SCREENSHOT 3-13   Excel Layout and Solver Entries for Loughry Group Mall

	A	B	C	D	E	F	G	H	I	J	K	L
1	**Loughry Group Mall**											
2												
3		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8			
4		Sat & Sun off	Sat & Tue off	Tue & Wed off	Mon & Thu off	Tue & Fri off	Thu & Fri off	Sun & Thu off	Sun & Wed off			
5	Number of staff	10.00	7.00	20.00	0.00	0.00	0.00	0.00	3.00			
6	Wages	$350	$375	$400	$425	$425	$400	$375	$375	$15,250.00		
7	Constraints:											
8	Monday needs	1	1	1		1	1	1	1	40.00	>=	22
9	Tuesday needs	1			1		1	1	1	13.00	>=	13
10	Wednesday needs	1	1		1	1	1	1		17.00	>=	15
11	Thursday needs	1	1	1		1			1	40.00	>=	20
12	Friday needs	1	1	1	1			1	1	40.00	>=	18
13	Saturday needs			1	1	1	1	1	1	23.00	>=	23
14	Sunday needs		1	1	1	1	1			27.00	>=	27
15	75% consecutive	1		1			1			30.00	>=	30
16	50% weekend day	1	1					1	1	20.00	>=	20
17										LHS	Sign	RHS

Solver Parameters ? X

Set Target Cell: $J$6

Equal To: ◯ Max ⦿ Min ◯ Value of: 0

By Changing Cells:
$B$5:$I$5

Subject to the Constraints:
$J$8:$J$16 >= $L$8:$L$16

Solve
Close
Guess
Options
Add

Constraints in rows 15 and 16 include formulas on both LHS and RHS.

All nine ≥ constraints entered as a single entry in Solver.

The solution indicates that while exactly meeting staffing needs for Tuesday, Saturday, and Sunday, Mark is left with way more than he needs on Monday, Thursday, and Friday. He should perhaps consider using part-time help to alleviate this mismatch in his staffing needs.

PROBLEMS

3-1   Winkler Furniture manufactures two different types of china cabinets: a French Provincial model and a Danish Modern model. Each cabinet produced must go through three departments: carpentry, painting, and finishing. The following table contains all relevant information concerning production times (hours per cabinet), production capacities for each operation per day, and revenue ($ per unit):

Type	Department			
	Carpentry	Painting	Finishing	Revenue
French Provincial	3	1.5	0.75	$28
Danish Modern	2	1.0	0.75	$25
Capacity (hours)	360	200	125	

The firm has a contract with an Indiana distributor to produce a minimum of 60 cabinets of each type per day.

Owner Bob Winkler would like to determine the product mix that maximizes his daily revenue. Formulate the problem as an LP model and solve it by using Excel.

3-2   Jose Garcia, a budding entrepreneur, has set up a small backpack company and wants to distribute the backpacks exclusively through the local bookstore. There are four models of backpacks: Canvas, Plastic, Nylon, and Leather. The bookstore wants no fewer than 15 and no more than 40 of any one model. The bookstore has agreed to pay Jose $35.50 for each canvas backpack, $39.50 for each plastic backpack, $42.50 for each nylon backpack, and $69.50 for each leather backpack he can deliver by the end of next week.

Jose has three student friends with sewing machines who have agreed to do the sewing for him. One of the students can work on either canvas or plastic, can complete a backpack in 1.5 hours, and will charge $7 per hour to do the work. She can commit to 90 hours of work in the next week. Another student can work on the nylon fabric. He can sew a bag in 1.7 hours, will charge $8 per hour to work, and can work 42.5 hours in the next week. The third student has the ability to sew leather. He can complete a book bag in 1.9 hours, will charge $9 per hour to work, and can work 80 hours during the next week. The following table provides additional information about each backpack:

	CANVAS	PLASTIC	NYLON	LEATHER
Square yards per pack	2.25	2.40	2.10	2.60
Square yards available	200	350	700	550
Cost per square yard	$4.50	$4.25	$7.65	$9.45

What is the best combination of backpacks for Jose to plan to deliver to the bookstore?

3-3   Quitmeyer Electronics Incorporated manufactures six microcomputer peripheral devices: internal modems, external modems, graphics circuit boards, floppy disk drives, hard disk drives, and memory expansion boards. Each of these technical products requires time, in minutes, on three types of electronic testing equipment, as shown in the table at the bottom of this page.

The first two test devices are available 120 hours per week. Test device 3 requires more preventive maintenance and may be used only 100 hours each week. The market for all six computer components is vast, and Quitmeyer Electronics believes that it can sell as many units of each product as it can manufacture. The following table summarizes the revenues and material costs for each product:

DEVICE	REVENUE PER UNIT	MATERIAL COST PER UNIT
Internal modem	$200	$ 35
External modem	$120	$ 25
Graphics circuit board	$180	$ 40
Floppy disk drive	$130	$ 45
Hard disk drive	$430	$170
Memory expansion board	$260	$ 60

In addition, variable labor costs are $15 per hour for test device 1, $12 per hour for test device 2, and $18 per hour for test device 3. Quitmeyer wants to determine the product mix that maximizes profits. Formulate the problem as an LP model and solve it by using Excel.

3-4   A manufacturer of car pillows is determining his production plan for the next month. He wishes to make at least 300 of each of the three models that his firm offers and no more than 1,200 of any one model. The specifics for each model are shown in the table at the top of page 126.

How many pillows of each type should be manufactured in order to maximize total profit?

3-5   Students at Morrison Elementary School are trying to raise funds to send their team to the national "Odyssey of the Mind" competition in Denver, Colorado, next month. A local pizza chain has agreed to sell them pizzas at a discount, which the students can then resell to families in the local community for a profit. It is expected that of the 500 families in the community, at most 70% will buy pizzas. Based on a survey of their personal preferences, the students believe that they should order no more than 120 cheese pizzas, no more than 150 pepperoni pizzas, and no more than 100 vegetarian pizzas. They also want to make sure that at least 20% of the total pizzas are cheese and at least 50% of the pizzas are pepperoni. They make a profit of $1.45, $1.75, and $1.98, respectively, for each cheese, pepperoni, and vegetarian pizza they resell. How many pizzas of each type should they buy?

