$.56
2	.40	.52	.50	.56	.57
3	.56	.53	.51	.54	.35

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Using Revenue Management to Set Orlando Magic Ticket Prices

Video Case

Revenue management was once the exclusive domain of the airline industry. But it has since spread its wings into the hotel business, auto rentals, and now even professional sports, with the San Francisco Giants, Boston Celtics, and Orlando Magic as leaders in introducing dynamic pricing into their ticketing systems. Dynamic pricing means looking at unsold tickets for every single game, every day, to see if the current ticket price for a particular seat needs to be lowered (because of slow demand) or raised (because of higher-than-expected demand).

Pricing can be impacted by something as simple as bad weather or by whether the team coming to play in the arena is on a winning streak or has just traded for a new superstar player. For example, a few years ago, a basketball star was traded in midseason to the Denver Nuggets; this resulted in an immediate runup in unsold ticket prices for the teams the Nuggets were facing on the road. Had the Nuggets been visiting the Orlando Magic 2 weeks after the trade and the Magic not raised prices, they would have been "leaving money on the table" (as shown in Figure 13.5).

As the Magic became more proficient in revenue management, they evolved from (l) setting the price for each seat at the start of the season and never changing it; to (2) setting the prices for each seat at season onset, based on the popularity of the opponent, the day of the week, and the time of season (see the Video Case in Chapter 4)—but keeping the prices frozen once the season began (see Table 13.11); to (3) pricing tickets based on projected demand, but adjusting them frequently to match market demand as the season progressed.

To track market demand, the Magic use listed prices on Stub Hub and other online ticket exchange services. The key is to sell out all 18,500 seats every home game, keeping the pressure on Anthony Perez, the director of business strategy, and Chris Dorso, the Magic's vice president of sales.

Perez and Dorso use every tool available to collect information on demand, including counting unique page views at the Ticketmaster Web site. If, for example, there are 5,000 page views for the Miami Heat game near Thanksgiving, it indicates enough demand that prices of unsold seats can be notched up. If there are only 150 Ticketmaster views for the Utah Jazz game 3 days later, there may not be sufficient information to make any changes yet.

TABLE 13.11 An Example of Variable Pricing for a $68 Terrace V seat in Zone 103

OPPONENT POPULARITY RATING	NUMBER OF GAMES IN THIS CATEGORY	PRICE
Tier I	3	$187
Tier II	3	$170
Tier III	4	$ 85
Tier IV	6	$ 75
Tier V	14	$ 60
Tier VI	9	$ 44
Tier VII	6	$ 40
Average		$ 68

With a database of 650,000, the Magic can use e-mail blasts to react quickly right up to game day. The team may discount seat prices, offer other perks, or just point out that prime seats are still available for a game against an exciting opponent.

Discussion Questions*

1. After researching revenue (yield) management in airlines, describe how the Magic system differs from that of American or other air carriers.
2. The Magic used its original pricing systems of several years ago and set the price for a Terrace V, Zone 103 seat at $68 per game. There were 230 such seats *not* purchased as part of season ticket packages and thus available to the public. If the team switched to the 7-price dynamic system (illustrated in Table 13.11), how would the profit-contribution for the 45-game season change? (Note that the 45-game season includes 4 preseason games.)
3. What are some concerns the team needs to consider when using dynamic pricing with frequent changes in price?

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

- **Additional Case Studies:** Visit MyOMLab for these free case studies:
  Cornwell Glass: Involves setting a production schedule for an auto glass producer.
  Southwestern University: (G) Requires developing an aggregate plan for a university police department.

Endnote

1. R. Oberwetter, "Revenue Management," *OR/MS Today* (June 2001): 41–44.

Chapter 13 *Rapid* Review

Main Heading	Review Material	MyOMLab
THE PLANNING PROCESS (pp. 532–533)	■ *Long-range plans* develop policies and strategies related to location, capacity, products and process, supply chain, research, and capital investment. ■ *Intermediate planning* develops plans that match production to demand. ■ *Short-run planning* translates intermediate plans into weekly, daily, and hourly schedules.	Concept Questions: 1.1–1.4
SALES AND OPERATIONS PLANNING (pp. 533–534)	■ **Sales and operation planning** (S&OP)—Balances resources and forecasted demand, and aligns the organization's competing demands, from supply chain to final customer, while linking strategic planning with operations over all planning horizons. ■ **Aggregate planning**—An approach to determine the quantity and timing of production for the intermediate future (usually 3 to 18 months ahead). Four things are needed for aggregate planning: 1. A logical unit for measuring sales and output 2. A forecast of demand for a reasonable intermediate planning period in these aggregate terms 3. A method for determining the relevant costs 4. A model that combines forecasts and costs so that scheduling decisions can be made for the planning period	Concept Questions: 2.1–2.4
THE NATURE OF AGGREGATE PLANNING (pp. 534–535)	Usually, *the objective of aggregate planning is to meet forecasted demand while minimizing cost over the planning period.* An aggregate plan looks at production *in the aggregate* (a family of products), not as a product-by-product breakdown. ■ **Disaggregation**—The process of breaking an aggregate plan into greater detail. ■ **Master production schedule**—A timetable that specifies what is to be made and when.	Concept Questions: 3.1–3.4
AGGREGATE PLANNING STRATEGIES (pp. 535–538)	The basic aggregate planning capacity (production) options are: ■ *Changing inventory levels* ■ *Varying workforce size by hiring or layoffs* ■ *Varying production rates through overtime or idle time* ■ *Subcontracting* ■ *Using part-time workers* The basic aggregate planning demand options are: ■ *Influencing demand* ■ *Back ordering during high-demand periods* ■ *Counterseasonal product and service mixing* ■ **Chase strategy**—A planning strategy that sets production equal to forecast demand. Many service organizations favor the chase strategy because the inventory option is difficult or impossible to adopt. ■ **Level scheduling**—Maintaining a constant output rate, production rate, or workforce level over the planning horizon. Level scheduling works well when demand is reasonably stable. ■ **Mixed strategy**—A planning strategy that uses two or more controllable variables to set a feasible production plan.	Concept Questions: 4.1–4.4
METHODS FOR AGGREGATE PLANNING (pp. 538–545)	■ **Graphical techniques**—Aggregate planning techniques that work with a few variables at a time to allow planners to compare projected demand with existing capacity. Graphical techniques are trial-and-error approaches that do not guarantee an optimal production plan, but they require only limited computations. A *cumulative* graph displays visually how the forecast deviates from the average requirements. ■ **Transportation method of linear programming**—A way of solving for the optimal solution to an aggregate planning problem. The transportation method of linear programming is flexible in that it can specify regular and overtime production in each time period, the number of units to be subcontracted, extra shifts, and the inventory carryover from period to period. Transportation problems require that supply equals demand, so when it does not, a dummy column called "unused capacity" may be added. Costs of not using capacity are zero.	Concept Questions: 5.1–5.4 Problems: 13.2–13.23 Virtual Office Hours for Solved Problems: 13.1, 13.2 ACTIVE MODEL 13.1

