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

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.

Frito-Lay North America

Frito-Lay North America

As potatoes arrive at the plant, they are promptly washed and peeled to ensure freshness and taste.

After peeling, potatoes are cut into thin slices, rinsed of excess starch, and cooked in sunflower and/or corn oil.

Frito-Lay North America

and dynamic local demand data from account managers to forecast demand. Planners then match the total demand profile to existing capacity, capacity expansion plans, and cost. This becomes the aggregate plan. The aggregate plan is communicated to each of the firm's 17 regions and to the 36 plants. Every quarter, headquarters and each plant modify the respective plans to incorporate changing market conditions and plant performance.

Each plant uses its quarterly plan to develop a 4-week plan, which in turn assigns specific products to specific product lines for production runs. Finally, each week raw materials and labor are assigned to each process. Effective aggregate planning is a major factor in high utilization and low cost. As the company's 60% market share indicates, excellent aggregate planning yields a competitive advantage at Frito-Lay.

Frito-Lay North America

After cooking is complete, inspection, bagging, weighing, and packing operations prepare Lay's potato chips for shipment to customers—all in a matter of hours.

LEARNING OBJECTIVES

The Planning Process

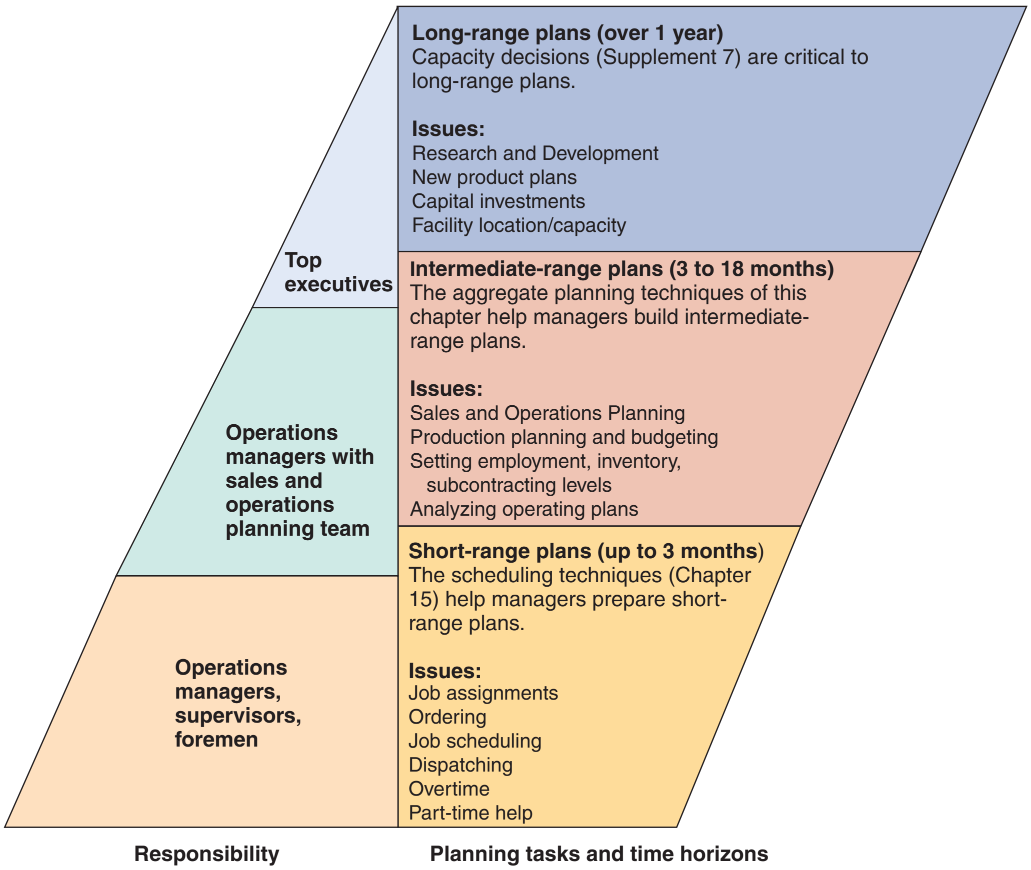
In Chapter 4, we saw that demand forecasting can address long-, medium-, and short-range decisions. Figure 13.1 illustrates how managers translate these forecasts into long-, intermediate-, and short-range plans. Long-range forecasts, the responsibility of top management, provide data for a firm's multi-year 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.

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.

LO 13.1 *Define* sales and operations planning

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.

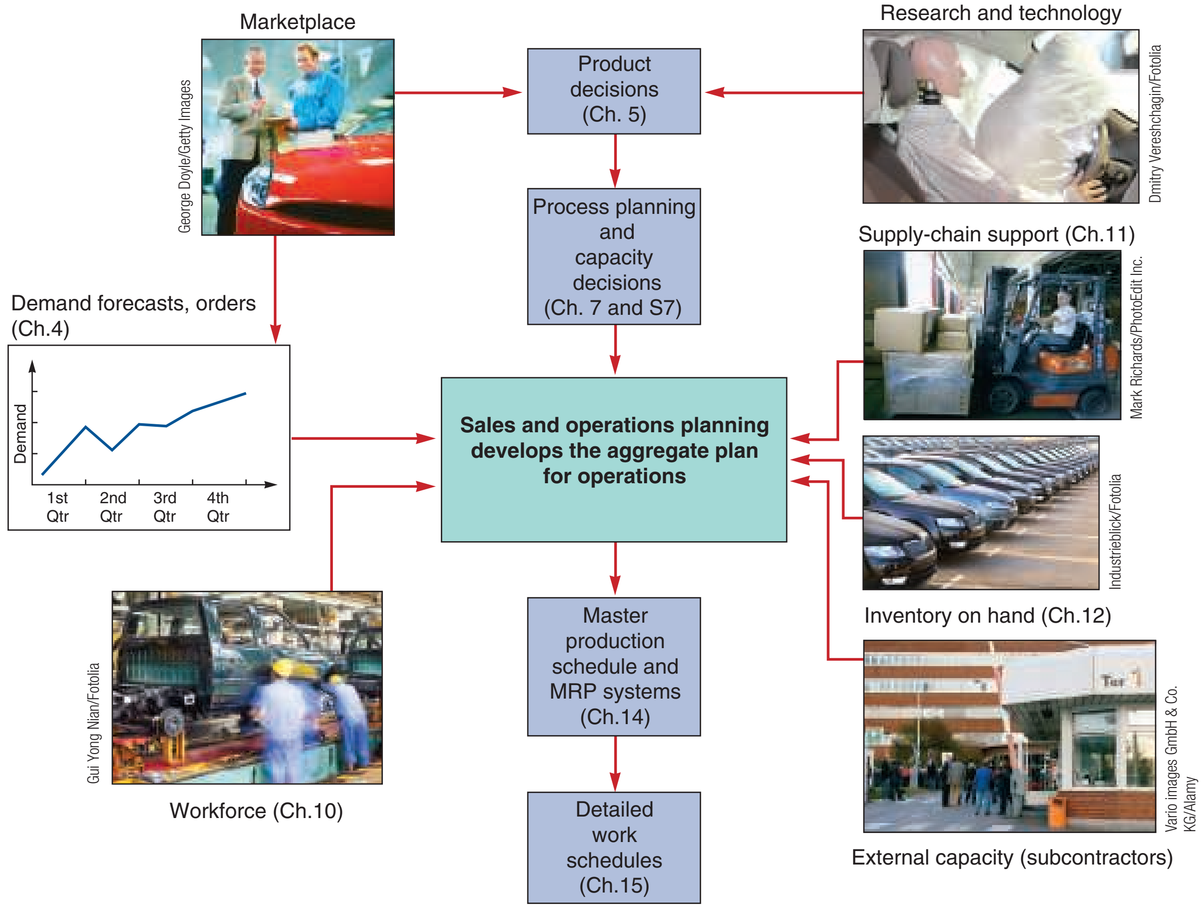


Figure 13.2

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.