3-6   Bob Bell's 40th birthday party promises to be the social event of the year in Cookeville. To prepare, Bob stocks up on the following liquors:

LIQUOR	AVAILABLE OUNCES
Bourbon	64
Brandy	38
Vodka	70
Dry vermouth	30
Sweet vermouth	40

Bob decides to mix four drinks for the party: Chaunceys, Sweet Italians, bourbon on the rocks, and Russian martinis. A Chauncey consists of 25% bourbon, 25% brandy, 25% vodka, and 25% sweet vermouth. A Sweet Italian contains 25% brandy, 25% dry vermouth, and 50% sweet vermouth. Bourbon on the

ime Requirements for Problem 3-3

	INTERNAL MODEM	EXTERNAL MODEM	CIRCUIT BOARD	FLOPPY DRIVE	HARD DRIVE	MEMORY BOARD
Test device 1	7	3	12	6	18	17
Test device 2	2	5	3	2	15	17
Test device 3	5	1	3	2	9	2

Table for Problem 3-4

| | SELLING PRICE | TIME REQUIRED PER PILLOW (HOURS) | | | |
		CUTTING	SEWING	FINISHING	PACKING
Junior Travel Pillow	$5.75	0.10	0.05	0.18	0.20
Travel Pillow	$6.95	0.15	0.12	0.24	0.20
Deluxe Travel Pillow	$7.50	0.20	0.18	0.20	0.20
Available hours		450	550	600	450
Cost per hour		$7.00	$9.00	$8.50	$7.25

rocks contains only bourbon. Finally, a Russian martini consists of 75% vodka and 25% dry vermouth. Each drink contains 4 fluid ounces.

Bob's objective is to mix these ingredients in such a way as to make the largest possible number of drinks in advance. Formulate Bob's problem as an LP model and solve it by using Excel.

3-7 A manufacturing company produces three different types of valves: V412, V512, and V612. It has a firm order from Acme Inc. for 2,000 V412 valves, 3,750 V512 valves, and 1,700 V612 valves. Between now and when the order is due to be delivered, it has 16,500 fabrication hours and 1,600 inspection hours, which are not enough to manufacture the total quantity ordered. The time required in each department by the various valves is shown in the following table:

VALVE	FABRICATION HOURS	INSPECTION HOURS	IN-HOUSE COST	OUTSOURCE COST
V412	2.50	0.25	$17.00	$20.40
V512	3.40	0.30	$19.00	$21.85
V612	3.80	0.45	$23.00	$25.76

Also shown are the costs to manufacture the valves in-house and the costs to outsource them. For labeling considerations, the company wants to manufacture in-house at least 60% of each type of valve that will be shipped to Acme.

How many valves of each type should be made in-house, and how much should be outsourced? What will be the total cost to produce Acme's order?

3-8 John's Gear Company is planning next week's production run for four types of gears. If necessary, it is possible to outsource any type of gear from Gary's Gears located down the street. For each type of gear, the table at the bottom of this page shows next week's demand, revenue per unit, outsource cost per unit, and time (in hours) required per unit in each production process:

If the hours in the three production departments are not used in making these gears, they can be used for some other products. Gary can supply a maximum of 300 units of each type of gear next week.

What should the production and/or outsource plan be for the next week in order to maximize profit?

3-9 The advertising director for Diversey Paint and Supply, a chain of four retail stores on Chicago's north side, is considering three media possibilities: (1) ads in the Sunday newspaper, (2) ads in a local trade magazine that is distributed free to all houses in the city and northwest suburbs, and (3) ads on a local TV station. The stores are expanding their lines of do-it-yourself tools, and the advertising director is interested in a total new-customer exposure level of at least 40% within the city and 60% in the northwest suburbs.

Each TV ad has a new-customer exposure level of 5% in the city and 3% in the northwest suburbs. The newspaper ads have corresponding exposure levels per ad of 3.5% and 3%, while the trade magazine has corresponding exposure levels per ad of 0.5% and 1%. The relevant costs are $1,000 per newspaper ad, $300 per trade magazine ad, and $2,000 per TV ad. So that all three types of media are used, Diversey would like to ensure that no single medium consumes more than 45% of the total amount spent.

Table for Problem 3-8

| GEAR TYPE | DEMAND | REVENUE | OUTSOURCE | PRODUCTION PROCESS | | |
				FORMING	HARDENING	DEBURRING
G311	400	$12.50	$7.50	0.30	0.20	0.30
G415	500	$15.60	$8.10	0.36	0.30	0.30
G517	450	$17.40	$8.40	0.38	0.24	0.35
G619	600	$19.30	$9.00	0.45	0.33	0.25
			Hours available =	500	300	300
			Cost per hour =	$9.00	$8.00	$7.50

Diversey would like to select the least costly advertising strategy that would meet desired exposure levels. Formulate the problem using LP and solve it by using Excel.

3-10 A polling service is being hired to interview registered voters in a district to gain insight into their opinions about certain issues. Each voter is to be interviewed in person. From experience, the service knows that the costs of interviewing different types of voters vary due to the differences in proportion throughout the population. The costs to interview males, for example, are $10 per Democrat, $9 per Republican, and $13.50 per Independent voter. The costs to interview females are $12, $11, and $13.50 for Democrat, Republican, and Independent voters, respectively. The polling service has been given certain criteria to which it must adhere:

- There must be at least 4,500 total interviews.
- At least 1,000 Independent voters must be polled.
- At least 2,000 males must be polled.
- At least 1,750 females must be polled.
- No more than 40% of those polled may be Democrat.
- No more than 40% of those polled may be Republican.
- No more than one-quarter of those polled may be Republican males.
- Each of the six categories of voters must be represented in the poll by at least 10% of the total interviews.

What is the least expensive sampling plan for the polling service, and what will be the total cost?

3-11 A political candidate is planning his campaign budget for an upcoming election. He has $90,000 to spend. His political consultants have provided him with the following estimates of additional votes as a result of the advertising effort:

- For every small sign placed by the roadside, he will garner 10 additional votes.
- For every large sign placed by the roadside, he will garner 30 additional votes.
- For every 1,000 bumper stickers placed on cars, he will garner 10 additional votes.
- For every 100 personal mailings to registered voters, he will garner 40 additional votes.
- For every ad heard daily in the last month before the election, he will garner 490 additional votes.

The costs for each of these advertising devices, along with the practical minimum and maximum that should be planned for each, are shown in the following table:

ADVERTISING DEVICE	COST	MINIMUM	MAXIMUM
Small roadside sign	$ 25	100	500
Large roadside sign	$ 60	50	300
Bumper stickers (in thousands)	$ 30	40	100
Personal mailings (in hundreds)	$ 82	500	800
Daily radio ads	$1,000	3	12

How should the candidate plan to spend his campaign money?

3-12 A grocery chain wants to promote the sale of a new flavor of ice cream by issuing up to 15,000 coupons by mail to preferred customers. The budget for this promotion has been limited to $12,000. The following table shows the expected increased sales per coupon and the probability of coupon usage for the various coupon amounts under consideration:

COUPON AMOUNT	INCREASED SALES PER COUPON	PROBABILITY COUPON WILL BE USED
$1.00	1.50 cartons	0.80
$0.85	1.40 cartons	0.75
$0.70	1.25 cartons	0.60
$0.55	1.00 carton	0.50
$0.40	0.90 cartons	0.42

For example, every $1 coupon issued will stimulate sales of 1.5 additional cartons. However, because the probability that a $1 coupon will actually be used is only 0.80, the expected increased sales per coupon issued is 1.2 (= 0.8 × 1.5) cartons.

