

13

CHAPTER

Aggregate Planning

DISCUSSION QUESTIONS

1. Aggregate planning is concerned with the quantity and timing of production for the intermediate future; typically encompasses a time horizon of three to eighteen months.

2. Aggregate means combining the appropriate products and resources into general, or overall, terms.

3. Strategic objectives: minimize cost over the planning period, smooth fluctuations in work force, drive down inventory levels for time-sensitive stock, and meet a high level of service regardless of cost. Cost minimization is the most often treated quantitatively and is generally the most important.

4. With a chase strategy production rates or work force levels are adjusted to match demand requirements over the planning horizon.

5. A pure strategy is one that varies only one factor—for example, maintain a constant work force level or maintain a constant inventory. Trade-offs are ignored.

6. Level scheduling is an aggregate plan in which daily capacities are uniform from month to month. The underlying philosophy is that stable employment leads to better quality, less turnover, less absenteeism, and more employee commitment.

7. Mixed strategy is a planning approach in which two or more options, such as overtime, subcontracting, hiring and layoff, etc., are used. There are both inventory changes and work force and production rate changes over the planning horizon. Typically, mixed strategies are better (result in lower costs) than pure strategies.

8. The advantage of varying the size of the workforce as required to adjust production capacity is that one has a fundamental ability to change production capacity in relatively small and precise increments. The disadvantages are that a ready supply of skilled labor is not always available, newly hired personnel must be trained, and layoffs undermine the morale of all employees and can lead to a widespread decrease in overall productivity.

9. Mathematical models are not more widely used because they tend to be relatively complex and are seldom understood by those persons performing the aggregate planning activities.

10. Aggregate planning in services differs from aggregate planning in manufacturing in the following ways:

- Most services are perishable and cannot be inventoried. It is virtually impossible to produce the service early in anticipation of higher demand at a later time.
- Demand for services is often difficult to predict. Demand variations may be more severe and more frequent.

- Services are more customized than manufactured goods and can be offered in many different forms. This variability makes it difficult to allocate capacity. Units of capacity may also be hard to define.
- Because most services cannot be transported, service capacity must be available at the appropriate place as well as at the appropriate time.
- Service capacity is generally altered by changes in labor, rather than by equipment or space, and labor is a highly flexible resource.

11. The master production schedule (MPS) is produced by disaggregating the aggregate plan.

12. *Graphical aggregate planning methods*, while based on trial and error, are useful because they require only limited computations and usually lead to optimal solutions.

13. *Limitations* of the *transportation method* include that it does not work well when one attempts to include the effect of hiring and layoffs in the model.

14. Yield management adds another set of decisions to the aggregate plan, to capacity planning, and to scheduling. However, of these yield management issues, the aggregate plan may be the one least affected. Auto rental companies, airlines, and hotels now all vary “inventory” (autos, seats, rooms) and prices to reflect ways to maximize their yield (profit). Lead time (vacationers price shop more and are willing to do so earlier), days of the week, seasons, holidays, and conventions all impact the yield. In many cases, the aggregate supply is the least affected.

ETHICAL DILEMMA

1. From the airline’s point of view, revenue (yield) management is crucial. Moreover, many firms, including hotels, restaurants, and universities practice revenue management. A good class discussion can be generated by asking students to discuss how other organizations practice yield management without all of the publicity (often adverse publicity) that airlines receive.

Hotels have various approaches, from weekend specials, to “points,” to computerized pricing to adjust to daily volume changes.

Restaurants have coupons, early bird specials, and special prices on slow nights. Huge portions of restaurant customers have some sort of discount. The authors have seen one figure that as high as 30 percent of restaurant customers use coupons (the figure varies substantially depending on the type of restaurant included.).

Universities have so many grants, scholarships, and loans that in many universities *most* of the students have some sort of “deal”; this is revenue management for the university.

These yield management techniques are designed to appeal to various market segments. And the pervasiveness of the techniques proves that it does work.

From the customer’s perspective there is often resentment at sitting next to someone on the airplane who has paid half as much for the same flight as you paid—or going to a restaurant and having the customer who arrived 15 minutes earlier than you or who has a coupon, pay half the price for the same meal. A sense of fairness suggests that something is wrong and some customers resent the difference.

2. Most customers have come to accept yield management and take full advantage of the opportunities it affords. The multiple pricing of yield management by definition satisfies more customers (customers use the services) and the firm utilizes resources more effectively.
3. Many customers do take exception to the variation in pricing—different prices for the same service seem inherently wrong to many people and management need to be prepared for the irate customer.
4. Some customers will manipulate the system by booking tickets on flights that have a stop over in a city they travel to, but which has a higher fare than the destination flight. They exit the plane at the stopover city—saving money. For instance, if the flight from New York to Chicago is less than the flight to the stopover city—say Pittsburgh, a customer can book the flight to Chicago but get off in Pittsburgh. You might ask students to discuss the ethics of this manipulation.

And, of course, customers use the system by finding the positions on the yield management curve that works for them. Sometimes this means shopping for tickets weeks in advance and taking the risk of a change

in plans, or going to the restaurant early, or finding and using those discount coupons. How much work do you want to do for a discount? It turns out that some people will not do the work necessary to use the system to their advantage.

ACTIVE MODEL EXERCISE

ACTIVE MODEL 13.1: Aggregate Planning

1. Each worker makes five units per day. If the number of workers is reduced from 10 to 9, dropping the daily capacity, what happens to the cost?

The cost actually drops to \$54,465. This is due to drops in the amount of inventory that is maintained.

2. What regular time level minimizes the total cost?
39 units

3. How low can the regular daily capacity get before overtime will be required?
At 22 units per day (4.4 workers), overtime is required.

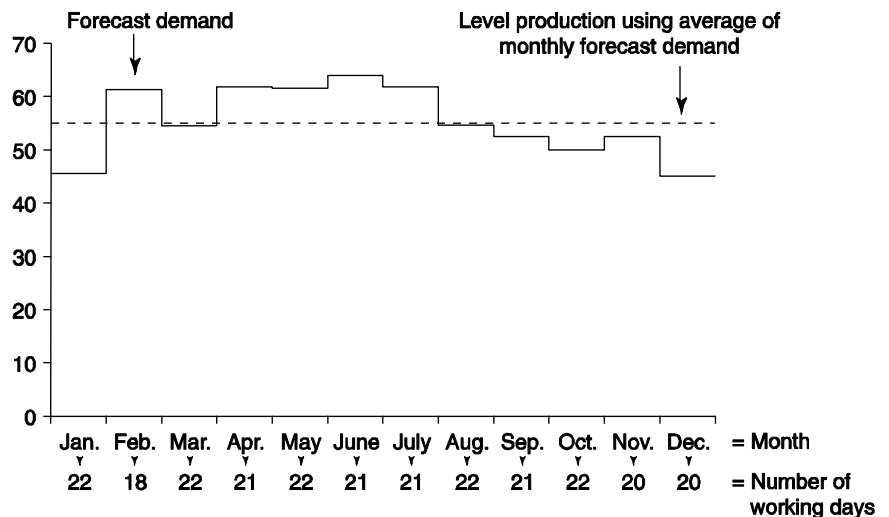
4. How low can the regular daily capacity get before there will not be enough capacity to meet the demand?
At 12 units per day (2.4 workers), demand cannot be met.