Chapter 13 *Rapid* Review *continued*

Main Heading	Review Material	MyOMLab
	Demand requirements are shown in the bottom row of a transportation table. Total capacity available (supply) is shown in the far right column. In general, to complete a transportation table, allocate as much production as you can to a cell with the smallest cost, without exceeding the unused capacity in that row or demand in that column. If there is still some demand left in that row, allocate as much as you can to the next-lowest-cost cell. You then repeat this process for periods 2 and 3 (and beyond, if necessary). When you are finished, the sum of all your entries in a row must equal total row capacity, and the sum of all entries in a column must equal the demand for that period. The transportation method does not work when nonlinear or negative factors are introduced.	
AGGREGATE PLANNING IN SERVICES (pp. 545–547)	Successful techniques for controlling the cost of labor in service firms include: 1. Accurate scheduling of labor-hours to ensure quick response to customer demand. 2. An on-call labor resource that can be added or deleted to meet unexpected demand. 3. Flexibility of individual worker skills that permits reallocation of available labor. 4. Flexibility in rate of output or hours of work to meet changing demand.	Concept Questions: 6.1–6.4 Problems: 13.24–13.25
REVENUE MANAGEMENT (pp. 547–550)	■ **Revenue** (or **yield**) **management**—Capacity decisions that determine the allocation of resources to maximize revenue. Organizations that have *perishable inventory*, such as airlines, hotels, car rental agencies, and cruise lines, have the following shared characteristics that make revenue management of interest: 1. Service or product can be sold in advance of consumption 2. Fluctuating demand 3. Relatively fixed resource (capacity) 4. Segmentable demand 5. Low variable costs and high fixed costs To make revenue management work, the company needs to manage three issues: 1. *Multiple pricing structures.* 2. *Forecasts of the use and duration of the use.* 3. *Changes in demand.*	Concept Questions: 7.1–7.4 Problem: 13.26 **VIDEO 13.1** Using Revenue Management to Set Orlando Magic Ticket Prices

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 13.1 The outputs from an S&OP process are:
- **a)** long-run plans.
- **b)** detail schedules.
- **c)** aggregate plans.
- **d)** revenue management plans.
- **e)** short-run plans.

LO 13.2 Aggregate planning is concerned with determining the quantity and timing of production in the:
- **a)** short term.
- **b)** intermediate term.
- **c)** long term.
- **d)** all of the above.

LO 13.3 Aggregate planning deals with a number of constraints. These typically are:
- **a)** job assignments, job ordering, dispatching, and overtime help.
- **b)** part-time help, weekly scheduling, and SKU production scheduling.
- **c)** subcontracting, employment levels, inventory levels, and capacity.
- **d)** capital investment, expansion or contracting capacity, and R&D.
- **e)** facility location, production budgeting, overtime, and R&D.

LO 13.4 Which of the following is not one of the graphical method steps?
- **a)** Determine the demand in each period.
- **b)** Determine capacity for regular time, overtime, and subcontracting each period.
- **c)** Find labor costs, hiring and layoff costs, and inventory holding costs.
- **d)** Construct the transportation table.
- **e)** Consider company policy that may apply to the workers or stock levels.
- **f)** Develop alternative plans and examine their total costs.

LO 13.5 When might a dummy column be added to a transportation table?
- **a)** When supply does not equal demand
- **b)** When overtime is greater than regular time
- **c)** When subcontracting is greater than regular time
- **d)** When subcontracting is greater than regular time plus overtime
- **e)** When production needs to spill over into a new period

LO 13.6 Revenue management requires management to deal with:
- **a)** multiple pricing structures.
- **b)** changes in demand.
- **c)** forecasts of use.
- **d)** forecasts of duration of use.
- **e)** all of the above.

Answers: LO 13.1. c; LO 13.2. b; LO 13.3. c; LO 13.4. d; LO 13.5. a; LO 13.6. e.