The selling price per carton of ice cream is $3.50 before the coupon value is applied. The chain wants at least 20% of the coupons issued to be of the $1 variety and at least 10% of the coupons issued to be of each of the other four varieties. What is the optimal combination of coupons to be issued, and what is the expected net increased revenue from this promotion?

3-13 I. Kruger Paint and Wallpaper Store is a large retail distributor of the Supertrex brand of vinyl wall coverings. Kruger will enhance its citywide image in Miami if it can outsell other local stores in total number of rolls of Supertrex next year. It is able to estimate the demand function as follows:

Number of rolls of Supertrex sold = 11 × dollars spent on advertising
+ 7 × dollars spent on in-store displays
+ 13 × dollars invested in on-hand wallpaper inventory
− 8,000 × markup taken above wholesale cost of a roll

The store budgets up to $17,000 for advertising, in-store displays, and on-hand inventory of Supertrex for the next year. It decides that at least 20% of the amount spent must be on advertising and at least 35% must be on on-hand inventory. Further, the amount spent on displays must be at least 10% of the amount invested in on-hand inventory. Markups on Supertrex at other local stores range from 20% to 45%. Kruger decides that its markup should be in this range as well. Formulate this problem as an LP model and solve it by using Excel.

3-14 One of its clients has just instructed the Heinlein and Krampf brokerage firm to invest $250,000 that she obtained recently through the sale of land holdings in Ohio. The client has a good deal of trust in the firm, but she also has her own ideas about the distribution of the funds being invested. In particular, she requests that the firm select whatever stocks and bonds it believes are well rated, but within the following guidelines:

- Municipal bonds, nursing home stock, and drug company stock should constitute at least 20%, 10%, and 10%, respectively, of the total amount invested.
- At least 40% of the funds should be placed in a combination of electronics and aerospace firms, with each accounting for at least 15%.
- No more than 50% of the total amount invested in electronics and aerospace firms should be placed in a combination of nursing home and drug company stock, both of which carry high risk.

Subject to these restraints, the client's goal is to maximize projected return on investments. The analysts at Heinlein and Krampf, aware of these guidelines, prepare a list of high-quality stocks and bonds and their corresponding rates of return:

Investment	Projected Rate of Return
Los Angeles municipal bonds	5.3%
Thompson Electronics, Inc.	6.8%
United Aerospace Corp.	4.9%
Palmer Drugs	8.4%
Happy Days Nursing Homes	11.8%

Formulate this portfolio selection problem using LP and solve it by using Excel.

3-15 An investor wishes to invest some or all of his $12.5 million in a diversified portfolio through a commercial lender. The types of investments, the expected interest per year, and the maximum allowed percentage investment he will consider include the following:

Investment	Expected Interest	Maximum Allowed
Low-income mortgage loans	7.00%	20%
Conventional mortgage loans	6.25%	40%
Government sponsored mortgage loans	8.25%	25%
Bond investments	5.75%	12%
Stock investments	8.75%	15%
Futures trading	9.50%	10%

The investor also wants at least 35% of his investments to be in non-mortgage instruments and no more than 60% to be in high-yield instruments (i.e., expected interest > 8%) that carry high risk. How should his investment be diversified to make the most interest income?

3-16 Clara Carter has just inherited $175,000 from her recently deceased grandfather. She would like to place some or all of this money in a portfolio of several different types of investments to improve the probability that she will be able to safely earn the most interest income.

Clara's mother believes that some of the investments she is considering are risky. These include international mutual funds, which should earn 12.25% over the next year, and U.S. stocks, which should earn 11.5% over the next year. Clara has therefore decided that she will put no more than 30% of her money in either of these investments and no more than a total of 50% in both investments.

Clara's father has cautioned her that she should not tie up all her money in investments that are not liquid, including school bonds, which return 5% interest, certificates of deposit (CD), which return 6.25% interest, and tax-free municipal bonds, which return 8.75%. In response to this, Clara has decided that she will keep a total of no more than 40% of her money in these investments and no more than 15% in any one of these investments.

Both parents are comfortable with investing in T-bills, which are considered liquid and less risky, and will return 7.5%. However, Clara has decided to invest no more than 25% of her investment in T-bills.

Clara does want to try her hand at investing in different types of instruments, so she will invest at least 10% of her money in each of the six types of investment choices. What is the optimal investment strategy for Clara to follow?

3-17 Felix and Maria Roberto have agreed to attend a "casino night" as part of a fundraiser for the local hospital, but they really don't like to gamble. They believe that gambling is generally a losing proposition, but for the sake of the charity, they have decided to attend and to allocate $300 for the games. There are to be four games, each involving standard decks of cards.

The first game, called Jack in 52, is won by selecting a Jack of a specific suit from the deck. The probability of actually doing this is, of course, 1 in 52 (= 0.0192). Gamblers may place a bet of $1, $2, or $4 on this game. If they win, the payouts are $12 for a $1 bet, $24.55 for a $2 bet, and $49 for a $4 bet.

The second game, called Red Face in 52, is won by selecting from the deck a red face card (i.e., red Jack, red Queen, or red King). The probability of winning is 6 in 52 (= 0.1154). Again, bets may be placed in denominations of $1, $2, and $4. Payouts are $8.10, $16.35, and $32.50, respectively.

The third game, called Face in 52, is won by selecting 1 of the 12 face cards from the deck. The probability of winning is 12 in 52 (= 0.2308). Payouts are $4, $8.15, and $16 for $1, $2, and $4 bets, respectively.

The last game, called Red in 52, is won by selecting a red card from the deck. The probability of winning is 26 in 52 (= 0.50). Payouts are $1.80, $3.80, and $7.50 for $1, $2, and $4 bets, respectively.

Given that they can calculate the expected return (or, more appropriately, loss) for each type of game and level of wager, the Robertos have decided to see if they can minimize their total expected loss by planning their evening using LP. For example, the expected return from a $1 bet in the game Jack in 52 is equal to $0.2308 (= $12 × 1/52 + $0 × 51/52). Because the amount bet is $1, the expected loss is equal to $0.7692 (= $1 − $0.2308). All other expected losses can be calculated in a similar manner.

The Robertos want to appear to be sociable and not as if they are trying to lose as little as possible. Therefore, they will place at least 20 bets (of any value) on each of the four games. Further, they will spend at least $26 on $1 bets at least $50 on $2 bets, and at least $72 on $4 bets. They will bet no more than (and no less than) the agreed-upon $300. What should be the Robertos' gambling plan, and what is their expected loss for the evening?