END-OF-CHAPTER PROBLEMS

13.1

Month	Production Days	Forecast Demand	Needed Production Each Day
Jan	22	1,000	45.5
Feb	18	1,100	61.1
Mar	22	1,200	54.5
Apr	21	1,300	61.9
May	22	1,350	61.4
Jun	21	1,350	64.3
July	21	1,300	61.9
Aug	22	1,200	54.5
Sep	21	1,100	52.4
Oct	22	1,100	50.0
Nov	20	1,050	52.5
Dec	20	900	45.0
	252	13,950	55.4

(on average)



13.2 (a) Plan 5

Month	Expected Demand	Production Days	Demand Per Day
Jan	900	22	41
Feb	700	18	39
Mar	800	21	38
Apr	1,200	21	57
May	1,500	22	68
Jun	1,100	20	55
	6,200	124	

$$\text{Average daily production requirement} = \frac{6,200}{124} = 50 \text{ units/day}$$

Constant workforce of 6 persons; subcontract to meet extra demand: Subcontract cost = \$20/unit

$$\text{Production rate/day} = \text{Persons} \times \frac{\text{Hours/day}}{\text{Hours/unit}} = 6 \times \frac{8}{1.6} = 30 \text{ units/day}$$

Month	Expected Demand	Production (@ 30/day)	Subcontract
Jan	900	660	240
Feb	700	540	160
Mar	800	630	170
Apr	1,200	630	570
May	1,500	660	840
Jun	1,100	600	500
			2,480

Plan 5 Cost analysis:
Regular production:

$$C_R = 6 \text{ persons} \times \$80 \times 124 = \$59,520$$

Subcontract cost @ \$10/unit:

$$C_{SC} = 2,480 \text{ units} \times \$20/\text{unit} = \$49,600$$

Total cost:

$$C_T = \$59,520 + \$49,600 = \$109,120 \text{ (not preferable to Plan 2 at } \$105,152, \text{ but preferable to Plan 4 at } \$113,488).$$

(b) Plan 6 Constant workforce of 7 persons; subcontract to meet extra demand: Labor → 1.6 hours/unit

$$\text{Production rate/day} = \text{Persons} \times \frac{\text{Hours/day}}{\text{Hours/unit}} = 7 \times \frac{8}{1.6} = 35 \text{ units/day}$$

Month	Expected Demand	Production (@ 35/day)	Subcontract
Jan	900	770	130
Feb	700	630	70
Mar	800	735	65
Apr	1,200	735	465
May	1,500	770	730
Jun	1,100	700	400
			1,860

Plan 6 Cost analysis:

Regular production:

$$C_R = 7 \text{ persons} \times \$80 \times 124 = \$69,440$$

Subcontracting:

$$C_{SC} = 1,860 \text{ units} \times \$20 = \$37,200$$

Total cost:

$$C_T = 69,440 + 37,200 = \$106,640$$

Plan 2 is still preferable, but Plan 6 has lower cost than Plan 5.

Comparing:

	Plan 1	Plan 2	Plan 3	Plan 4	Plan 5	Plan 6
Carrying cost	9,250	0	0	400	0	0
Reg. time	99,200	75,392	99,200	79,360	59,520	69,440
Overtime	0	0	0	33,728	49,600	0
Subcont.	0	29,870	0	0	0	37,200
Hire	0	0	9,000	0	0	0
Layoff	0	0	9,600	0	0	0
Total cost	108,450	105,152	117,800	113,488	109,120	106,640

Based simply upon total cost, Plan 2 is preferable. From a practical viewpoint, Plans 1, 5, and 6 will likely have equivalent costs. Practical implementation of Plan 2 may, for example, require the employment of eight full-time employees, rather than seven full-time and one part-time employee. When several plans have roughly equivalent costs, other parameters gain importance—such as the amount of control one would have over production and excess wear on equipment and personnel. Plan 3 should be avoided.

13.3

Period	Expected Demand
1	1,400
2	1,600
3	1,800
4	1,800
5	2,200
6	2,200
7	1,800
8	1,400
	14,200

13.3 (cont'd)

Plan A						
Period	Demand	Production (Result of Previous Month)	Inventory (Units)	Stockout (Units)	Hire (Units)	Layoff Personnel (Units) Cost
1 (Jan)	1,400	1,600	400			200 \$15,000 ←(cost to go from 1,600 in Jan to 1,400 in Feb)
2 (Feb)	1,600	1,400	200		200	10,000 ←(cost to go from 1,400 in Feb to 1,600 in Mar)
3 (Mar)	1,800	1,600			200	10,000
4 (Apr)	1,800	1,800				—
5 (May)	2,200	1,800		400	400	20,000
6 (June)	2,200	2,200				—
7 (July)	1,800	2,200	400			400 30,000
8 (Aug)	1,400	1,800	800			400 30,000 ←(cost to go from 1,800 in August to 1,400 in Sept)
			1,800	\$400	Total	\$115,000
			@ \$20	@ \$100	Personnel Cost:	
			=\$36,000	=\$40,000		

Note: December demand was 1,600, and because our strategy is chasing prior-period demand, our January production is 1,600. So 200 units remain in inventory, and January production adds 200 units to this inventory, for a total of 400 units. Inventory units: Jan. 400 + Feb. 200 + July 400 + Aug. 800 (400 from July and 400 from August) = 1,800 units at \$20 = \$36,000. Stockout units: May 400 units at \$100 = \$40,000. Hiring and layoff costs = \$115,000. Total costs = \$36,000 + \$40,000 + \$115,000 = \$191,000.

13.4

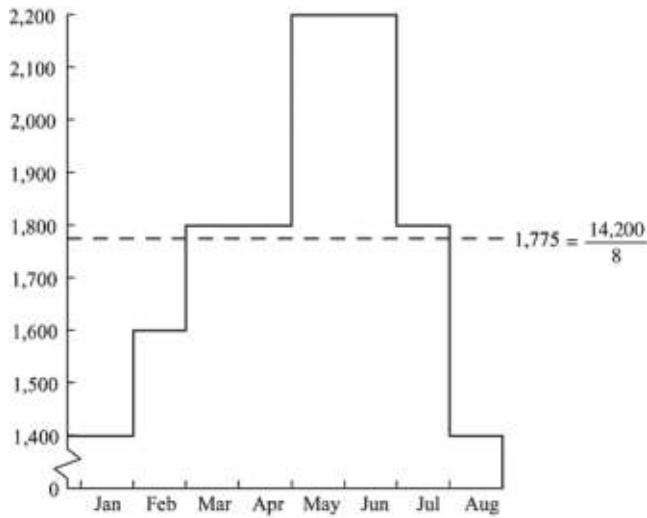
Plan B					
Period	Demand	Production	Ending Inv.	Subcon (Units)	Extra Cost
0			200		
1	1,400	1,400	200	—	\$4,000
2	1,600	1,400	0	—	—
3	1,800	1,400	0	400	30,000
4	1,800	1,400	0	400	30,000
5	2,200	1,400	0	800	60,000
6	2,200	1,400	0	800	60,000
7	1,800	1,400	0	400	30,000
8	1,400	1,400	0	—	—
					Total Extra Cost: \$214,000

13.5 (a)

Plan C					
Period	Demand	Production*	Ending Inv.	Stockouts (Units)	Extra Cost
0			200		
1	1,400	1,775	575		\$11,500
2	1,600	1,775	750		15,000
3	1,800	1,775	725		14,500
4	1,800	1,775	700		14,000
5	2,200	1,775	275		5,500
6	2,200	1,775	0	150	15,000
7	1,800	1,775	0	25	2,500
8	1,400	1,775	375		7,500
					Total Extra Cost: \$85,500

*(14,200/8) = 1,775 average. All other things being equal, it would appear that Plan C, with a cost of \$85,500 and stockout costs ignored, should be recommended over Plan A (cost = \$224,000) or Plan B (cost = \$214,000).