Stefan Kiefer/imageBROKER/Alamy

John Deere and Company, the "granddaddy" of farm equipment manufacturers, uses sales incentives to smooth demand. During the fall and winter off-seasons, sales are boosted with price cuts and other incentives. About 70% of Deere's big machines are ordered in advance of seasonal use—about double the industry rate. Incentives hurt margins, but Deere keeps its market share and controls costs by producing more steadily all year long. Similarly, service businesses like L.L. Bean offer customers free shipping on orders placed before the Christmas rush.

On the other hand, with low inventory on hand and increasing demand, shortages can occur, resulting in longer lead times and poor customer service.

2. *Varying workforce size by hiring or layoffs:* One way to meet demand is to hire or lay off production workers to match production rates. However, new employees need to be trained, and productivity drops temporarily as they are absorbed into the workforce. Layoffs or terminations, of course, lower the morale of all workers and also lead to lower productivity.
3. *Varying production rates through overtime or idle time:* Keeping a constant workforce while varying working hours may be possible. Yet when demand is on a large upswing, there is a limit on how much overtime is realistic. Overtime pay increases costs, and too much overtime can result in worker fatigue and a drop in productivity. Overtime also implies added overhead costs to keep a facility open. On the other hand, when there is a period of decreased demand, the company must somehow absorb workers' idle time—often a difficult and expensive process.
4. *Subcontracting:* A firm can acquire temporary capacity by subcontracting work during peak demand periods. Subcontracting, however, has several pitfalls. First, it may be costly; second, it risks opening the door to a competitor. Third, developing the perfect subcontract supplier can be a challenge.
5. *Using part-time workers:* Especially in the service sector, part-time workers can fill labor needs. This practice is common in restaurants, retail stores, and supermarkets.

Demand Options

The basic demand options are:

1. *Influencing demand:* When demand is low, a company can try to increase demand through advertising, promotion, personal selling, and price cuts. Airlines and hotels have long offered weekend discounts and off-season rates; theaters cut prices for matinees; some colleges give discounts to senior citizens; and air conditioners are least expensive in winter. However, even special advertising, promotions, selling, and pricing are not always able to balance demand with production capacity.
2. *Back ordering during high-demand periods:* Back orders are orders for goods or services that a firm accepts but is unable (either on purpose or by chance) to fill at the moment.

TABLE 13.1 Aggregate Planning Options: Advantages and Disadvantages

OPTION	ADVANTAGES	DISADVANTAGES	COMMENTS
Changing inventory levels	Changes in human resources are gradual or none; no abrupt production changes.	Inventory holding costs may increase. Shortages may result in lost sales.	Applies mainly to production, not service, operations.
Varying workforce size by hiring or layoffs	Avoids the costs of other alternatives.	Hiring, layoff, and training costs may be significant.	Used where size of labor pool is large.
Varying production rates through overtime or idle time	Matches seasonal fluctuations without hiring/training costs.	Overtime premiums; tired workers; may not meet demand.	Allows flexibility within the aggregate plan.
Subcontracting	Permits flexibility and smoothing of the firm's output.	Loss of quality control; reduced profits; potential loss of future business.	Applies mainly in production settings.
Using part-time workers	Is less costly and more flexible than full-time workers.	High turnover/training costs; quality suffers; scheduling difficult.	Good for unskilled jobs in areas with large temporary labor pools.
Influencing demand	Tries to use excess capacity. Discounts draw new customers.	Uncertainty in demand. Hard to match demand to supply exactly.	Creates marketing ideas. Overbooking used in some businesses.
Back ordering during high-demand periods	May avoid overtime. Keeps capacity constant.	Customer must be willing to wait, but goodwill is lost.	Many companies back order.
Counterseasonal product and service mixing	Fully utilizes resources; allows stable workforce.	May require skills or equipment outside firm's areas of expertise.	Risky finding products or services with opposite demand patterns.

If customers are willing to wait without loss of their goodwill or order, back ordering is a possible strategy. Many firms back order, but the approach often results in lost sales.

3. *Counterseasonal product and service mixing:* A widely used active smoothing technique among manufacturers is to develop a product mix of counterseasonal items. Examples include companies that make both furnaces and air conditioners or lawn mowers and snowblowers. However, companies that follow this approach may find themselves involved in products or services beyond their area of expertise or beyond their target market.

These eight options, along with their advantages and disadvantages, are summarized in Table 13.1.

Mixing Options to Develop a Plan

Although each of the five capacity options and three demand options discussed above may produce an effective aggregate schedule, some combination of capacity options and demand options may be better.

Many manufacturers assume that the use of the demand options has been fully explored by the marketing department and those reasonable options incorporated into the demand forecast. The operations manager then builds the aggregate plan based on that forecast. However, using the five capacity options at his command, the operations manager still has a multitude of possible plans. These plans can embody, at one extreme, a *chase strategy* and, at the other, a *level-scheduling strategy*. They may, of course, fall somewhere in between.

Chase Strategy A chase strategy typically attempts to achieve output rates for each period that match the demand forecast for that period. This strategy can be accomplished in a variety of ways. For example, the operations manager can vary workforce levels by hiring or laying off or can vary output by means of overtime, idle time, part-time employees, or subcontracting. Many service organizations favor the chase strategy because the changing inventory levels option is difficult or impossible to adopt. Industries that have moved toward a chase strategy include education, hospitality, and construction.

Chase strategy
A planning strategy that sets production equal to forecast demand.

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.

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:

LO 13.4 *Prepare* a graphical aggregate plan

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	

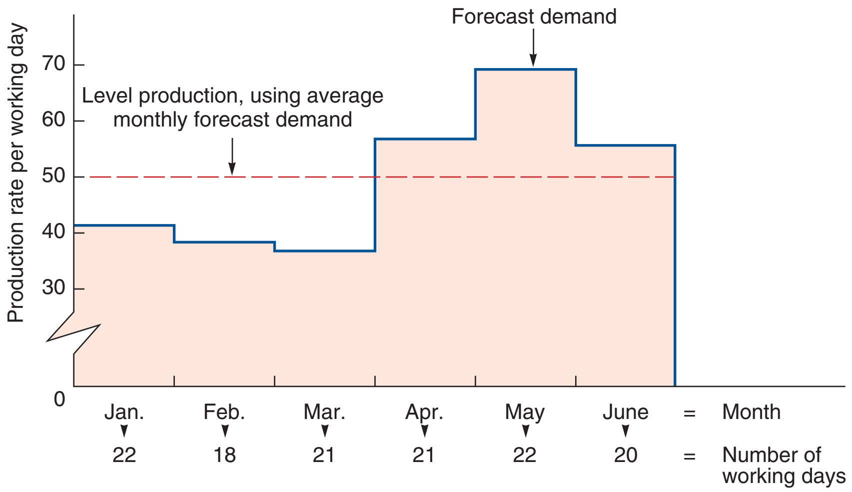
APPROACH ▶ Plot daily and average demand to illustrate the nature of the aggregate planning problem.

SOLUTION ▶ First, compute demand per day by dividing the expected monthly demand by the number of production days (working days) each month and drawing a graph of those forecast demands (Figure 13.3). Second, draw a dotted line across the chart that represents the production rate required to meet average demand over the 6-month period. The chart is computed as follows:

$$\text{Average requirement} = \frac{\text{Total expected demand}}{\text{Number of production days}} = \frac{6{,}200}{124} = 50 \text{ units per day}$$

Figure **13.3**

Graph of Forecast and Average Forecast Demand



INSIGHT ▶ Changes in the production rate become obvious when the data are graphed. Note that in the first 3 months, expected demand is lower than average, while expected demand in April, May, and June is above average.

LEARNING EXERCISE ▶ If demand for June increases to 1,200 (from 1,100), what is the impact on Figure 13.3? [Answer: The daily rate for June will go up to 60, and average production will increase to 50.8 (6,300/124).]

RELATED PROBLEM ▶ 13.1

The graph in Figure 13.3 illustrates how the forecast differs from the average demand. Some strategies for meeting the forecast were listed earlier. The firm, for example, might staff in order to yield a production rate that meets *average* demand (as indicated by the dashed line). Or it might produce a steady rate of, say, 30 units and then subcontract excess demand to other roofing suppliers. Other plans might combine overtime work with subcontracting to absorb demand or vary the workforce by hiring and laying off. Examples 2 to 4 illustrate three possible strategies.