3-18 The famous Y.S. Chang Restaurant is open 24 hours a day. Waiters and busboys report for duty at 3 A.M., 7 A.M., 11 A.M., 3 P.M., 7 P.M., or 11 P.M., and each works an 8-hour shift. The following table shows the minimum number of workers needed during the six periods into which the day is divided:

PERIOD	TIME	WORKERS REQUIRED
1	3 A.M.−7 A.M.	3
2	7 A.M.−11 A.M.	12
3	11 A.M.−3 P.M.	16
4	3 P.M.−7 P.M.	9
5	7 P.M.−11 P.M.	11
6	11 P.M.−3 A.M.	4

How should Chang schedule his workers so that the total staff required for one day's operation is minimized?

3-19 A nursing home employs attendants who are needed around the clock. Each attendant is paid the same, regardless of when his or her shift begins. Each shift is eight consecutive hours. Shifts begin at 2 A.M., 6 A.M., 10 A.M., 2 P.M., 6 P.M., and 10 P.M. The nursing home has a requirement for the numbers of attendants to be on duty during specific time periods as shown in the table at the bottom of this page.

(a) What is the minimum number of attendants needed to satisfy the nursing home's requirements?
(b) The nursing home would like to use the same number of attendants determined in part (a) but would now like to minimize the total salary paid. Attendants are paid $16 per hour during 8 A.M.–8 P.M. and receive a 25% premium per hour during 8 P.M.–8 A.M. How should the attendants be scheduled?

3-20 Elaine Jones, lab supervisor at St. Jude's Hospital, is considering scheduling her techs to work 12-hour shifts instead of the usual 8-hour shifts. Instead of working five 8-hour days, the lab techs would work three days on, four days off, followed by four days on and three days off, for a total of 84 hours every two weeks. Elaine feels this would be an improved schedule and would serve as a good incentive because it would give the employees more consecutive days off.

Elaine has decided that because the peak demand times in the hospital appear to be between 5 A.M. and 7 A.M., and between 5 P.M. and 7 P.M., she will arrange four 12-hour shifts according to the following table:

Shift	Work Times	Pay Rate/Week
A and A (alt)	5 A.M.–5 P.M.	$756
B and B (alt)	7 A.M.–7 P.M.	$840
C and C (alt)	5 P.M.–5 A.M.	$882
D and D (alt)	7 P.M.–7 A.M.	$924

The shift pay differentials are based on the most and least desirable times to begin and end work. In any one week, techs on shift A might work Sunday through Tuesday, while techs on shift A (alt) would work at the same times, but on Wednesday through Saturday. In the following week, techs on shift A would work Sunday through Wednesday, while techs on shift A (alt) would work the corresponding Thursday through Saturday. Therefore, the same number of techs would be scheduled for shift A as for shift A (alt). The requirements for lab techs during the 24-hour day are as shown in the table at the top of page 130.

Table for Problem 3-19

	6 A.M.–10 A.M.	10 A.M.–2 P.M.	2 P.M.–6 P.M.	6 P.M.–10 P.M.	10 P.M.–2 A.M.	2 A.M.–6 A.M.
Attendants needed	27	9	23	29	22	5

Table for Problem 3-20

	5 A.M. – 7 A.M.	7 A.M. – 5 P.M.	5 P.M. – 7 P.M.	7 P.M. – 5 A.M.
Lab techs needed	10	6	12	8

Table for Problem 3-21

	6 A.M. – 9 A.M.	9 A.M. – NOON	NOON – 3 P.M.	3 P.M. – 6 P.M.	6 P.M. – 9 P.M.
Ticket agents needed	12	20	16	24	12

What is the most economical schedule for the lab techs?

3-21 An airline with operations in San Diego, California, must staff its ticket counters inside the airport. Ticket attendants work six-hour shifts at the counter. There are two types of agents—those who speak English as a first language and those who are fully bilingual (English and Spanish). The requirements for the number of agents are a function of the numbers of people expected to pass through the airline's ticket counters during various hours. The airline believes that the need for agents between the hours of 6 A.M. and 9 P.M. are as in the table above.

Agents begin work either at 6 A.M., 9 A.M., noon, or 3 P.M. The shifts are designated as shifts A, B, C, and D, respectively. It is the policy of the airline that at least half of the agents needed in any time period will speak English as the first language. Further, at least one-quarter of the agents needed in any time period should be fully bilingual.

(a) How many and what type of agents should be hired for each shift to meet the language and staffing requirements for the airline?

(b) What is the optimal hiring plan if English-speaking agents are paid $19 per hour and bilingual agents are paid $23 per hour? Does the total number of agents needed change from that computed in part (a)?

3-22 A small trucking company is determining the composition of its next trucking job. Peter Letmathe, the load master, has his choice of seven different types of cargo, which may be loaded in full or in part. The specifications of the cargo types are shown in the following table:

CARGO TYPE	FREIGHT PER POUND	VOLUME PER POUND (CU. FT.)	POUNDS AVAILABLE
A	$4.00	3.0	200
B	$6.00	2.7	150
C	$3.50	6.3	90
D	$5.75	8.4	120
E	$9.50	5.5	190
F	$5.25	4.9	340
G	$8.60	3.1	250

Peter's goal is to maximize the amount of freight he can charge for the trip. The truck can hold up to 800 pounds of cargo in a 2,255-cubic-foot space.

What cargo should Peter load, and what will be the total freight that he will be able to charge?

3-23 The load master for a freighter wants to determine the mix of cargo to be carried on the next trip. The ship's volume limit for cargo is 100,000 cubic meters, and its weight capacity is 2,310 tons. The master has five different types of cargo from which to select and wishes to maximize the value of the selected shipment. However, to make sure that none of his customers are ignored, the master would like to make sure that at least 20% of each cargo's available weight is selected. The specifications for the five cargoes are shown in the following table:

CARGO TYPE	TONS AVAILABLE	VALUE PER TON	VOLUME PER TON (CU. M.)
A	970	$1,350	26
B	850	$1,675	54
C	1,900	$1,145	28
D	2,300	$ 850	45
E	3,600	$1,340	37

What mix of cargo should the load master carry on the next trip?