(b) Graph of Plan C



13.6 (a) Plan D: Maximum units in overtime = $0.20 \times 1,600 = 320$

Plan D						
Period	Demand	Reg. (Units)	O.T. (Units)	End Inv. (Units)	Stockouts (Units)	Extra Cost
0				200		
1	1,400	1,600	—	400		\$8,000
2	1,600	1,600	—	400		8,000
3	1,800	1,600	—	200		4,000
4	1,800	1,600	—	—		0
5	2,200	1,600	320	—	280	44,000
6	2,200	1,600	320	—	280	44,000
7	1,800	1,600	200	—		10,000
8	1,400	1,600	—	200		4,000
						Total Extra Cost: \$122,000

Noting that the additional cost of a stockout is much greater than the sum of the additional costs for overtime plus inventory storage, one might “look ahead” and *schedule overtime* where possible. The resulting aggregate plan would be:

Period	Demand	Reg. (Units)	O.T. (Units)	End Inv. (Units)	Stockouts (Units)	Extra Cost
0				200		
1	1,400	1,600	—	400		\$8,000
2	1,600	1,600	—	400		8,000
3	1,800	1,600	80	280		9,600
4	1,800	1,600	320	400		24,000
5	2,200	1,600	320	120		18,400
6	2,200	1,600	320	—	160	32,000
7	1,800	1,600	200	—		10,000
8	1,400	1,600	—	200		4,000
						Total Extra Cost: \$114,000

(b)

Plan E					
Period	Demand	Production	Subcont (Units)	Ending Inv.	Extra Cost
0				200	
1	1,400	1,600		400	\$8,000
2	1,600	1,600		400	8,000
3	1,800	1,600		200	4,000
4	1,800	1,600			0
5	2,200	1,600	600		45,000
6	2,200	1,600	600		45,000
7	1,800	1,600	200		15,000
8	1,400	1,600		200	4,000
					Total Extra Cost: \$129,000

All other things being equal, it would appear that Plan D, with a cost of \$122,000, should be recommended over Plan E (cost = \$129,000).

Note that of all the plans discussed, it would appear that Plan C, with a cost of \$85,500, should be recommended over all others.

13.7

Month	Expected Demand
Jul	400
Aug	500
Sep	550
Oct	700
Nov	800
Dec	700

Production per person per day: 8 hr/person ÷ 4 hours/disk

Therefore, each person can produce 2 disks per day, or 40 disks per month.

(a) Aggregate plan, hiring/layoff only:

Period	Unit Demand	Beg. Inventory Over (or Short)	Units Required	Hours Required at 4 each	Personnel Required at 20 days at 8 hrs	Personnel on staff	Units Produced	Production Over (or Short)	Hire \$40	Layoff \$80	Costs
											Hire: 40
Jun		150				8					
Jul	400	150	250	1,000	6.25	6	240	-10		2	\$160
Aug	500	-10	510	2,040	12.75	13	520	10*	7		\$280
Sep	550	10	540	2,160	13.50	14	560	20*	1		\$40
Oct	700	20	680	2,720	17.00	17	680	0	3		\$120
Nov	800	0	800	3,200	20.00	20	800	0	3		\$120
Dec	700	0	700	2,800	17.50	17	680	-20		3	\$240
											Total Cost: \$960

* Inventory (August = 10 and Sept. = 20) = 30 × 8 = \$240

Inventory Cost = 30 × 8 = \$240

Hiring/Layoff Cost = $\frac{960}{3,200}$
\$1,200

Note: In computing cost, we assumed that, if the capacity of a fraction of a worker was needed (was excess), one worker was hired (laid off). Solution by POM for Windows, in which the increase cost is \$1 per unit and the decrease cost is \$2 per unit, yields a similar result, with a total extra cost of \$890.

(b) Aggregate plan, overtime only:

Period	Demand	Production (Regular)	Production (Overtime)	Ending Inv.	Inventory Holding Cost @ \$8/unit/month
Jun				150	
Jul	400	320		70	560
Aug	500	320	110		
Sep	550	320	230		
Oct	700	320	380		
Nov	800	320	480		
Dec	700	320	380		
				Total 1,580	\$560

$1,580 \times (\$72 - \$48) = \$37,920 = \text{Extra total (OT) cost} + \$560 \text{ holding cost} = \$38,480$

↑ ↑ ↙
Units made on \$72 = 4 hr \$48 = 4 hr
overtime (OT) each × \$18 each × \$12

13.8 Calculating added costs for various planning options to complement Problem 13.7:

- Holding: \$8/unit/month
- Subcontracting: \$80/unit
- Overtime: \$24/unit (\$18/hour over 8 hours:
\$72 – \$48 = \$24)
- Hiring: \$1/unit
- Layoff: \$2/unit

Your strategy is one that involves hiring 5 workers in August and 5 more in October, as follows:

Period	Unit Demand	Beg. Inventory Over (or Short)	Units Required	Hours Required at 4 each	Personnel Required at 20 days at 8 hrs	Personnel on staff	Units Produced	Production			Costs Inventory = \$8 Hire: 40 Layoff: 80
								Over (or Short)	Hire \$40	Layoff \$80	
Jun		150				8					
Jul	400	150	250	1,000	8.00	8	320	70		0	\$560 = (70 × 8)
Aug	500	70	430	1,720	13.00	13	520	90	5		\$920 = (90 × 8) + 200
Sep	550	90	460	1,840	13.00	13	520	60	0		\$480 = (60 × 8)
Oct	700	60	640	2,560	18.00	18	720	80	5		\$840 = (80 × 8) + 200
Nov	800	80	720	2,880	18.00	18	720	0	0		—
Dec	700	0	700	2,800	18.00	18	720	20	0	0	\$160 = (20 × 8)
Total Extra Cost: \$2,960											

Students should be encouraged to consider the long-range implications of any aggregate planning strategy involving planned hiring/firing with respect to the development of an appropriate labor pool, etc.

13.9

Month	Expected Demand
Jul	1,000
Aug	1,200
Sep	1,400
Oct	1,800
Nov	1,800
Dec	1,600

- (a) Plan A: Minimum rate of 1,000/month, subcontract for additional.

Plan A					
Period	Demand	Production	Ending Inv.	Subcont. (Units)	Extra Cost
Jul	1,000	1,000	0	—	0
Aug	1,200	1,000	0	200	12,000
Sep	1,400	1,000	0	400	24,000
Oct	1,800	1,000	0	800	48,000
Nov	1,800	1,000	0	800	48,000
Dec	1,600	1,000	0	600	36,000
Total Extra Cost: \$168,000					

Plan B: Vary workforce.

Plan B					
Period	Demand	Production (Existing)	Hire (Units)	Layoffs (Units)	Extra Cost
Jul	1,000	1,300	—	300	\$18,000
Aug	1,200	1,000	200		6,000
Sep	1,400	1,200	200		6,000
Oct	1,800	1,400	400		12,000
Nov	1,800	1,800	—		—
Dec	1,600	1,800	—	200	12,000
Total Extra Cost:					\$54,000

(b) Plan B is best because of cost. But note that production is only 8,500 units.

13.10 (a)

Plan C					
Period	Demand	Production (Units)	Subcont. (Units)	Ending Inv.	Extra Cost
Jun				300	
Jul	1,000	1,300		600	\$15,000
Aug	1,200	1,300		700	17,500
Sep	1,400	1,300		600	15,000
Oct	1,800	1,300		100	2,500
Nov	1,800	1,300	400	0	24,000
Dec	1,600	1,300	300	0	18,000
Total Extra Cost:					\$92,000

(b) Plan D: Maximum units in overtime = $0.20 \times 1,300 = 260$

Plan D							
Month	Demand	Reg. (Units)	O.T. (Units)	End Inv.	Subcont. Units	Idle Time (Units)	Extra Cost
Jul	1,000	1,300		180		120	\$11,700
Aug	1,200	1,300		180		100	10,500
Sep	1,400	1,300		80			2,000
Oct	1,800	1,300	260	0	160		20,000
Nov	1,800	1,300	260	0	240		24,800
Dec	1,600	1,300	260	0	40		12,800
Total Extra Cost:							\$81,800

If our object in comparing the plans is to identify the elements of an optimal plan, we must consider the following:

Plans A, B, and D begin with zero initial inventory, Plan C begins with an initial inventory of 300 units. It is therefore inappropriate to compare directly the results of Plan C with those of Plans A, B, and D.