Example 2

PLAN 1 FOR THE ROOFING SUPPLIER—A CONSTANT WORKFORCE

One possible strategy (call it plan 1) for the manufacturer described in Example 1 is to maintain a constant workforce throughout the 6-month period. A second (plan 2) is to maintain a constant workforce at a level necessary to meet the lowest demand month (March) and to meet all demand above this level by subcontracting. Both plan 1 and plan 2 have level production and are, therefore, called *level strategies*. Plan 3 is to hire and lay off workers as needed to produce exact monthly requirements—*a chase strategy*. Table 13.3 provides cost information necessary for analyzing these three alternatives.

TABLE 13.3 Cost Information

Inventory carrying cost	$ 5 per unit per month
Subcontracting cost per unit	$ 20 per unit
Average pay rate	$ 10 per hour ($80 per day)
Overtime pay rate	$ 17 per hour (above 8 hours per day)
Labor-hours to produce a unit	1.6 hours per unit
Cost of increasing daily production rate (hiring and training)	$300 per unit
Cost of decreasing daily production rate (layoffs)	$600 per unit

ANALYSIS OF PLAN 1 APPROACH ▶ Here we assume that 50 units are produced per day and that we have a constant workforce, no overtime or idle time, no safety stock, and no subcontractors. The firm accumulates inventory during the slack period of demand, January through March, and depletes it during the higher-demand warm season, April through June. We assume beginning inventory = 0 and planned ending inventory = 0.

SOLUTION ▶ We construct the table below and accumulate the costs:

MONTH	PRODUCTION DAYS	PRODUCTION AT 50 UNITS PER DAY	DEMAND FORECAST	MONTHLY INVENTORY CHANGE	ENDING INVENTORY
Jan.	22	1,100	900	+200	200
Feb.	18	900	700	+200	400
Mar.	21	1,050	800	+250	650
Apr.	21	1,050	1,200	−150	500
May	22	1,100	1,500	−400	100
June	20	1,000	1,100	−100	0
					1,850

Total units of inventory carried over from one month to the next month = 1,850 units

Workforce required to produce 50 units per day = 10 workers

Because each unit requires 1.6 labor-hours to produce, each worker can make 5 units in an 8-hour day. Therefore, to produce 50 units, 10 workers are needed.

Finally, the costs of plan 1 are computed as follows:

COST		CALCULATIONS
Inventory carrying	$ 9,250	(= 1,850 units carried × $5 per unit)
Regular-time labor	99,200	(= 10 workers × $80 per day × 124 days)
Other costs (overtime, hiring, layoffs, subcontracting)	0	
Total cost	$108,450	

INSIGHT ▶ Note the significant cost of carrying the inventory.

LEARNING EXERCISE ▶ If demand for June decreases to 1,000 (from 1,100), what is the change in cost? [Answer: Total inventory carried will increase to 1,950 at $5, for an inventory cost of $9,750 and total cost of $108,950.]

RELATED PROBLEMS ▶ 13.2–13.12, 13.19 (13.23 is available in MyOMLab)

EXCEL OM Data File **Ch13Ex2.xls** can be found in MyOMLab.

ACTIVE MODEL 13.1 This example is further illustrated in Active Model 13.1 in MyOMLab.

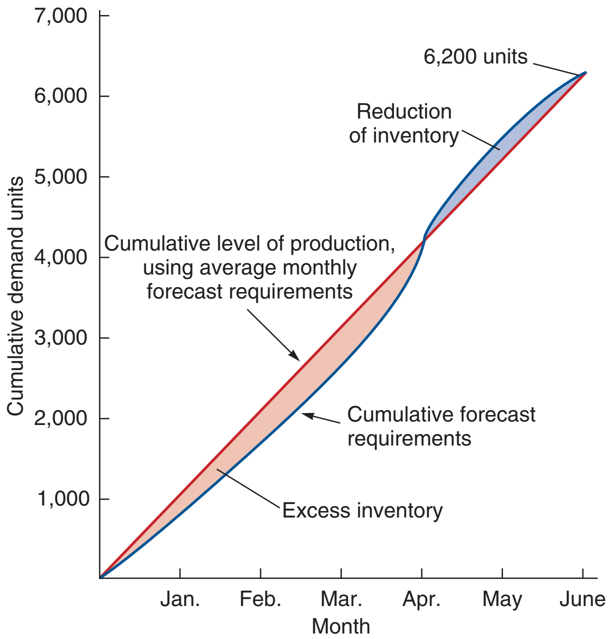


Figure 13.4

Cumulative Graph for Plan 1

STUDENT TIP

We saw another way to graph this data in Figure 13.3.

The graph for Example 2 was shown in Figure 13.3. Some planners prefer a *cumulative* graph to display visually how the forecast deviates from the average requirements. Such a graph is provided in Figure 13.4. Note that both the level production line and the forecast line produce the same total production.

Example 3

PLAN 2 FOR THE ROOFING SUPPLIER—USE OF SUBCONTRACTORS WITHIN A CONSTANT WORKFORCE

ANALYSIS OF PLAN 2 APPROACH ▶ Although a constant workforce is also maintained in plan 2, it is set low enough to meet demand only in March, the lowest demand-per-day month. To produce 38 units per day (800/21) in-house, 7.6 workers are needed. (You can think of this as 7 full-time workers and 1 part-timer.) *All* other demand is met by subcontracting. Subcontracting is thus required in every other month. No inventory holding costs are incurred in plan 2.

SOLUTION ▶ Because 6,200 units are required during the aggregate plan period, we must compute how many can be made by the firm and how many must be subcontracted:

$$\text{In-house production} = 38 \text{ units per day} \times 124 \text{ production days}$$
$$= 4{,}712 \text{ units}$$
$$\text{Subcontract units} = 6{,}200 - 4{,}712 = 1{,}488 \text{ units}$$

The costs of plan 2 are computed as follows:

COST		CALCULATIONS
Regular-time labor	$ 75,392	(= 7.6 workers × $80 per day × 124 days)
Subcontracting	29,760	(= 1,488 units × $20 per unit)
Total cost	$105,152	

INSIGHT ▶ Note the lower cost of regular labor but the added subcontracting cost.

LEARNING EXERCISE ▶ If demand for June increases to 1,200 (from 1,100), what is the change in cost? [Answer: Subcontracting requirements increase to 1,588 at $20 per unit, for a subcontracting cost of $31,760 and a total cost of $107,152.]

RELATED PROBLEMS ▶ 13.2–13.12, 13.19 (13.23 is available in MyOMLab)

Example 4

PLAN 3 FOR THE ROOFING SUPPLIER—HIRING AND LAYOFFS

ANALYSIS OF PLAN 3 APPROACH ▶ The final strategy, plan 3, involves varying the workforce size by hiring and layoffs as necessary. The production rate will equal the demand, and there is no change in production from the previous month, December.

SOLUTION ▶ Table 13.4 shows the calculations and the total cost of plan 3. Recall that it costs $600 per unit produced to reduce production from the previous month's daily level and $300 per unit change to increase the daily rate of production through hirings.

TABLE 13.4 Cost Computations for Plan 3

MONTH	FORECAST (UNITS)	DAILY PRODUCTION RATE	BASIC PRODUCTION COST (DEMAND × 1.6 HR PER UNIT × $10 PER HR)	EXTRA COST OF INCREASING PRODUCTION (HIRING COST)	EXTRA COST OF DECREASING PRODUCTION (LAYOFF COST)	TOTAL COST
Jan.	900	41	$14,400	—	—	$ 14,400
Feb.	700	39	11,200	—	$1,200 (= 2 × $600)	12,400
Mar.	800	38	12,800	—	$ 600 (= 1 × $600)	13,400
Apr.	1,200	57	19,200	$5,700 (= 19 × $300)	—	24,900
May	1,500	68	24,000	$3,300 (= 11 × $300)	—	27,300
June	1,100	55	17,600	—	$7,800 (= 13 × $600)	$ 25,400
			$99,200	$9,000	$9,600	$117,800

Thus, the total cost, including production, hiring, and layoff, for plan 3 is $117,800.

INSIGHT ▶ Note the substantial cost associated with changing (both increasing and decreasing) the production levels.