3-24 A cargo transport plane is to be loaded to maximize the revenue from the load carried. The plane may carry any combination and any amount of cargoes A, B, and C. The relevant values for these cargoes are shown in the following table:

CARGO TYPE	TONS AVAILABLE	REVENUE PER TON	VOLUME PER TON (CU. FT.)
A	10	$780	2,000
B	12	$570	3,500
C	17	$630	3,000

The plane can carry as many as 32 tons of cargo. The plane is subdivided into compartments, and there is a weight and volume limitation for each compartment. It is critical for safety reasons that the weight ratios be strictly observed. The requirements

for cargo distribution are shown in the following table:

Compartment	Maximum Volume (cu. ft.)	Compartment Weight/Total Weight Ratio
Right fore	16,000	Must equal 18% of total weight loaded
Right center	20,000	Must equal 25% of total weight loaded
Right aft	14,000	Must equal 7% of total weight loaded
Left fore	10,000	Must equal 18% of total weight loaded
Left center	20,000	Must equal 25% of total weight loaded
Left aft	12,000	Must equal 7% of total weight loaded

Which cargoes should be carried, and how should they be allocated to the various compartments?

3-25 The owner of a private freighter is trying to decide which cargo he should carry on his next trip. He has two choices of cargo, which he can agree to carry in any combination. He may carry up to 15 tons of cargo A, which takes up 600 cubic feet per ton and earns revenue of $80 per ton. Or, he may carry up to 54 tons of cargo B, with a volume of 450 cubic feet per ton and revenue of $65 per ton.

The freighter is divided into two holds, starboard and port. The starboard hold has a volume of 14,000 cubic feet and a weight capacity of 26 tons. The port hold has a volume of 15,400 cubic feet and a weight capacity of 32 tons. For steering reasons, it is necessary that the weight be distributed equally between the two sides of the freighter. However, the freighter engines and captain's bridge, which together weigh 6 tons, are on the starboard side of the freighter. This means that the port side is usually loaded with 6 tons more cargo to equalize the weight. The owner may carry any combination of the two cargoes in the same hold without a problem. How should this freighter be loaded to maximize total revenue?

3-26 Capitol Hill Construction Company (CHCC) must complete its current office building renovation as quickly as possible. The first portion of the project consists of six activities, some of which must be finished before others are started. The activities, their precedences, and their estimated times are shown in the following table:

Activity	Symbol	Precedence	Time (Days)
Prepare financing options	A	—	2
Prepare preliminary sketches	B	—	3
Outline specifications	C	—	1
Prepare drawings	D	A	4
Write specifications	E	C and D	5
Run off prints	F	B	1

Formulate CHCC's problem as an LP model. Solve it by using Excel to determine the earliest finish time of the entire project. (*Hint:* The decision variables are the earliest start times of the activities.)

3-27 The Grover farm is making plans for next year's planting on its 50-acre land. It is considering planting corn, tomato, potato, and okra. The data the farm has collected, along with the availability of resources, is shown in the table at the bottom of this page.

Determine the best mix of crops to maximize the farm's revenue.

3-28 The Grover farm (see Problem 3-27) has the opportunity to take over the neighboring 80-acre Gupta farm. If Grover acquires this farm, it will be able to increase the amounts of time available to 1,800 hours for planting, 825 hours for tending, and 1,400 hours for harvesting. Between the two farms, there are 510 units of water and 6,000 pounds of fertilizer available. However, Gupta farm has not been cultivated in a while. Therefore, each acre of this farm will take an additional four hours to plant and an additional two hours to tend. Because of the condition of the new farm, Grover expects the yields per acre planted there to be only 46 bushels, 37 bushels, 42 bushels, and 45 bushels, respectively, for corn, tomato, potato, and okra. In order to make sure that both farms are used

Table for Problem 3-27

Crop	Yield (Bushels/Acre)	Revenue/Bushel	Planting Hours/Acre	Tending Hours/Acre	Harvest Hours/Acre	Water (Units/Acre)	Fertilizer (Pounds/Acre)
Corn	50	$55	10	2	6	2.5	50
Tomato	40	$85	15	8	20	3.0	60
Potato	46	$57	12	2	9	2.0	45
Okra	48	$52	18	12	20	3.0	35
Available			770	550	770	300	2,000

effectively, Grover would like at least 80% of each farm's acreage to be planted. What is the best combination of crops to plant at each farm in order to maximize revenue?

3-29 Margaret Young's family owns five parcels of farmland, broken into a southeast sector, a north sector, a northwest sector, a west sector, and a southwest sector. Young is involved primarily in growing wheat, alfalfa, and barley crops and is currently preparing her production plan for next year. The Pennsylvania Water Authority has just announced its yearly water allotment, with the Young farm receiving 7,400 acre-feet. Each parcel can only tolerate a certain amount of irrigation per growing season, as specified in the following table:

Parcel	Area (Acres)	Water Irrigation Limit (Acre-Feet)
Southeast	2,000	3,200
North	2,300	3,400
Northwest	600	800
West	1,100	500
Southwest	500	600

Each of Young's crops needs a minimum amount of water per acre, and there is a projected limit on sales of each crop. Crop data follow:

Crop	Maximum Sales	Water Needed per Acre (Acre-Feet)
Wheat	110,000 bushels	1.6
Alfalfa	1,800 tons	2.9
Barley	2,200 tons	3.5

Young's best estimate is that she can sell wheat at a net profit of $2 per bushel, alfalfa at $40 per ton, and barley at $50 per ton. One acre of land yields an average of 1.5 tons of alfalfa and 2.2 tons of barley. The wheat yield is approximately 50 bushels per acre. Formulate and solve Young's production plan as an LP model.

3-30 Susan has divided her farmland into three plots and wants to plant three crops in each plot: corn, wheat, and soy. Plot sizes, crop acreage, profit per acre, and manure needed (pounds per acre) are given in the following table:

Plot	Acreage	Crop	Maximum Crop Acreage	Profit per Acre	Manure per Acre
A	500	Corn	900	$600	200
B	800	Wheat	700	$450	300
C	700	Soy	1,000	$300	150

The maximum acreage for each crop denotes the total acres of that crop that can be planted over all three plots. Susan currently has 450,000 pounds of manure

available. To ensure that the plots are used equitably, she wants the same proportion of each plot to be under cultivation (i.e., the ratio of acreage cultivated to acreage available must be the same for all three plots). How much of each crop should be planted at each plot to maximize total profit?

3-31 A fuel cell manufacturer can hire union, non-union permanent, or temporary help. She has a contract to produce at the rate of 2,100 fuel cells per day and would like to achieve this at minimum cost. Union workers work seven hours per day and can make up to 10 fuel cells per hour. Their wages and benefits cost the company $15 and $7 per hour, respectively. Union workers are assured that there will be no more than 80% of their number working in non-union permanent positions and that there will be no more than 20% of their number working in temporary positions.

Non-union permanent workers work eight hours per day and can also make up to 10 fuel cells per hour. Their wages are the same as the union employees, but their benefits are worth only $3 per hour.

Temporary workers work six hours per day, can make up to 5 fuel cells per hour, and earn only $10 per hour. They do not receive any benefits.