In addition, we can assume that the warehouse constraint introduced in Plan D would have affected the costs of Plan A and Plan C had it been in effect in those plans.

What one can say is that the aggregate planning options should be utilized as available, in the following order:

- Carryover of inventory: \$25/unit
- Overtime: \$40/unit

- Hiring: \$30/unit
- Layoff: \$60/unit
- Subcontracting: \$60/unit
- Stockout: \$100/unit

13.11 Initial data:

Costs (per unit)		Initial inventory	=	0
Reg Time	= \$ 30	Units last period	=	1,500
Overtime	= \$15extra per unit			
Subcontract	= not available			
Holding	= 10			
Stockout	= 50			
Hiring	= 40			
Layoffs	= 80			

(a) The Chase plan:

Period	Demand	Reg. Time Production	Change	Hiring	Layoffs
Quarter 1	1,400	1,400	-100	0	100
Quarter 2	1,200	1,200	-200	0	200
Quarter 3	1,500	1,500	300	300	0
Quarter 4	1,300	1,300	-200	0	200
Total	5,400	5,400		300	500
Cost		@\$30/unit \$162,000		@\$40/unit \$12,000	@\$80/unit \$40,000
Total Cost:	\$214,000				

Overtime production = \$0

Subcontract = \$0 and

Inventory holding and shortage cost = \$0

(b) The Level plan:

Period	Demand	Reg. Time Production	Inventory	Holding	Shortage	Change	Hiring	Layoffs
Quarter 1	1,400	1,350	-50	0	50	-150	0	150
Quarter 2	1,200	1,350	100	100	0	0	0	0
Quarter 3	1,500	1,350	-50	0	50	0	0	0
Quarter 4	1,300	1,350	0	0	0	0	0	0
Total	5,400*	5,400		100	100		0	150
Cost		\$162,000		\$1,000	\$5,000		\$0	\$12,000
Total Cost:	\$180,000							

* $(5,400/4) = 1,350 =$ average demand.

(c) A Level plan will cost \$180,000, while a Chase plan will cost \$214,000.

13.12 Initial data:

Costs (per case)	Initial inventory = 0	Quarter	Forecast Demand
Reg time = \$30	Production last period = 1300	1	1,800 cases
Overtime = 45		2	1,100 cases
Subcontract = 60		3	1,600 cases
Holding = 40		4	900 cases
Stockout = 150			
Hiring = 40			
Layoff = 80			

(a) Plan A: Chase plan

Period	Demand	Reg. Time Production	Change	Hiring (Increase)	Layoffs (Decrease)
Quarter 1	1,800	1,800	500	500	0
Quarter 2	1,100	1,100	-700	0	700
Quarter 3	1,600	1,600	500	500	0
Quarter 4	900	900	-700	0	700
Total	5,400	5,400		1,000	1,400
Cost		\$162,000		\$40,000	\$112,000
Total Cost:	\$314,000				

(b) Plan B: Level Strategy of 1,350 cases

Period	Forecast	Reg. Time Production	Inventory	Holding	Shortage	Change	Hiring (Increase)	Layoffs (Decrease)
Quarter 1	1,800	1,350	-450	0	450	50	50	0
Quarter 2	1,100	1,350	-200	0	200	0	0	0
Quarter 3	1,600	1,350	-450	0	450	0	0	0
Quarter 4	900	1,350	0	0	0	0	0	0
Total	5,400	5,400		0	1,100		50	0
Cost		\$162,000		\$0	\$165,000		\$2,000	\$0
Total Cost: \$329,000								

An alternative way of viewing this problem assigns the same costs to regular time production and to hiring (i.e., \$162,000 and \$2,000) but places holding cost at \$28,000 and shortage cost at \$67,500. Total cost is then \$259,500.

(c) Plan C: Level Strategy at 1200, plus subcontracting:

Period	Forecast	Reg. Time Production	Overtime Production	Subcontract Production	Inventory	Holding	Change	Hiring (Increase)	Layoffs (Decrease)
Quarter 1	1,800	1,200		600	0	0	-100	0	100
Quarter 2	1,100	1,200			100	100	0	0	0
Quarter 3	1,600	1,200		300	0	0	0	0	0
Quarter 4	900	1,200			300	300	0	0	0
Total	5,400	4,800	0	900		400		0	100
Cost		\$144,000	\$0	\$54,000		\$16,000		\$0	\$8,000
Total Cost: \$222,000									

(d, e) The boss implements Plan C because it is not only the lowest cost, but has the added advantage of providing steady employment for the employees after the initial first quarter layoff.

13.13 Assuming that back orders are not permitted, the solution is:

To/From	Demand Period 1	Demand Period 2	Demand Period 3	Excess	Supply
Initial Inventory	0	4	8	0	20
Reg. Time Period 1	100	104	108	0	30
Overtime Period 1	150	154	158	0	10
Subcont. Period 1	200	204	208	0	5
Reg. Time Period 2	∞	100	104	0	35
Overtime Period 2	∞	150	154	0	12
Subcont. Period 2	∞	200	204	0	5
Reg. Time Period 3	∞	∞	100	0	30
Overtime Period 3	∞	∞	150	0	10
Subcont. Period 3	∞	∞	200	0	5
Demand	40	50	40	32	

Total cost = \$11,790

13.14 Assuming that back orders are not permitted, the solution is:

To From	Demand Month 1	Demand Month 2	Demand Month 3	Demand Month 4	Excess	Supply
Reg. Time Month 1	985 235	1,085	1,185	1,285	0	235
Overtime Month 1	1,310 20	1,410	1,510	1,610	0	20
Subcont. Month 1	1,500	1,600	1,700	1,800	0 12	12
Reg. Time Month 2	∞	985 255	1,085	1,185	0	255
Overtime Month 2	∞	1,310 24	1,410	1,510	0	24
Subcont. Month 2	∞	1,500 15	1,600	1,700	0	15
Reg. Time Month 3	∞	∞	985 290	1,085	0	290
Overtime Month 3	∞	∞	1,310 26	1,410	0	26
Subcont. Month 3	∞	∞	1,500 5	1,600	0 10	15
Reg. Time Month 4	∞	∞	∞	985 300	0	300
Overtime Month 4	∞	∞	∞	1,310 1	0 23	24
Subcont. Month 4	∞	∞	∞	1,500	0	17
Demand	255	294	321	301	62	

Total cost = \$1,186,810

13.15 Assuming that back orders are not permitted, the solution is:

To From	Demand Month 1	Demand Month 2	Demand Month 3	Demand Month 4	Excess	Supply
Initial Inventory	0 500	4	8	12	0	500
Reg. Time Month 1	70 1,100	74 400	78	82	0	1,500
Overtime Month 1	110 400	114	118	122	0	400
Subcont. Month 1	120	124	128	132	0 600	600
Reg. Time Month 2	∞	70 1,600	74	78	0	1,600
Overtime Month 2	∞	110 400	114	118	0	400
Subcont. Month 2	∞	120 100	124	128	0 500	600
Reg. Time Month 3	∞	∞	70 750	74	0	750
Overtime Month 3	∞	∞	110 200	114	0	200
Subcont. Month 3	∞	∞	120 550	124	0 50	600
Reg. Time Month 4	∞	∞	∞	70 1,600	0	1,600
Overtime Month 4	∞	∞	∞	110 400	0	400
Subcont. Month 4	∞	∞	∞	120 100	0 500	600
Demand	2,000	2,500	1,500	2,100	1,150	

Total cost = \$627,100

An alternative solution is:

To From	Demand Month 1	Demand Month 2	Demand Month 3	Demand Month 4	Excess	Supply
Initial Inventory	0 500	4	8	12	0	500
Reg. Time Month 1	70 1,500	74	78	82	0	1,500
Overtime Month 1	110	114 400	118	122	0	400
Subcont. Month 1	120	124	128	132	0 600	600
Reg. Time Month 2	∞	70 1,600	74	78	0	1,600
Overtime Month 2	∞	110 400	114	118	0	400
Subcont. Month 2	∞	120 100	124	128	0 500	600
Reg. Time Month 3	∞	∞	70 750	74	0	750
Overtime Month 3	∞	∞	110 200	114	0	200
Subcont. Month 3	∞	∞	120 550	124	0 50	600
Reg. Time Month 4	∞	∞	∞	70 1,600	0	1,600
Overtime Month 4	∞	∞	∞	110 400	0	400
Subcont. Month 4	∞	∞	∞	120 100	0 500	600
Demand	2,000	2,500	1,500	2,100	1,150	

Total cost = \$627,100

13.16 Assuming that back orders are not permitted, the solution is:

To From	Jan 1	Feb 2	Mar 3	Apr 4	May 5	Jun 6	Excess	Supply
Reg. Time Jan	12 700	13	14	15	16	17	0	800
Overtime Jan	16 300	17	18	19	20	21	0	300
Reg. Time Feb	∞	12 800	13	14	15	16	0	800
Overtime Feb	∞	16 300	17	18	19	20	0	300
Reg. Time Mar	∞	∞	12 800	13	14	15	0	800
Overtime Mar	∞	∞	16 300	17	18	19	0	300
Reg. Time Apr	∞	∞	∞	12 800	13	14	0	800
Overtime Apr	∞	∞	∞	16 300	17	18	0	300
Reg. Time May	∞	∞	∞	∞	11 1,100	12	0	1,100
Overtime May	∞	∞	∞	∞	16 300	17	0 100	400
Reg. Time Jun	∞	∞	∞	∞	∞	11 1,100	0	1,100
Overtime Jun	∞	∞	∞	∞	∞	16 300	0 100	400
Subcont.	18.5	18.5	18.5 150	18.5 350	18.5	18.5	0	500
Demand	1,000	1,200	1,250	1,450	1,400	1,400	200	

Total cost = \$100,750

13.17 (a) The cost matrix and the optimal plan are shown below:

Cost Matrix:	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Ending Inv.	Supply
Beg. inv.	0.2	0.4	0.6	0.8	1	250
Reg. time 1	1	1.2	1.4	1.6	1.8	400
Overtime 1	1.5	1.7	1.9	2.1	2.3	80
Subcontract 1	2	2.2	2.4	2.6	2.8	100
Reg. time 2	1.5	1	1.2	1.4	1.6	400
Overtime 2	2	1.5	1.7	1.9	2.1	80
Subcontract 2	2.5	2	2.2	2.4	2.6	100
Reg. time 3	2	1.5	1	1.2	1.4	800
Overtime 3	2.5	2	1.5	1.7	1.9	160
Subcontract 3	3	2.5	2	2.2	2.4	100
Reg. time 4	2.5	2	1.5	1	1.2	400
Overtime 4	3	2.5	2	1.5	1.7	80
Subcontract 4	3.5	3	2.5	2	2.2	100
Demand	500	750	900	450		2600/3050

Optimal Plan:	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Ending Inv.	Dummy
Beg. inv.	100	150				
Reg. time 1	400					
Overtime 1		80				
Subcontract 1						100
Reg. time 2		400				
Overtime 2		80				
Subcontract 2						100
Reg. time 3			800			
Overtime 3		40	100			20
Subcontract 3						100
Reg. time 4				400		
Overtime 4				50		30
Subcontract 4						100
	500	750	900	450		

Optimal cost = \$2,641

- (b) The cost of the optimal plan is \$2,641. Alternate optimal solutions are possible.
- (c) All regular time is used.
- (d) 40 units are backordered in Quarter 2 and produced on overtime in Quarter 3 at a cost of \$.50 each for a total cost of \$20.

13.18 Assuming that back orders are not permitted, one solution, of multiple optional solutions, is:

From \ To	Demand 1	Demand 2	Demand 3	Demand 4	Demand 5	End Inv	(Dummy) Excess	Supply
Subcont.	135	135	135	135	135	135	0	100
Reg. Time 1	150	103	106	109	112	115	0	150
Overtime 1	125	128	131	134	137	140	0	20
Reg. Time 2	∞	150	103	106	109	112	0	150
Overtime 2	∞	10	128	131	134	137	0	20
Reg. Time 3	∞	∞	130	103	106	109	0	150
Overtime 3	∞	∞	10	128	131	134	0	10
Reg. Time 4	∞	∞	∞	150	103	106	0	150
Overtime 4	∞	∞	∞	10	128	131	0	10
Reg. Time 5	∞	∞	∞	∞	150	103	0	150
Overtime 5	∞	∞	∞	∞	10	128	0	10
Demand	150	160	130	200	210	20	50	

Total cost = \$90,850

Note: Ending inventory of 20 units held to period 6 each require the additional carrying cost of \$3 if produced on regular or overtime. Because they are optimally produced by subcontracting (which is available, at any time), no additional carrying cost is incurred.

13.19 (a) Method → Produce to demand (let workforce vary)

Shortages: Lost sales — Shortages not carried from month to month

Month	Demnd	Capacities			\$1,000	\$1,300	\$1,800	\$200	\$0	\$0	\$0
		Regtm	Ovrtm	Subcon	Regtm	Ovrtm	Subcon	Holdng	Shortg	Increase	Decrease
Init	0	0	0	0							
Jan	255	235	20	12	235	20	0	0	0	0	0
Feb	294	255	24	16	255	24	15	0	0	20	0
Mar	321	290	26	15	290	26	5	0	0	35	0
Apr	301	300	24	17	300	1	0	0	0	10	0
May	330	300	30	17	300	30	0	0	0	0	0
June	320	290	28	19	290	28	2	0	0	0	10
July	345	300	30	19	300	30	15	0	0	10	0
Aug	340	290	30	20	290	30	20	0	0	0	10
Tot	2,506	2,260	212	135	2,260	189	57	0	0	75	20
Subtotal Costs					2,260,000	245,700	102,600	0	0	0	0

Summary Table		
Type	Units	Cost
Regtm	2,260	\$2,260,000
Ovrtm	189	\$245,700
Subcon	57	\$102,600
Holdng	0	\$0
Shortg	0	\$0
Increase	75	\$0
Decrease	20	\$0
Total cost = \$2,608,300		

(b) Method → Produce to demand (let workforce vary)

Shortages: Lost sales — Shortages not carried from month to month

All pds →		Capacities			\$1,000	\$1,300	\$1,800	\$200	\$0	\$0	\$0
Month	Demnd	Regtm	Ovrtm	Subcon	Regtm	Ovrtm	Subcon	Holdng	Shortg	Increase	Decrease
Init	0	0	0	0							
Jan	255	275	20	12	255	0	0	0	0	0	0
Feb	294	275	24	16	275	19	0	0	0	20	0
Mar	321	275	26	15	275	26	15	0	5	0	0
Apr	301	275	24	17	275	24	2	0	0	0	0
May	330	275	30	17	275	30	17	0	8	0	0
June	320	275	28	19	275	28	17	0	0	0	0
July	345	275	30	19	275	30	19	0	21	0	0
Aug	340	275	30	20	275	30	20	0	15	0	0
Tot	2,506	2,200	212	135	2,180	187	90	0	49	20	0
Subtotal Costs					2,180,000	243,100	162,000	0	0	0	0

Summary Table		
Type	Units	Cost
Regtm	2,180	\$2,180,000
Ovrtm	187	\$243,100
Subcon	90	\$162,000
Holdng	0	\$0
Shortg	49	\$0
Increase	20	\$0
Decrease	0	\$0
Total cost = \$2,585,100, or about \$50,000 savings		

(c) Method → Produce to demand (let workforce vary)