LEARNING EXERCISE ▶ If demand for June increases to 1,200 (from 1,100), what is the change in cost? [Answer: Daily production for June is 60 units, which is a decrease of 8 units in the daily production rate from May's 68 units, so the new June layoff cost is $4,800 (= 8 × $600), but an additional production cost for 100 units is $1,600 (100 × 1.6 × $10) with a total plan 3 cost of $116,400.]

RELATED PROBLEMS ▶ 13.2–13.12, 13.19 (13.23 is available in MyOMLab)

The final step in the graphical method is to compare the costs of each proposed plan and to select the approach with the least total cost. A summary analysis is provided in Table 13.5. We see that because plan 2 has the lowest cost, it is the best of the three options.

TABLE 13.5 Comparison of the Three Plans

COST	PLAN 1 (CONSTANT WORKFORCE OF 10 WORKERS)	PLAN 2 (WORKFORCE OF 7.6 WORKERS PLUS SUBCONTRACTORS)	PLAN 3 (HIRING AND LAYOFFS TO MEET DEMAND)
Inventory carrying	$ 9,250	$ 0	$ 0
Regular labor	99,200	75,392	99,200
Overtime labor	0	0	0
Hiring	0	0	9,000
Layoffs	0	0	9,600
Subcontracting	0	29,760	0
Total cost	$108,450	$105,152	$117,800

Of course, many other feasible strategies can be considered in a problem like this, including combinations that use some overtime. Although graphing is a popular management tool, its help is in evaluating strategies, not generating them. To generate strategies, a systematic approach that considers all costs and produces an effective solution is needed.

Mathematical Approaches

This section briefly describes mathematical approaches to aggregate planning.

The Transportation Method of Linear Programming When an aggregate planning problem is viewed as one of allocating operating capacity to meet forecast demand, it can be formulated in a linear programming format. The **transportation method of linear programming** is not a trial-and-error approach like graphing but rather produces an optimal plan for minimizing costs. It is also 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 method of linear programming
A way of solving for the optimal solution to an aggregate planning problem.

In Example 5, the supply consists of on-hand inventory and units produced by regular time, overtime, and subcontracting. Costs per unit, in the upper-right corner of each cell of the matrix in Table 13.7, relate to units produced in a given period or units carried in inventory from an earlier period.

Example 5

AGGREGATE PLANNING WITH THE TRANSPORTATION METHOD

Farnsworth Tire Company would like to develop an aggregate plan via the transportation method. Data that relate to production, demand, capacity, and cost at its West Virginia plant are shown in Table 13.6.

TABLE 13.6 Farnsworth's Production, Demand, Capacity, and Cost Data

	SALES PERIOD		
	MAR.	APR.	MAY
Demand	800	1,000	750
Capacity:			
Regular	700	700	700
Overtime	50	50	50
Subcontracting	150	150	130
Beginning inventory	100 tires		

COSTS	
Regular time	$40 per tire
Overtime	$50 per tire
Subcontract	$70 per tire
Carrying cost	$ 2 per tire per month

APPROACH ▶ Solve the aggregate planning problem by minimizing the costs of matching production in various periods to future demands.

SOLUTION ▶ Table 13.7 illustrates the structure of the transportation table and an initial feasible solution.

LO 13.5 *Solve* an aggregate plan via the transportation method

TABLE 13.7 Farnsworth's Transportation Table[a]

SUPPLY FROM		DEMAND FOR: *Period 1 (Mar.)*	*Period 2 (Apr.)*	*Period 3 (May)*	*Unused Capacity (dummy)*	TOTAL CAPACITY AVAILABLE (supply)
Beginning inventory		0 / 100	2	4	0	100
Period 1	*Regular time*	40 / 700	42	44	0	700
	Overtime	50	52 / 50	54	0	50
	Subcontract	70	72 / 150	74	0	150
Period 2	*Regular time*	×	40 / 700	42	0	700
	Overtime	×	50 / 50	52	0	50
	Subcontract	×	70 / 50	72	0 / 100	150
Period 3	*Regular time*	×	×	40 / 700	0	700
	Overtime	×	×	50 / 50	0	50
	Subcontract	×	×	70	0 / 130	130
TOTAL DEMAND		800	1,000	750	230	2,780

[a]Cells with an *x* indicate that back orders are not used at Farnsworth. When using Excel OM or POM for Windows to solve, you must insert a *very* high cost (e.g., 9999) in each cell that is not used for production.

When setting up and analyzing this table, you should note the following:

1. Carrying costs are $2/tire per month. Tires produced in 1 period and held for 1 month will have a $2 higher cost. Because holding cost is linear, 2 months' holdover costs $4. So when you move across a row from left to right, regular time, overtime, and subcontracting costs are lowest when output is used in the same period it is produced. If goods are made in one period and carried over to the next, holding costs are incurred. Beginning inventory, however, is generally given a unit cost of 0 if it is used to satisfy demand in period 1.
2. Transportation problems require that supply equals demand, so a dummy column called "unused capacity" has been added. Costs of not using capacity are zero.
3. Because back ordering is not a viable alternative for this particular company, no production is possible in those cells that represent production in a period to satisfy demand in a past period (i.e., those periods with an "×"). If back ordering is allowed, costs of expediting, loss of goodwill, and loss of sales revenues are summed to estimate backorder cost.
4. Quantities in red in each column of Table 13.7 designate the levels of inventory needed to meet demand requirements (shown in the bottom row of the table). Demand of 800 tires in March is met by using 100 tires from beginning inventory and 700 tires from regular time.
5. In general, to complete the 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 the total row capacity, and the sum of all entries in a column must equal the demand for that period. (This step can be accomplished by the transportation method or by using POM for Windows or Excel OM software.)

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.

Restaurants

In a business with a highly variable demand, such as a restaurant, aggregate scheduling is directed toward (1) smoothing the production rate and (2) finding the optimal size of the workforce. The general approach usually requires building very modest levels of inventory during slack periods and depleting inventory during peak periods, but using labor to accommodate most of the changes in demand. Because this situation is very similar to those found in manufacturing, traditional aggregate planning methods may be applied to restaurants as well. One difference is that even modest amounts of inventory may be perishable. In addition, the relevant units of time may be much smaller than in manufacturing. For example, in fast-food restaurants, peak and slack periods may be measured in fractions of an hour, and the "product" may be inventoried for as little as 10 minutes.

Hospitals

Hospitals face aggregate planning problems in allocating money, staff, and supplies to meet the demands of patients. Michigan's Henry Ford Hospital, for example, plans for bed capacity and personnel needs in light of a patient-load forecast developed by moving averages. The necessary labor focus of its aggregate plan has led to the creation of a new floating staff pool serving each nursing pod.

National Chains of Small Service Firms

With the advent of national chains of small service businesses such as funeral homes, oil change outlets, and photocopy/printing centers, the question of aggregate planning versus independent planning at each business establishment becomes an issue. Both purchases and production capacity may be centrally planned when demand can be influenced through special promotions. This approach to aggregate scheduling is often advantageous because it reduces costs and helps manage cash flow at independent sites.

Miscellaneous Services

Most "miscellaneous" services—financial, transportation, and many communication and recreation services—provide intangible output. Aggregate planning for these services deals mainly with planning for human resource requirements and managing demand. The twofold goal is to level demand peaks and to design methods for fully utilizing labor resources during low-demand periods. Example 6 illustrates such a plan for a legal firm.

Example 6

AGGREGATE PLANNING IN A LAW FIRM

Klasson and Avalon, a medium-size Tampa law firm of 32 legal professionals, wants to develop an aggregate plan for the next quarter. The firm has developed 3 forecasts of billable hours for the next quarter for each of 5 categories of legal business it performs (column 1, Table 13.8). The 3 forecasts (best, likely, and worst) are shown in columns 2, 3, and 4 of Table 13.8.