How many union, non-union, and temporary workers should be hired to minimize the cost to the manufacturer? What is the average cost of a fuel cell?

3-32 A chemical company wishes to mix 3 elements (E, F, and G) to create 3 alloys (X, Y, and Z). The costs of the elements are as follows:

Element	Cost per Ton
E	$3.00
F	$4.00
G	$3.50

To maintain the required quality for each alloy, it is necessary to specify certain maximum or minimum percentages of the elements. These are as follows:

Alloy	Specifications	Selling Price per Ton
X	No more than 30% of E, at least 40% of F, no more than 50% of G	$5.50
Y	No more than 50% of E, at least 10% of F	$4.00
Z	No more than 70% of E, at least 20% of G	$6.00

The usage of each element is limited to 5,000 tons, and the total usage of all three elements is limited to 10,000 tons. Further, due to the relatively uncertain demand for alloy Z, the company would like to ensure that Z constitutes no more than 30% of the total

quantity of the three alloys produced. Determine the mix of the three elements that will maximize profit under these conditions.

3-33 The WoofWoof Store specializes in food products for dogs and other household pets. In developing a new puppy food, company nutritionists have specified that the mixture must contain at least 16% protein, 13% fat, 12% vitamin, and no more than 15% fiber. The percentages of each nutrient in the available ingredients, along with their cost per pound, are shown in the following table:

	INGREDIENT					
NUTRIENT	BEEF	PORK	CORN	LAMB	RICE	CHICKEN
Protein (%)	16.9	12.0	8.5	15.4	8.5	18.0
Fat (%)	26.0	4.1	3.8	6.3	3.8	17.9
Vitamin (%)	19.0	10.2	4.7	3.7	4.2	23.0
Fiber (%)	29.0	8.3	2.7	2.4	2.7	28.8
Cost ($/lb)	0.22	0.19	0.10	0.10	0.07	0.20

What is the mixture that will have the minimum cost per pound and meet the stated nutritional requirements?

3-34 Battery Park Stable feeds and houses the horses used to pull tourist-filled carriages through the streets of Charleston's historic waterfront area. The stable owner, a former racehorse trainer, recognizes the need to set a nutritional diet for the horses in his care. At the same time, he would like to keep the overall daily cost of feed to a minimum. The feed mixes available for the horses' diet are an oat product, a highly enriched grain, and a mineral product. Each of these mixes contains a certain amount of five ingredients needed daily to keep the average horse healthy. The

following table shows these minimum requirements, units of each nutrient per pound of feed mix, and costs for the three mixes:

	FEED MIX			MINIMUM
NUTRIENT	OAT (UNITS/LB.)	GRAIN (UNITS/LB.)	MINERAL (UNITS/LB.)	NEEDED (UNITS/DAY)
A	2.0	3.0	1.0	6
B	0.5	1.0	0.5	2
C	3.0	5.0	6.0	9
D	1.0	1.5	2.0	8
E	0.5	0.5	1.5	5
Cost/lb.	$0.09	$0.14	$0.17	

In addition, the stable owner is aware that an overfed horse is a sluggish worker. Consequently, he determines that 5 pounds of feed per day is the most that any horse needs to function properly.

Formulate this problem and solve for the optimal daily mix of the three feeds.

3-35 Kathy Roniger, campus dietitian for a small Idaho college, is responsible for formulating a nutritious meal plan for students. For an evening meal, she feels that the following five meal-content requirements should be met: (1) between 900 and 1,500 calories; (2) at least 4 milligrams of iron; (3) no more than 50 grams of fat; (4) at least 26 grams of protein; and (5) no more than 50 grams of carbohydrates. On a particular day, Roniger's food stock includes seven items that can be prepared and served for supper to meet these requirements. The cost per pound for each food item and its contribution to each of the five nutritional requirements are given in the following table:

Table for Problem 3-35

	TABLE OF FOOD VALUES AND COSTS					
FOOD ITEM	CALORIES/POUND	IRON (MG/LB.)	FAT (GM/LB.)	PROTEIN (GM/LB.)	CARBOHYDRATES (GM/LB.)	COST/POUND
Milk	295	0.2	16.0	16	22	$0.60
Ground meat	1,216	0.2	96.0	81	0	$2.35
Chicken	394	4.3	9.0	74	0	$1.15
Fish	358	3.2	0.5	83	0	$2.25
Beans	128	3.2	0.8	7	28	$0.58
Spinach	118	14.1	1.4	14	19	$1.17
Potatoes	279	2.2	0.5	8	63	$0.33

*Source: C. F. Church and H. N. Church. *Bowes and Church's Food Values of Portions Commonly Used*, 12/e. Philadelphia: J.B. Lippincott, 1975.

(a) What combination and amounts of food items will provide the nutrition Roniger requires at the least total food cost? Formulate and solve this as an LP problem.

(b) Is this a well-balanced diet? Why or why not?

3-36 Amalgamated Products has just received a contract to construct steel body frames for automobiles that are to be produced at the new Japanese factory in Tennessee. The Japanese auto manufacturer has strict quality control standards for all its component subcontractors and has informed Amalgamated that each frame must have the following steel content:

MATERIAL	MINIMUM	MAXIMUM
Manganese	2.10%	3.10%
Silicon	4.30%	6.30%
Carbon	1.05%	2.05%

Amalgamated mixes batches of eight different available materials to produce 1 ton of steel used in the body frames. The table at the bottom of this page details these materials.

Formulate and solve the LP model and indicate how much of each of the eight materials should be blended into a 1-ton load of steel so that Amalgamated meets its requirements while minimizing costs.

3-37 A meat packing house is creating a new variety of hot dog for the low-calorie, low-fat, low-cholesterol market. This new hot dog will be made of beef and pork, plus either chicken, turkey, or both. It will be marketed as a 2-ounce all-meat hot dog, with no fillers. Also, it will have no more than 6 grams of fat, no more than 27 grams of cholesterol, and no more than 100 calories. The cost per pound for beef, pork, chicken, and turkey, plus their calorie, fat, and cholesterol counts are shown in the following table:

	COST/ POUND	CALORIES/ POUND	FAT G/POUND	CHOLESTEROL G/POUND
Beef	$0.76	640	32.5	210
Pork	$0.82	1,055	54.0	205
Chicken	$0.64	780	25.6	220
Turkey	$0.58	528	6.4	172

The packer would like each 2-ounce hot dog to be at least 25% beef and at least 25% pork. What is the most economical combination of the four meats to make this hot dog?

3-38 A distributor imports olive oil from Spain and Italy in large casks. He then mixes these oils in different proportions to create three grades of olive oil that are sold domestically in the United States. The domestic grades include (a) Commercial, which must be no more than 35% Italian, (b) Virgin, which may be any mix of the two olive oils, and (c) Extra Virgin, which must be at least 55% Spanish. The cost to the distributor for Spanish olive oil is $6.50 per gallon. Italian olive oil costs him $5.75 per gallon. The weekly demand for the three types of olive oils is 700 gallons of Commercial, 2,200 gallons of Virgin, and 1,400 gallons of Extra Virgin.