Shortages: Lost sales — Shortages not carried from month to month

All months →		Capacities			\$1,000	\$1,400	\$1,800	\$200	\$0	\$0	\$0
Month	Demnd	Regtm	Ovrtm	Subcon	Regtm	Ovrtm	Subcon	Holdng	Shortg	Increase	Decrease
Init	0	0	0	0							
Jan	255	235	20	12	235	20	0	0	0	0	0
Feb	294	255	24	16	255	24	15	0	0	20	0
Mar	321	290	26	15	290	26	5	0	0	35	0
Apr	301	300	24	17	300	1	0	0	0	10	0
May	330	300	30	17	300	30	0	0	0	0	0
June	320	290	28	19	290	28	2	0	0	0	10
July	345	300	30	19	300	30	15	0	0	10	0
Aug	340	290	30	20	290	30	20	0	0	0	10
Tot	2,506	2,260	212	135	2,260	189	57	0	0	75	20
Subtotal Costs					2,260,000	264,600	102,600	0	0	0	0

Summary Table—Overtime Costs: \$1400		
Type	Units	Cost
Regtm	2,260	\$2,260,000
Ovrtm	189	\$264,600
Subcon	57	\$102,600
Holdng	0	\$0
Shortg	0	\$0
Increase	75	\$0
Decrease	20	\$0
Total cost = \$2,627,200		

There is no change in the solution other than higher cost.

Method → Produce to demand (let workforce vary)

Shortages: Lost sales — Shortages not carried from month to month

All months →		Capacities			\$1,000	\$1,200	\$1,800	\$200	\$0	\$0	\$0
Month	Demnd	Regtm	Ovrtm	Subcon	Regtm	Ovrtm	Subcon	Holdng	Shortg	Increase	Decrease
Init	0	0	0	0							
Jan	255	235	20	12	235	20	0	0	0	0	0
Feb	294	255	24	16	255	24	15	0	0	20	0
Mar	321	290	26	15	290	26	5	0	0	35	0
Apr	301	300	24	17	300	1	0	0	0	10	0
May	330	300	30	17	300	30	0	0	0	0	0
June	320	290	28	19	290	28	2	0	0	0	10
July	345	300	30	19	300	30	15	0	0	10	0
Aug	340	290	30	20	290	30	20	0	0	0	10
Tot	2,506	2,260	212	135	2,260	189	57	0	0	75	20
Subtotal Costs					\$2,260,000	\$226,800	\$102,600	0	0	0	0

Summary Table—Overtime Costs: \$1,200		
Type	Units	Cost
Regtm	2,260	\$2,260,000
Ovrtm	189	\$226,800
Subcon	57	\$102,600
Holdng	0	\$0
Shortg	0	\$0
Increase	75	\$0
Decrease	20	\$0
Total cost = \$2,589,400		

Again there is no change in the solution other than a lower cost.

13.20 (a, b) Aggregate plan and its costs

Month	Estimated Billable hours	CPAs	Reg. time billable hours	Reg. Time cost	“Overtime” hours	Overtime cost	Forrester hours	Forrester cost
Jan	600	4	640	\$20,000	0	\$0	0	0
Feb	500	4	640	\$20,000	0	\$0	0	\$0
Mar	1,000	4	640	\$20,000	320	\$20,000	40	\$5,000
Apr	1,200	4	640	\$20,000	320	\$20,000	240	\$30,000
May	650	4	640	\$20,000	10	\$625	0	\$0
June	590	4	640	\$20,000	0	\$0	0	\$0
				\$120,000	650	\$40,625	280	\$35,000

Total cost = \$120,000 + \$40,625 + \$35,000 = \$195,625

- (c) The accounting business, as everyone recognizes, has one extremely busy season (during March and April tax preparation time), and several less hectic but still very active months (such as when quarterly payments are due). Could another CPA be justified at \$60,000 per year in salary? Based solely on savings in overtime costs and the cost of Forrester, it would appear to be unclear, as savings total only \$30,625. On the other hand, current employees are drawing overtime pay of \$40,000 (averaging \$10,000 each) during March and April, and may be very unhappy over the loss of income. We would have to carefully examine the other 6 months to see if hiring is merited.

13.21 (a)

Month	Estimated Billable hours	CPAs	Reg. Time Billable Hours	Reg. Time Cost	Overtime Hours	Overtime Cost	Forrester Hours	Forrester Cost
Jan	660	5	800	\$25,000	0	\$0	0	\$0
Feb	550	5	800	\$25,000	0	\$0	0	\$0
Mar	1,100	5	800	\$25,000	300	\$18,750	0	\$0
Apr	1,320	5	800	\$25,000	400	\$25,000	120	\$15,000
May	715	5	800	\$25,000	0	\$0	0	\$0
June	649	5	800	\$25,000	0	\$0	0	\$0
				\$150,000	700	\$43,750	120	\$15,000

Total cost = \$150,000 + \$43,750 + \$15,000 = \$208,750

- (b) With the increase in business, 5 accountants appear to be necessary. There is still a need for overtime during the tax season (about the same as in Problem 13.20), but there is a big savings in Forrester's pay (which is double that of overtime for a regular employee). What Cohen needs to do is find additional accounting activities that his staff can work on during the "off-peak" season.

13.22 (a) Current model—Single price at Southeastern Airlines

$$\begin{aligned} \text{Sales} &= 80 \text{ passengers} \times (\text{Net price/seat}) \\ &= 80 \times (\$140 - 25) = \$9,200 \end{aligned}$$

(b) Proposed model—two price points

$$\begin{aligned} \text{Sales} &= 65 \text{ passengers} \times (\$80 - \$25) + 35 \text{ passengers} \times (\$190 - \$25) \\ &= (65)(\$55) + (35)(\$165) \\ &= \$3,575 + \$5,775 \\ &= \$9,350 \end{aligned}$$

The new approach is only slightly better in terms of sales but provides a more complicated ticketing system. The issue of fairness is always paramount.

ADDITIONAL HOMEWORK PROBLEMS

Here are solutions to additional homework problems (13.23–13.26) that appear on our Web site, at www.myomlab.com.

13.23 The intent of the authors is that this problem be solved using the transportation problem format. Assuming that back orders are not permitted, the solution is:

To From	Demand Month 1	Demand Month 2	Demand Month 3	Excess	Supply
Reg. Time Month 1	5 1,000	6	7	0	1,000
Overtime Month 1	7 200	8	9	0	200
Subcont. Month 1	8 50	9	10	0 100	150
Reg. Time Month 2	∞	5 1,000	6	0	1,000
Overtime Month 2	∞	7 200	8	0	200
Subcont. Month 2	∞	8 50	9	0 100	150
Reg. Time Month 3	∞	∞	5 1,000	0	1,000
Overtime Month 3	∞	∞	7 200	0	200
Subcont. Month 3	∞	∞	8 50	0 100	150
Demand	1,250	1,250	1,250	300	

Total cost = \$20,400

13.24 Assuming that back orders are not permitted, the solution is:

To From	Demand April	Demand May	Demand June	Excess	Supply
Beginning Inventory	0 50	4	8	0	50
Reg. Time April	100 2,880	104	108	0	2,880
Overtime April	140 70	144	148	0 285	355
Reg. Time May	∞	100 2,750	104 30	0	2,780
Overtime May	∞	140	144	0 315	315
Reg. Time June	∞	∞	100 2,760	0	2,760
Overtime June	∞	∞	140 160	0 145	305
Demand	3,000	2,750	2,950	745	

Total cost = \$874,320

13.25 Even though back orders are permitted, note they are not used. One of the multiple optimal solutions is:

To From	Demand 1	Demand 2	Demand 3	Demand 4	End Inv	Excess	Supply
Initial Inventory	0 4	200	400	600	800	0	4
Reg. Time 1	2,000 25	2,200	2,400	2,600	2,800	0	25
Overtime 1	2,475 3	2,675 2	2,875	3,075	3,275	0	5
Subcont. 1	3,200	3,400	3,600	3,800	4,000	0 6	6
Reg. Time 2	2,600	2,000 28	2,200	2,400	2,600	0	28
Overtime 2	3,075	2,475 2	2,675 2	2,875	3,075	0	4
Subcont. 2	3,800	3,200	3,400	3,600	3,800	0 6	6
Reg. Time 3	3,200	2,600	2,000 30	2,200	2,400	0	30
Overtime 3	3,675	3,075	2,475 8	2,675	2,875	0	8
Subcont. 3	4,400	3,800	3,200	3,400 1	3,600	0 5	6
Reg. Time 4	3,800	3,200	2,600	2,000 29	2,200	0	29
Overtime 4	4,275	3,675	3,075	2,475 6	2,675	0	6
Subcont. 4	5,000	4,400	3,800	3,200 4	3,400 3	0	7
Demand	32	32	40	40	3	17	

Total cost = \$308,125

Note: Ending inventory of 3 units held to period 5 each require the additional carrying cost of \$200. You may wish to convey this hint to students when assigning the problem.