TABLE 13.8 Labor Allocation at Klasson and Avalon, Forecasts for Coming Quarter (1 lawyer = 500 hours of labor)

FORECASTED LABOR-HOURS REQUIRED				CAPACITY CONSTRAINTS	
(1) CATEGORY OF LEGAL BUSINESS	(2) BEST (HOURS)	(3) LIKELY (HOURS)	(4) WORST (HOURS)	(5) MAXIMUM DEMAND FOR PERSONNEL	(6) NUMBER OF QUALIFIED PERSONNEL
Trial work	1,800	1,500	1,200	3.6	4
Legal research	4,500	4,000	3,500	9.0	32
Corporate law	8,000	7,000	6,500	16.0	15
Real estate law	1,700	1,500	1,300	3.4	6
Criminal law	3,500	3,000	2,500	7.0	12
Total hours	19,500	17,000	15,000		
Lawyers needed	39	34	30		

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.

OM in Action — Revenue Management Makes Disney the "King" of the Broadway Jungle

Disney accomplished the unthinkable for long-running Broadway musicals: *The Lion King* transformed from a declining money-maker into the top-grossing Broadway show. How? Hint: It's not because the show added performances after 16 years.

The show's producers are using a previously undisclosed computer algorithm to recommend the highest ticket prices that audiences would be likely to pay for each of the 1,700 seats. Other shows also employ this dynamic pricing model to raise seat prices during tourist-heavy holiday weeks, but only Disney has reached the level of sophistication achieved in the airline and hotel industries. By continually using its algorithm to calibrate prices based on ticket demand and purchasing patterns, Disney was able to achieve the 2013 sales record.

By charging $10 more here, $20 more there, *The Lion King* stunned Broadway at year's end as the No. 1 earner for the first time since 2003, bumping off the champ, *Wicked*. And Disney even managed to do it by charging half as much for top tickets as some rivals. "Credit the management science experts at Disney's corporate offices—a data army that no Broadway producer could ever match—for helping develop the winning formula," writes *The New York Times*. Disney's algorithm, a software tool that draws on *Lion King* data for 11.5 million past customers, recommends prices for multiple categories of performances—peak dates such as Christmas, off-peak dates such as a weeknight in February, and various periods in between. "The Lion King" is widely believed to have sold far more seats for $227 than most Broadway shows sell at their top rates, a situation that bolsters its grosses.

Sources: NY Daily News (September 22, 2014); and *The New York Times* (March 17, 2014).

American Airlines' success in revenue management spurred many other companies and industries to adopt the concept. Revenue management in the hotel industry began in the late 1980s at Marriott International, which now claims an additional $400 million a year in profit from its management of revenue. The competing Omni hotel chain uses software that performs more than 100,000 calculations every night at each facility. The Dallas Omni, for example, charges its highest rates on weekdays but heavily discounts on weekends. Its sister hotel in San Antonio, which is in a more tourist-oriented destination, reverses this rating scheme, with better deals for its consumers on weekdays. Similarly, Walt Disney World has multiple prices: an annual admission "premium" pass for an adult was recently quoted at $779, but for a Florida resident, $691, with different discounts for AAA members and active-duty military. The *OM in Action* box, "Revenue Management Makes Disney the 'King' of the Broadway Jungle," describes this practice in the live theatre industry. The video case at the end of this chapter addresses revenue management for the Orlando Magic.

VIDEO 13.1
Using Revenue Management to Set Orlando Magic Ticket Prices

Organizations that have *perishable inventory*, such as airlines, hotels, car rental agencies, cruise lines, and even electrical utilities, have the following shared characteristics that make yield management of interest:[1]

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

LO 13.6 *Understand* and solve a revenue management problem

Example 7 illustrates how revenue management works in a hotel.

Example 7

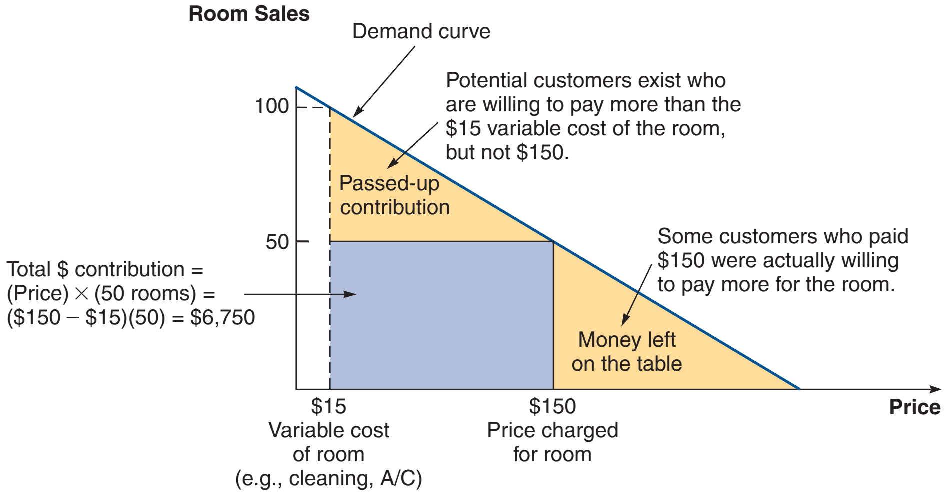
REVENUE MANAGEMENT

The Cleveland Downtown Inn is a 100-room hotel that has historically charged one set price for its rooms, $150 per night. The variable cost of a room being occupied is low. Management believes the cleaning, air-conditioning, and incidental costs of soap, shampoo, and so forth, are $15 per room per night. Sales average 50 rooms per night. Figure 13.5 illustrates the current pricing scheme. Net sales are $6,750 per night with a single price point.

APPROACH ▶ Analyze pricing from the perspective of revenue management. We note in Figure 13.5 that some guests would have been willing to spend more than $150 per room—"money left on the table." Others would be willing to pay more than the variable cost of $15 but less than $150—"passed-up contribution."

Figure **13.5**

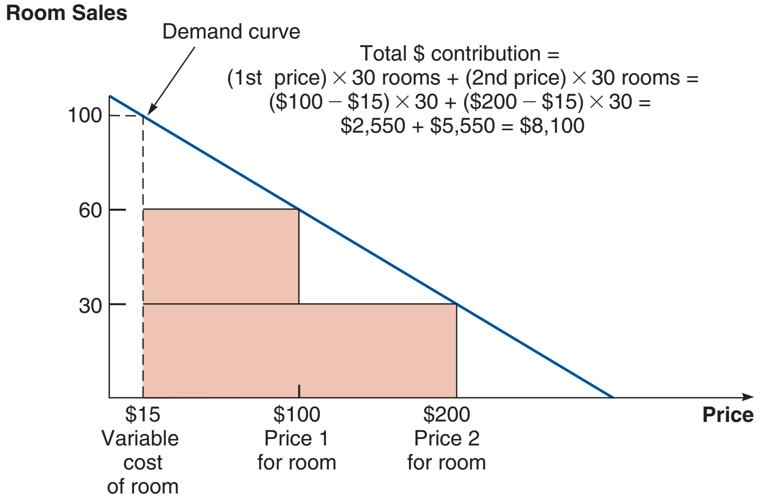
Hotel Sets Only One Price Level



SOLUTION ▶ In Figure 13.6, the inn decides to set *two* price levels. It estimates that 30 rooms per night can be sold at $100 and another 30 rooms at $200, using revenue management software that is widely available.

Figure **13.6**

Hotel with Two Price Levels



INSIGHT ▶ Revenue management has increased total contribution to $8,100 ($2,550 from $100 rooms and $5,550 from $200 rooms). It may be that even more price levels are called for at Cleveland Downtown Inn.

LEARNING EXERCISE ▶ If the hotel develops a third price of $150 and can sell half of the $100 rooms at the increased rate, what is the contribution? [Answer: $8,850 = (15 × $85) + (15 × $135) + (30 × $185).]