How should he blend the two olive oils to meet his demand most economically?

3-39 A paint company has two types of bases from which it blends two types of paints: Tuffcoat and Satinwear. Each base has a certain proportion of ingredients X, Y and Z, as shown in the following table, along with their costs:

	INGREDIENT X	INGREDIENT Y	INGREDIENT Z	COST/ GALLON
Paint Base A	25%	34%	10%	$4.50
Paint Base B	35%	42%	15%	$6.50

The specifications for the two paints are as follows:

TUFFCOAT	SATINWEAR
Must contain at least 33% ingredient X	Must contain at least 30% ingredient X
Must contain at least 35% ingredient Y	Must contain at least 38% ingredient Y
Must contain no more than 14% ingredient Z	Must contain no more than 13% ingredient Z
Demand = 1,600 gallons	Demand = 1,250 gallons

Table for Problem 3-36

MATERIAL AVAILABLE	MANGANESE	SILICON	CARBON	POUNDS AVAILABLE	COST PER POUND
Alloy 1	70.0%	15.0%	3.0%	No limit	$0.12
Alloy 2	55.0%	30.0%	1.0%	300	$0.13
Alloy 3	12.0%	26.0%	0%	No limit	$0.15
Iron 1	1.0%	10.0%	3.0%	No limit	$0.09
Iron 2	5.0%	2.5%	0%	No limit	$0.07
Carbide 1	0%	24.0%	18.0%	50	$0.10
Carbide 2	0%	25.0%	20.0%	200	$0.12
Carbide 3	0%	23.0%	25.0%	100	$0.09

How should the two bases be blended to manufacture the two paints at a minimum cost? What is the cost per gallon for each paint?

3-40 The StarvYu Company is designing a new product to appeal to people who want a very high-protein, low-carbohydrate instant canned breakfast. The can will contain 11 fluid ounces, or 325 ml of product. The design specifications are as follows: The drink should have at least 15 grams of protein, no more than 3 grams of fat, no more than 38 grams of carbohydrates, and no more than 310 mg of sodium. To make the drink, StarvYu plans to mix two ingredients it already makes, Liquid A and Liquid B, together with a new ingredient, Liquid Protein. The following table describes the costs and the nutritional content of the three ingredients:

	PROTEIN (G)	FAT (G)	CARBOHYDRATE (G)	SODIUM (MG)	COST/ LITER
Liquid A	6	8	147	1770	$3.25
Liquid B	9	12	96	720	$4.50
Liquid Protein	230	2	24	320	$28.00

COMPOSITION OF THE INGREDIENTS (PER LITER)

Determine the least-cost mixture for the new StarvYu drink.

3-41 Lizard Loaf, food for pet lizards, is made in 40 pound bags from five potential feeds. For labeling purposes, feed A must constitute at least 20% of each bag by weight, and each of feeds B to E must be at least 5% of the total weight. Further, feeds B and D must together constitute at least 30% by weight, and feeds B, C, and E together must be no more than 50% by weight. The costs per pound for feeds A to E are, respectively, $0.960, $0.850, $0.775, $0.450, and $0.375. How shall Lizard Loaf be made, and what is the cost per bag?

3-42 South Central Utilities has just announced the August 1 opening of its second nuclear generator at its Baton Rouge, Louisiana, nuclear power plant. Its personnel department has been directed to determine how many nuclear technicians need to be hired and trained over the remainder of the year.

The plant currently employs 350 fully trained technicians and projects the following personnel needs:

MONTH	PERSONNEL HOURS NEEDED
August	40,000
September	45,000
October	35,000
November	50,000
December	45,000

By Louisiana law, a reactor employee can actually work no more than 130 hours per month. (Slightly over 1 hour per day is used for check-in and check-out, record keeping, and daily radiation health scans.) Policy at South Central Utilities also dictates that lay-offs are not acceptable in those months when the nuclear plant is overstaffed. So, if more trained employees are available than are needed in any month, each worker is still fully paid, even though he or she is not required to work the 130 hours.

Training new employees is an important and costly procedure. It takes one month of one-on-one classroom instruction before a new technician is permitted to work alone in the reactor facility. Therefore, South Central must hire trainees one month before they are actually needed. Each trainee teams up with a skilled nuclear technician and requires 90 hours of that employee's time, meaning that 90 hours less of the technician's time are available that month for actual reactor work.

Personnel department records indicate a turnover rate of trained technicians at 2% per month. In other words, 2% of the skilled technicians at the start of any month resign by the end of that month. A trained technician earns a monthly salary of $4,500, while trainees are paid $2,000 during their one month of instruction.

Formulate this staffing problem using LP and solve it by using Excel.

3-43 A manufacturer of integrated circuits is planning production for the next four months. The forecasted demand for the circuits is shown in the following table:

	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
IC341	650	875	790	1,100
IC256	900	350	1,200	1,300

At the beginning of September, the warehouse is expected to be completely empty. There is room for no more than 1,800 integrated circuits to be stored. Holding costs for both types is $0.05 per unit per month. Because workers are given time off during the holidays, the manufacturer wants to have at least 800 IC341s and 850 IC256s already in the warehouse at the beginning of January.

Production costs are $1.25 per unit for IC341s and $1.35 per unit for IC256s. Because demand for raw materials is rising, production costs are expected to rise by $0.05 per month through the end of the year.

Labor to make model IC341 is 0.45 hour per unit; to make model IC256 takes 0.52 hour of labor. Management has agreed to schedule at least 1,000 hours per month of labor. As many as 200 extra hours per month are available to management at the same cost, except during the month of December, when only 100 extra hours are possible. What should be the production schedule for IC341s and IC256s for the four months?

3-44 Monique Brown recently won a lottery with a prize amount of $356,000. As she had no immediate need for the money at the time she won it, she decided to invest some or all of it on January 1, $200n$, with a goal of making the money grow to $500,000 by December 31, $200n+5$. She has the following investments to consider:

	RATE	MATURES
Fund A	7%	December 31 (at the end of one year)
Fund B	16%	December 31 (at the end of the second year after investment)
Fund C	24%	December 31 (at the end of the third year after investment)
Fund D	32%	December 31 (at the end of the fourth year after investment)

Monique wants to set up this investment strategy at the start of year 1. If she does not need to invest all the lottery winnings to have $500,000 at the end of year 6, she will find another purpose for the remainder. She may choose to place a sum of money in any or all of the investments available at the start of year 1. From that point, however, all subsequent investments should come from the matured investments of previous years. To ensure that funds are spread over different investment choices, Monique does not want any single *new* investment in any year to be over $120,000 (note that prior investments in a fund do not count toward this limit).