13.26 Costs (per refrigerator)

Reg time	= \$48 = 4 hr × \$12/hr.
Overtime	= 72 = 4 hr × \$18/hr.
Subcontract	= 80
Holding	= 8
Stockout	= 0
Hiring	= 40
Layoff	= 80

Forecast	Demand
Jan	400
Feb	500
Mar	550
Apr	700
May	800
June	700

Initial inventory	250
Units last period	320

(a)

Period	Reg Time		Inventory	Holding	Shortage	Change	Increase	Decrease
	Demand	Production						
Jan	400	400	250	250	0	80	80	0
Feb	500	500	250	250	0	100	100	0
Mar	550	550	250	250	0	50	50	0
Apr	700	700	250	250	0	150	150	0
May	800	800	250	250	0	100	100	0
June	700	700	250	250	0	-100	0	100
Total	3650	3650		1500	0		480	100
Cost		\$175,200		\$12,000	\$0		\$19,200	\$8,000
Total Cost	\$214,400							

- (b) Each employee produces 2 units per day. So,
 $2 \times 10 \text{ employees} \times 20 \text{ days} = 400 \text{ units per period}$

Period	Forecast Demand	Reg Time Production	Inventory	Holding	Shortage	Change	Increase	Decrease
Jan	400	400	250	250	0	80	80	0
Feb	500	400	150	150	0	0	0	0
Mar	550	400	0	0	0	0	0	0
Apr	700	400	-300	0	300	0	0	0
May	800	400	-700	0	700	0	0	0
June	700	400	-1000	0	1000	0	0	0
Total	3650	2400		400	2000		80	0
Cost		\$115,200		\$3,200	\$0		\$3,200	\$0
Total Cost	\$121,600							

- (c) Plan B is certainly less expensive, but over the six months Bell Refrigeration has a shortage of 2000 refrigerators . . . about half of its sales. The loss suggests this is *not* a good plan

CASE STUDIES

1 SOUTHWESTERN UNIVERSITY: G

This case provides the student with quantitative information to develop an aggregate capacity plan, but, as often occurs in services, demand is so variable that there are not many viable staffing alternatives. Students may also be frustrated by the lack of detailed data on the nature of service demand and the resources required to meet demand. Even with these drawbacks, the student should be able to gain insight into the aggregate planning problem and help the chief justify his personnel requests. Students may want to talk with the police department at their own university to see how it handles similar problems.

- Which variations in demand for police services should be considered in an aggregate plan for resources? Which variations can be handled with short-term scheduling adjustments?
 An aggregate plan should set full-time staffing levels; estimate part-time and overtime needs for budget purposes; determine times of the year for training, vacations, and other nonessential duties; and establish an agreed-upon level of police services for the university community (i.e., What role is the police officer to play? What response time to calls for service is appropriate? What services should be provided?). Short-term scheduling adjustments can be made for different days of the week, shifts, and special events.
- Evaluate the current staffing plan. What does it cost? Are 26 officers sufficient to handle the normal workload?

Cost of current staffing plan:

<i>Salaries:</i>		
26 officers × \$28,000 per year	=	\$728,000
<i>Overtime:</i>		
2,400 hours per year × \$18 per hour	=	\$43,200
<i>Subcontractors:</i>		
40 officers × 9 hours × \$18 per hour × 5 football games per year	=	\$32,400
25 part-timers × 9 hours × \$9 per hour × 5 football games per year	=	\$10,125
		<u>\$813,725</u>

Normal workload during fall and spring semesters:

	Weekday	Weekend	7-day Average
1st shift	5	4	4.7
2nd shift	5	6	5.3
3rd shift	6	8	<u>6.6</u>
			16.6

Number of 24-hour positions each week = $16.6/3 = 5.5$

Number of persons required = 5.5 positions
 × 5 persons/position
 = 27.6 persons

Normal workload during the summer:

	Weekday	Weekend	7-day Average
1st shift	2.5	2	2.4
2nd shift	2.5	3	2.7
3rd shift	3	4	<u>3.3</u>
			8.4

Number of 24-hour positions each week = $8.4/3 = 2.8$

Number of persons required = 2.8 positions × 5 persons/position
 = 14 persons

Twenty-six officers is more than enough to handle the normal workload during the three summer months. However, during the remaining nine months of the year, the police department is almost two persons short. Obviously, some overtime is currently being used to meet the demands of the normal workweek.

- What would be the additional cost of the chief's proposal? How would you suggest that the chief justify his request?

Salary: 4 officers × \$28,000 per year = \$112,000

Overtime: no additional cost, as subcontracting and overtime costs are the same.

To justify his proposal, the chief should point out that two positions (representing \$56,000) are needed to pursue the university's request for more crime prevention, safety, and health programs. The other two positions could save up to \$18,720 in overtime premiums (total OT of 2,400 hours minus football game OT of 1,360 hours times \$18 per hour) and are needed to maintain the desired level of police services. On a per hour basis, the salaried services are more cost effective than using overtime or subcontracting (@ \$18/hour).

4. How much does it currently cost the university to provide police services for football games? What would be the pros and cons of subcontracting this work completely to outside law enforcement agencies?

Cost of police officers for football games:

18 officers work 8 hours overtime @ \$18/hr
 8 officers work 16 hours overtime @ \$18/hr
 40 outside officers work 9 hours @ \$18/hr
 25 part-timers work 9 hours @ \$9/hr
 5 football games per year

$$\begin{aligned} \text{Cost} &= [(18 \times 8 \times 18) + (8 \times 16 \times 18) + (40 \times 9 \times 18) \\ &\quad + (25 \times 9 \times 9)] \times 5 \\ &= [2,592 + 2,304 + 6,480 + 2,025] \times 5 \\ &= [13,401] \times 5 = \$67,005 \end{aligned}$$

Subcontracting security for football games would relieve the weary campus police and allow them to perform their normal duties more effectively. However, football security is highly visible, and the absence of campus police may hurt their image in the university community and rob them of the opportunity to work closely with law enforcement personnel from agencies in a noncrisis situation. It may also be difficult for the university to maintain the same level of control over subcontracted work, especially in terms of discretionary treatment of students and alumni.

In terms of cost, it is doubtful that the work could be subcontracted as cheaply as it is currently performed because the cost of supervisory and managerial personnel would have to be included in the package (and currently no supervisors or managers are paid overtime for their work).