RELATED PROBLEM ▶ 13.26

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

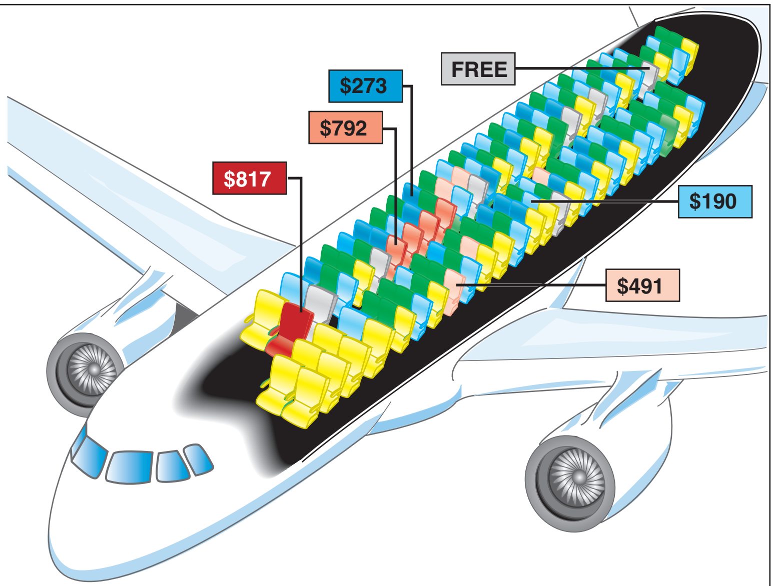


Figure **13.7**

Revenue Management Seat Costs on a Typical Flight

Discussion Questions

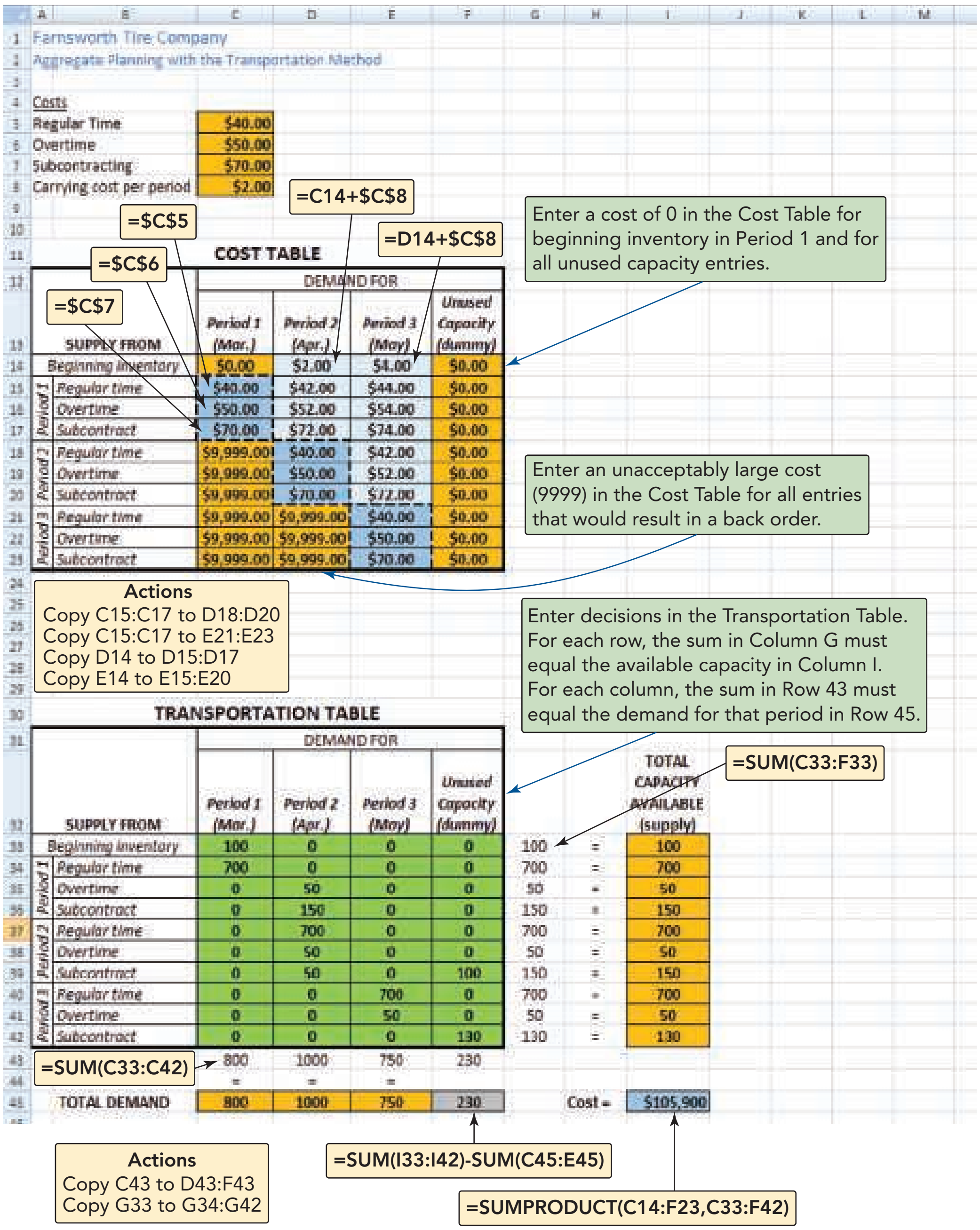
1. Define *sales* and *operations planning*.
2. Why are S&OP teams typically cross-functional?
3. Define *aggregate planning*.
4. Explain what the term *aggregate* in "aggregate planning" means.
5. List the strategic objectives of aggregate planning. Which one of these is most often addressed by the 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

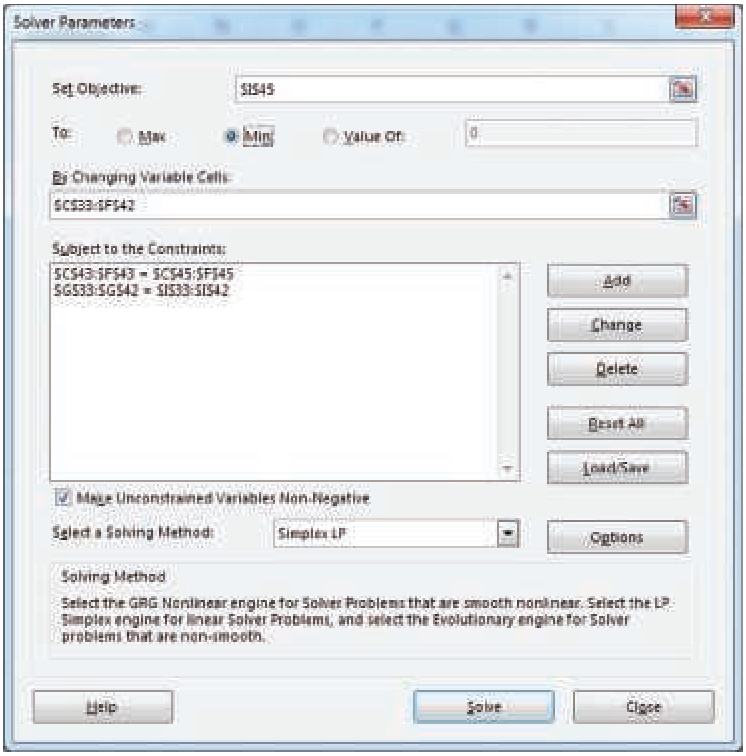
Program 13.1 illustrates how you can make an Excel model to solve Example 5, which uses the transportation method for aggregate planning.



Program **13.1**

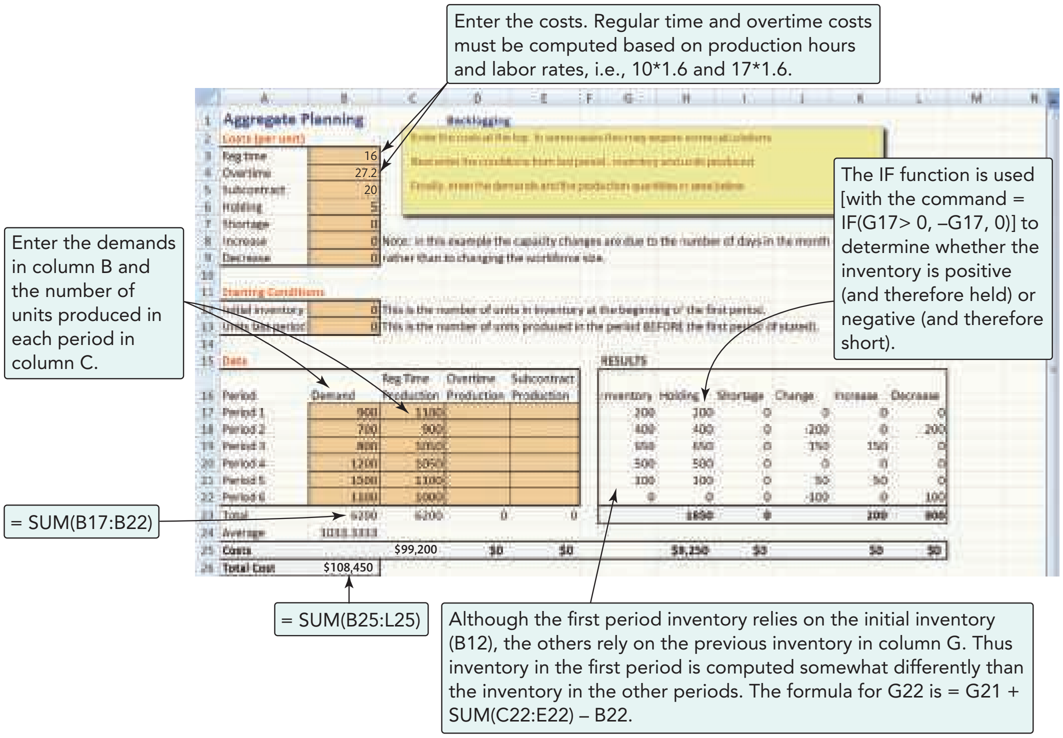
Using Excel for Aggregate Planning Via the Transportation Method, with Data from Example 5

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.



USING EXCEL OM

Excel OM's Aggregate Planning module is demonstrated in Program 13.2. Using data from Example 2, Program 13.2 provides input and some of the formulas used to compute the costs of regular time, overtime, subcontracting, holding, shortage, and increase or decrease in production. The user must provide the production plan for Excel OM to analyze.



Program 13.2

Using Excel OM for Aggregate Planning, with Example 2 Data

USING POM FOR WINDOWS

The POM for Windows Aggregate Planning module performs aggregate or production planning for up to 90 time periods. Given a set of demands for future periods, you can try various plans to determine the lowest-cost plan based on holding, shortage, production, and changeover costs. Four methods are available for planning. More help is available on each after you choose the method. See Appendix IV for further details.

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

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

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?

Supply Capacity Available (units)

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

Demand Forecast

PERIOD	DEMAND (UNITS)
1	450
2	550
3	750

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:

$$\begin{aligned}
&\text{Period 1:}\quad 50(\$0) + 300(\$50) + 50(\$65) + 50(\$80) = \$22{,}250\\
&\text{Period 2:}\quad 400(\$50) + 50(\$65) + 100(\$80) = \$31{,}250\\
&\text{Period 3:}\quad 50(\$81) + 450(\$50) + 50(\$65) + 200(\$80) = \$45{,}800^{*}\\
&\qquad\qquad\text{Total cost}\qquad \$99{,}300
\end{aligned}$$

*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

Her operations manager is considering a new plan, which begins in January with 200 units on hand. Stockout cost of lost sales is $100 per unit. Inventory holding cost is $20 per unit per month. Ignore any idle-time costs. The plan is called plan A.

Plan A: Vary the workforce level to execute a strategy that produces the quantity demanded in the *prior* month. The December demand and rate of production are both 1,600 units per month. The cost of hiring additional workers is $5,000 per 100 units. The cost of laying off workers is $7,500 per 100 units. Evaluate this plan.

Note: Both hiring and layoff costs are incurred in the month of the change. For example, going from 1,600 in January to 1,400 in February incurs a cost of layoff for 200 units in February.

•• **13.4** Using the information in Problem 13.3, develop plan B. Produce at a constant rate of 1,400 units per month, which will meet minimum demands. Then use subcontracting, with additional units at a premium price of $75 per unit. Evaluate this plan by computing the costs for January through August.

•• **13.5** Hill is now considering plan C: Keep a stable workforce by maintaining a constant production rate equal to the average requirements and allow varying inventory levels. Beginning inventory, stockout costs, and holding costs are provided in Problem 13.3.

Plot the demand with a graph that also shows average requirements. Conduct your analysis for January through August.

••• **13.6** Hill's operations manager (see Problems 13.3 through 13.5) is also considering two mixed strategies for January–August: Produce in overtime or subcontracting only when there is no inventory.

- *Plan D:* Keep the current workforce stable at producing 1,600 units per month. Permit a maximum of 20% overtime at an additional cost of $50 per unit. A warehouse now constrains the maximum allowable inventory on hand to 400 units or less.
- *Plan E:* Keep the current workforce, which is producing 1,600 units per month, and subcontract to meet the rest of the demand.

Evaluate plans D and E and make a recommendation.

Note: Do not produce in overtime if production or inventory are adequate to cover demand.

••• **13.7** Consuelo Chua, Inc., is a disk drive manufacturer in need of an aggregate plan for July through December. The company has gathered the following data:

COSTS	
Holding cost	$8/disk/month
Subcontracting	$80/disk
Regular-time labor	$12/hour
Overtime labor	$18/hour for hours above 8 hours/worker/day
Hiring cost	$40/worker
Layoff cost	$80/worker

DEMAND*	
July	400
Aug.	500
Sept.	550
Oct.	700
Nov.	800
Dec.	700

*No costs are incurred for unmet demand, but unmet demand (backorders) must be handled in the following period. If half or more of a worker is needed, round up.

OTHER DATA	
Current workforce (June)	8 people
Labor-hours/disk	4 hours
Workdays/month	20 days
Beginning inventory	150 disks**
No requirement for ending inventory	0 disks

**Note that there is no holding cost for June.

What will each of the two following strategies cost?

a) Vary the workforce so that production meets demand. Chua had eight workers on board in June.

b) Vary overtime only and use a constant workforce of eight.

•• **13.8** You manage a consulting firm down the street from Consuelo Chua, Inc., and to get your foot in the door, you have told Ms. Chua (see Problem 13.7) that you can do a better job at aggregate planning than her current staff. She said, "Fine. You do that, and you have a one year contract." You now have to make good on your boast using the data in Problem 13.7. You decide to hire 5 workers in August and 5 more in October. Your results?

••• **13.9** The S&OP team at Kansas Furniture, has received the following estimates of demand requirements:

July	Aug.	Sept.	Oct.	Nov.	Dec.
1,000	1,200	1,400	1,800	1,800	1,800

Stephanie Klein-Davis/The Roanoke Times/ AP Images

a) Assuming one-time stockout costs for lost sales of $100 per unit, inventory carrying costs of $25 per unit per month, and zero beginning and ending inventory, evaluate these two plans on an *incremental* cost basis:

- *Plan A:* Produce at a steady rate (equal to minimum requirements) of 1,000 units per month and subcontract additional units at a $60 per unit premium cost.
- *Plan B:* Vary the workforce, to produce the prior month's demand. The firm produced 1,300 units in June. The cost of hiring additional workers is $3,000 per 100 units produced. The cost of layoffs is $6,000 per 100 units cut back.

Note: Both hiring and layoff costs are incurred in the month of the change, (i.e. going from production of 1,300 in July to 1,000 in August requires a layoff (and related costs) of 300 units in August, just as going from production of 1,000 in August to 1,200 in September requires hiring (and related costs) of 200 units in September).

b) Which plan is best and why?

••• **13.10** The S&OP team (see Problem 13.9) is considering two more mixed strategies. Using the data in Problem 13.9, compare plans C and D with plans A and B and make a recommendation.

- *Plan C:* Keep the current workforce steady at a level producing 1,300 units per month. Subcontract the remainder to meet demand. Assume that 300 units remaining from June are available in July.

- *Plan D:* Keep the current workforce at a level capable of producing 1,300 units per month. Permit a maximum of 20% overtime at a premium of $40 per unit. Assume that warehouse limitations permit no more than a 180-unit carryover from month to month. This plan means that any time inventories reach 180, the plant is kept idle. Idle time per unit is $60. Any additional needs are subcontracted at a cost of $60 per incremental unit.