5. Can you propose any other alternatives?

Many of the innovative suggestions for handling the variability in demand for services involve using part-time workers. Police officers require extensive training, so this alternative usually means hiring off-duty police officers from other agencies. Under these circumstances, the hours that off-duty officers can moonlight are limited, and, except for football Saturdays, may be hard to schedule (i.e., all part-time agencies are busy at the same time). Another way to handle part-time or seasonal requirements for work is to find complementary work for the full-time employees that follows a different demand pattern. In this case, the nonpeak period for police services falls during the summer months. What other university services increase during those months? Perhaps the idled officers could be used as campus guides during summer orientation, as aides for the summer camps and other summer programs held on campus, or as part of the grounds crew. At least one small private college utilizes its police officers in this expanded fashion. It certainly increases the officers' involvement with the university community.

2 ANDREW-CARTER, INC.

This case presents some of the basic concepts of aggregate planning by the transportation method. The case involves solving a

rather complex set of transportation problems. Four different configurations of operating plants have to be tested. The solutions, although requiring relatively few iterations to optimality, involve degeneracy if solved manually.

The costs are:

Configuration	Total Variable Cost	Total Fixed Cost	Total Cost
All plants operating	\$179,730	\$41,000	\$220,730
1 & 2 operating, 3 closed	188,930	33,500	222,430
1 & 3 operating, 2 closed	183,430	34,000	217,430
2 & 3 operating, 1 closed	188,360	33,000	221,360

The lowest weekly total cost, operating plants 1 and 3 with 2 closed, is \$217,430. This is \$3,300 per week (\$171,600 per year) or 1.5% less than the next most economical solution, operating all 3 plants. Closing a plant without expanding capacity of the remaining plants means unemployment. The optimum solution, using plants 1 and 3, indicates overtime production of 4,000 units at 3 and 0 overtime at 1. The all-plant optima have no use of overtime and include substantial idle regular time capacity: 11,000 units (55%) in plant 2 and either 5,000 units in 1 (19% of capacity) or 5,000 in 3 (20% of capacity). The idled capacity versus unemployment question is an interesting, nonquantitative aspect of the case and could lead to discussion of the forecasts for the housing market and thus the plant's product.

The optimum producing and shipping pattern is:

From	To (Amount)
Plant 1 (R.T.)	W2 (13,000); W4 (14,000)
Plant 3 (R.T.)	W1 (5,000); W3 (11,000); W4 (1,000); W5 (8,000)
Plant 3 (O.T.)	W1 (4,000)

There are three alternative optimal producing and shipping patterns.

Getting the solution manually should not be attempted. It will take eight tableaux to do the "All Plants" configuration, with degeneracy appearing in the seventh tableau; the "1 & 2" configuration takes five tableaux, etc. It is strongly suggested that POM for Windows, Excel, or other software be used.

ADDITIONAL CASE STUDY*

CORNWELL GLASS

Entering the data provided into software, then toggling the pure strategies and trying them yields the following costs:

Plan 1 (smooth production): \$849,077
 Plan 2 (meet demand exactly): \$104,575
 Plan 3 (produce 1,900 as base, then use
 OT and subcontracting): \$82,858

At this point, the question is, can we do better with trial and error? A better solution follows.

* This case is found on our Companion Web site, www.pearsonhighered.com/heizer.

Note: December demand was 1,600, because our strategy is chasing prior-

Aggregate Planning												
Time periods 52												
Shortages: Back orders—Carry shortages from period to period												
All pds →		1,900	0	0	\$0	\$8.00	\$10	\$0.12	\$20.0	\$5.63	\$15.73	
		Schedule						Units				
Pd	Demnd	Regtm	Ovrtm	Subcon	Regtm	Ovrtm	Subcon	Holdng	Shortg	Incrs	Decres	
Init	73	1,900	0	0								
April 15	1,829	1,900	250	0	1,900	250	0	394	0	0	0	
22	1,820	1,900	250	0	1,900	250	0	724	0	0	0	
29	1,887	1,900	250	0	1,900	250	0	987	0	0	0	
May 6	1,958	1,900	250	0	1,900	250	0	1,179	0	0	0	
13	2,011	1,900	250	0	1,900	250	0	1,318	0	0	0	
20	2,063	1,900	250	0	1,900	250	0	1,405	0	0	0	
27	2,104	1,900	250	0	1,900	250	0	1,451	0	0	0	
June 3	2,161	1,900	250	0	1,900	250	0	1,440	0	0	0	
10	2,258	1,900	250	0	1,900	250	0	1,332	0	0	0	
17	2,307	1,900	250	0	1,900	250	0	1,175	0	0	0	
24	2,389	1,900	250	0	1,900	250	0	936	0	0	0	
July 1	2,434	1,900	250	0	1,900	250	0	652	0	0	0	
8	2,402	1,900	250	0	1,900	250	0	400	0	0	0	
15	2,385	1,900	250	0	1,900	250	0	165	0	0	0	
22	2,330	1,900	250	15	1,900	250	15	0	0	0	0	
29	2,323	1,900	250	173	1,900	250	173	0	0	0	0	
Aug. 5	2,317	1,900	250	167	1,900	250	167	0	0	0	0	
12	2,222	1,900	250	72	1,900	250	72	0	0	0	0	
19	2,134	1,900	234	0	1,900	234	0	0	0	0	0	
26	2,065	1,900	165	0	1,900	165	0	0	0	0	0	
Sept. 2	1,973	1,900	73	0	1,900	73	0	0	0	0	0	
9	1,912	1,900	12	0	1,900	12	0	0	0	0	0	
16	1,854	1,900	0	0	1,900	0	0	46	0	0	0	
23	1,763	1,900	0	0	1,900	0	0	183	0	0	0	
30	1,699	1,900	0	0	1,900	0	0	384	0	0	0	
Oct. 7	1,620	1,900	0	0	1,900	0	0	664	0	0	0	
14	1,689	1,900	0	0	1,900	0	0	875	0	0	0	
21	1,754	1,900	0	0	1,900	0	0	1,021	0	0	0	
28	1,800	1,900	207	0	1,900	207	0	1,328	0	0	0	
Nov. 4	1,864	1,900	250	0	1,900	250	0	1,614	0	0	0	
11	1,989	1,900	250	0	1,900	250	0	1,775	0	0	0	
18	2,098	1,900	250	0	1,900	250	0	1,827	0	0	0	
25	2,244	1,900	250	0	1,900	250	0	1,733	0	0	0	
Dec. 2	2,357	1,900	250	0	1,900	250	0	1,526	0	0	0	
9	2,368	1,900	250	0	1,900	250	0	1,308	0	0	0	
16	2,387	1,900	250	0	1,900	250	0	1,071	0	0	0	
23	2,402	1,900	250	0	1,900	250	0	819	0	0	0	
30	2,418	1,900	250	0	1,900	250	0	551	0	0	0	
Jan. 6	2,417	1,900	250	0	1,900	250	0	284	0	0	0	
13	2,324	1,900	250	0	1,900	250	0	110	0	0	0	
20	2,204	1,900	250	0	1,900	250	0	56	0	0	0	
27	2,188	1,900	250	0	1,900	250	0	18	0	0	0	
Feb. 3	2,168	1,900	250	0	1,900	250	0	0	0	0	0	
10	2,086	1,900	186	0	1,900	186	0	0	0	0	0	
17	1,954	1,900	54	0	1,900	54	0	0	0	0	0	
24	1,877	1,900	0	0	1,900	0	0	23	0	0	0	
Mar. 3	1,822	1,900	0	0	1,900	0	0	101	0	0	0	
10	1,803	1,900	0	0	1,900	0	0	198	0	0	0	
17	1,777	1,900	0	0	1,900	0	0	321	0	0	0	
24	1,799	1,900	0	0	1,900	0	0	422	0	0	0	
31	1,803	1,900	0	0	1,900	0	0	519	0	0	0	
Apr. 7	1,805	1,900	0	0	1,900	0	0	614	0	0	0	
Total	107,544	98,800	8,931	427	98,800	8,931	427	32,949	0	0	0	
					Subtotal Costs →	0	71,448	4,270	3,953.9	0	0	0

Total cost = \$79,671.88