••• **13.11** Deb Bishop Health and Beauty Products has developed a new shampoo, and you need to develop its aggregate schedule. The cost accounting department has supplied you the costs relevant to the aggregate plan, and the marketing department has provided a four-quarter forecast. All are shown as follows:

QUARTER	FORECAST
1	1,400
2	1,200
3	1,500
4	1,300

COSTS	
Previous quarter's output	1,500 units
Beginning inventory	0 units
Stockout cost for backorders	$50 per unit
Inventory holding cost	$10 per unit for every unit held at the end of the quarter
Hiring workers	$40 per unit
Layoff workers	$80 per unit
Unit cost	$30 per unit
Overtime	$15 extra per unit
Subcontracting	Not available

Your job is to develop an aggregate plan for the next four quarters.

a) First, try hiring and layoffs (to meet the forecast) as necessary.
b) Then try a plan that holds employment steady.
c) Which is the more economical plan for Deb Bishop Health and Beauty Products? PX

••• **13.12** Southeast Soda Pop, Inc., has a new fruit drink for which it has high hopes. John Mittenthal, the production planner, has assembled the following cost data and demand forecast:

QUARTER	FORECAST
1	1,800
2	1,100
3	1,600
4	900

COSTS/OTHER DATA
Previous quarter's output = 1,300 cases
Beginning inventory = 0 cases
Stockout cost = $150 per case
Inventory holding cost = $40 per case at end of quarter
Hiring employees = $40 per case
Terminating employees = $80 per case
Subcontracting cost = $60 per case
Unit cost on regular time = $30 per case
Overtime cost = $15 extra per case
Capacity on regular time = 1,800 cases per quarter


Africa Studio/Shutterstock

John's job is to develop an aggregate plan. The three initial options he wants to evaluate are:

- *Plan A:* a strategy that hires and fires personnel as necessary to meet the forecast.
- *Plan B:* a level strategy.
- *Plan C:* a level strategy that produces 1,200 cases per quarter and meets the forecast demand with inventory and subcontracting.

a) Which strategy is the lowest-cost plan?
b) If you are John's boss, the VP for operations, which plan do you implement and why? PX

•• **13.13** Ram Roy's firm has developed the following supply, demand, cost, and inventory data. Allocate production capacity to meet demand at a minimum cost using the transportation method. What is the cost? Assume that the initial inventory has no holding cost in the first period and backorders are not permitted.

Supply Available

PERIOD	REGULAR TIME	OVERTIME	SUBCONTRACT	DEMAND FORECAST
1	30	10	5	40
2	35	12	5	50
3	30	10	5	40

Initial inventory	20 units
Regular-time cost per unit	$100
Overtime cost per unit	$150
Subcontract cost per unit	$200
Carrying cost per unit per month	$ 4

PX

•• **13.14** Jerusalem Medical Ltd., an Israeli producer of portable kidney dialysis units and other medical products, develops a 4-month aggregate plan. Demand and capacity (in units) are forecast as follows:

CAPACITY SOURCE	MONTH 1	MONTH 2	MONTH 3	MONTH 4
Labor				
Regular time	235	255	290	300
Overtime	20	24	26	24
Subcontract	12	15	15	17
Demand	255	294	321	301

The cost of producing each dialysis unit is $985 on regular time, $1,310 on overtime, and $1,500 on a subcontract. Inventory carrying cost is $100 per unit per month. There is to be no beginning or ending inventory in stock and backorders are not permitted. Set up a production plan that minimizes cost using the transportation method. PX

•• **13.15** The production planning period for flat-screen monitors at Louisiana's Roa Electronics, Inc., is 4 months. Cost data are as follows:

Regular-time cost per monitor	$ 70
Overtime cost per monitor	$110
Subcontract cost per monitor	$120
Carrying cost per monitor per month	$ 4

For each of the next 4 months, capacity and demand for flat-screen monitors are as follows:

	PERIOD			
	MONTH 1	MONTH 2	MONTH 3[a]	MONTH 4
Demand	2,000	2,500	1,500	2,100
Capacity				
Regular time	1,500	1,600	750	1,600
Overtime	400	400	200	400
Subcontract	600	600	600	600

[a]Factory closes for 2 weeks of vacation.

CEO Mohan Roa expects to enter the planning period with 500 monitors in stock. Back ordering is not permitted (meaning, for example, that monitors produced in the second month cannot be used to cover first month's demand). Develop a production plan that minimizes costs using the transportation method. Px

•• **13.16** A large St. Louis feed mill, Robert Orwig Processing, prepares its 6-month aggregate plan by forecasting demand for 50-pound bags of cattle feed as follows: January, 1,000 bags; February, 1,200; March, 1,250; April, 1,450; May, 1,400; and June, 1,400. The feed mill plans to begin the new year with no inventory left over from the previous year, and backorders are not permitted. It projects that capacity (during regular hours) for producing bags of feed will remain constant at 800 until the end of April, and then increase to 1,100 bags per month when a planned expansion is completed on May 1. Overtime capacity is set at 300 bags per month until the expansion, at which time it will increase to 400 bags per month. A friendly competitor in Sioux City, Iowa, is also available as a backup source to meet demand—but can provide only 500 bags total during the 6-month period. Develop a 6-month production plan for the feed mill using the transportation method.

Cost data are as follows:

Regular-time cost per bag (until April 30)	$12.00
Regular-time cost per bag (after May 1)	$11.00
Overtime cost per bag (during entire period)	$16.00
Cost of outside purchase per bag	$18.50
Carrying cost per bag per month	$ 1.00

Px

•• **13.17** Yu Amy Xia has developed a specialized airtight vacuum bag to extend the freshness of seafood shipped to restaurants. She has put together the following demand cost data:

QUARTER	FORECAST (UNITS)	REGULAR TIME	OVERTIME	SUB-CONTRACT
1	500	400	80	100
2	750	400	80	100
3	900	800	160	100
4	450	400	80	100

Initial inventory = 250 units
Regular time cost = $1.00/unit
Overtime cost = $1.50/unit
Subcontracting cost = $2.00/unit
Carrying cost = $0.20/unit/quarter
Back order cost = $0.50/unit/quarter

Yu decides that the initial inventory of 250 units will incur the 20¢/unit cost from each prior quarter (unlike the situation in most other companies, where a 0 unit cost is assigned).

a) Find the optimal plan using the transportation method.
b) What is the cost of the plan?
c) Does any regular time capacity go unused? If so, how much in which periods?
b) What is the extent of backordering in units and dollars? Px

••• **13.18** José Martinez of El Paso has developed a polished stainless steel tortilla machine that makes it a "showpiece" for display in Mexican restaurants. He needs to develop a 5-month aggregate plan. His forecast of capacity and demand follows:

	MONTH				
	1	2	3	4	5
Demand	150	160	130	200	210
Capacity					
Regular	150	150	150	150	150
Overtime	20	20	10	10	10

Subcontracting: 100 units available over the 5-month period
Beginning inventory: 0 units
Ending inventory required: 20 units

COSTS	
Regular-time cost per unit	$100
Overtime cost per unit	$125
Subcontract cost per unit	$135
Inventory holding cost per unit per month	$ 3

Assume that backorders are not permitted. Using the transportation method, what is the total cost of the optimal plan? Px

•••• **13.19** Dwayne Cole, owner of a Florida firm that manufactures display cabinets, develops an 8-month aggregate plan. Demand and capacity (in units) are forecast as follows:

CAPACITY SOURCE (UNITS)	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.
Regular time	235	255	290	300	300	290	300	290
Overtime	20	24	26	24	30	28	30	30
Subcontract	12	16	15	17	17	19	19	20
Demand	255	294	321	301	330	320	345	340

The cost of producing each unit is $1,000 on regular time, $1,300 on overtime, and $1,800 on a subcontract. Inventory carrying cost is $200 per unit per month. There is no beginning or ending inventory in stock, and no backorders are permitted from period to period.

Let the production (workforce) vary by using regular time first, then overtime, and then subcontracting.

a) Set up a production plan that minimizes cost by producing exactly what the demand is each month. This plan allows no backorders or inventory. What is this plan's cost?
b) Through better planning, regular-time production can be set at exactly the same amount, 275 units, per month. If demand cannot be met there is no cost assigned to shortages and they will not be filled. Does this alter the solution?

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

PLANT	VARIABLE COST (PER UNIT)	FIXED COST PER WEEK	
		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

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

Source: Reprinted by permission of Professor Michael Ballot, University of the Pacific, Stockton, CA.

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**

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.