How much money will Monique have to invest, and in what investments, on January 1, $200n$, to meet her goal of $500,000 at the end of the sixth year?

3-45 Mt. Sinai Hospital in New Orleans is a large, private, 600-bed facility complete with laboratories, operating rooms, and x-ray equipment. In seeking to increase revenues, Mt. Sinai's administration has decided to make a 90-bed addition on a portion of adjacent land currently used for staff parking. The administrators feel that the labs, operating rooms, and x-ray department are not being fully utilized at present and do not need to be expanded to handle additional patients. The addition of 90 beds, however, involves deciding how many beds should be allocated to the medical staff for medical patients and how many to the surgical staff for surgical patients.

The hospital's accounting and medical records departments have provided the following pertinent information. The average hospital stay for a medical patient is 8 days, and the average medical patient generates $2,280 in revenues. The average surgical patient is in the hospital 5 days and receives a $1,515 bill. The laboratory is capable of handling 15,000 tests per year more than it has been handling. The average medical patient requires 3.1 lab tests, and the average surgical patient takes 2.6 lab tests. Furthermore, the average medical patient uses one x-ray, whereas the average surgical patient requires two x-rays. If the hospital was expanded by 90 beds, the x-ray department could handle up to 7,000 x-rays without significant additional cost. Finally, the administration estimates that up to 2,800 additional operations could be performed in existing operating room facilities. Medical patients, of course, require no surgery, whereas each surgical patient generally has one surgery performed.

Formulate this problem so as to determine how many medical beds and how many surgical beds should be added to maximize revenues. Assume that the hospital is open 365 days a year. Then solve the problem.

3-46 Palmetto Paper Mill (PPM) sells rolls of paper to newspapers, which usually place orders for rolls of different widths. PPM has just received a large order for 1.5 million feet of 4-foot-wide paper, 6 million feet of 9-foot-wide paper, and 3 million feet of 12-foot-wide paper. PPM produces rolls of the following two sizes: (1) 3,000 feet long and 14 feet wide, at a cost of $600 per roll, and (2) 3,000 feet long and 20 feet wide, at a cost of $1,100 per roll. Large cutting machines are used to cut these rolls to rolls of desired widths.

(a) What should PPM do to satisfy this order at minimum cost? *Hint:* You need to first identify the different ways in which 14-foot and 20-foot wide rolls can be cut into rolls that are 4 feet, 9 feet, and 12 feet wide.

(b) PPM is very concerned about the environment. Rather than determine the cheapest way of satisfying the current order, the firm would like to determine the least wasteful way (i.e., minimize the amount of paper wasted). What is the solution with this revised objective, and what is the new cost?

3-47 A company that manufactures product in two plants ships locally, using its own transportation system, but it has orders that must be sent to customers too far away to be serviced by the local fleet. It therefore contracts with a middle-distance carrier to complete its shipping. The locations of the two manufacturing plants, amounts available at each plant to be shipped per week, locations of the three customers, their weekly requirements, and shipping costs ($ per unit) between each plant and customer are shown in the following table:

PLANTS	CUSTOMER ($ PER UNIT SHIPPED)			
	SAVANNAH	MOBILE	ROANOKE	AVAILABLE
Columbia	$13	$42	$38	450
Greensboro	$25	$48	$17	290
Required	250	225	210	

What is the optimal shipping plan to satisfy the demand at the lowest total shipping cost?

⇒ CASE STUDY

Chase Manhattan Bank

The workload in many areas of bank operations has the characteristics of a non-uniform distribution with respect to time of day. For example, at Chase Manhattan Bank in New York, the number of domestic money transfer requests received from customers, if plotted against time of day, would appear to have the shape of an inverted U curve, with the peak around 1 P.M. For efficient use of resources, the personnel available should, therefore, vary correspondingly. Figure 3.1 shows a typical workload curve and corresponding personnel requirements at different hours of the day.
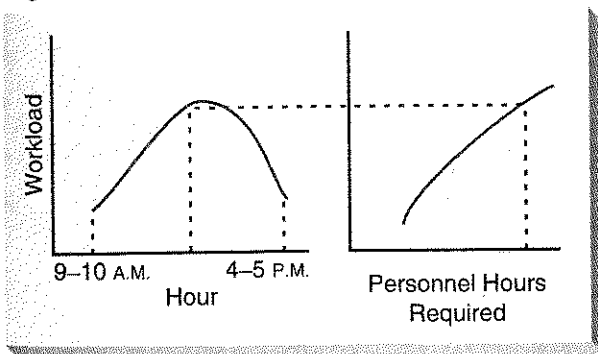
A variable capacity can be achieved effectively by employing part-time personnel. Because part-timers are not entitled to all the fringe benefits, they are often more economical than full-time employees. Other considerations, however, may limit the extent to which part-time people can be hired in a given department. The problem is to find an optimum workforce schedule that would meet personnel requirements at any given time and also be economical.

Some of the factors affecting personnel assignment are listed here:

a. By corporate policy, part-time personnel hours are limited to a maximum of 40% of the day's total requirement.

b. Full-time employees work for 8 hours (1 hour for lunch included) per day. Thus, a full-timer's productive time is 35 hours per week.

c. Part-timers work for at least 4 hours per day but less than 8 hours and are not allowed a lunch break.

d. Fifty percent of the full-timers go to lunch between 11 A.M. and noon, and the remaining 50% go between noon and 1 P.M.

e. The shift starts at 9 A.M. and ends at 7 P.M. (i.e., overtime is limited to 2 hours). Any work left over at 7 P.M. is considered holdover for the next day.

f. A full-time employee is not allowed to work more than 5 hours of overtime per week. He or she is paid at the normal rate for overtime hours—*not* at one and one-half times the normal rate applicable to hours in excess of 40 per week. Fringe benefits are not applied to overtime hours.

In addition, the following costs are pertinent:

a. The average cost per full-time personnel hour (fringe benefits included) is $10.11.

b. The average cost per overtime personnel hour for full-timers (straight rate, excluding fringe benefits) is $8.08.

c. The average cost per part-time personnel hour is $7.82.

The personnel hours required, by hour of day, are given in Table 3.17. The bank's goal is to achieve the minimum possible personnel cost subject to meeting or exceeding the hourly workforce requirements as well as the constraints on the workers listed earlier.

Discussion Questions

1. What is the minimum-cost schedule for the bank?
2. What are the limitations of the model used to answer question 1?

FIGURE 3.1

Figure for Case: Chase Manhattan Bank

TABLE 3.17

Data for Chase Manhattan Bank

TIME PERIOD	HOURS REQUIRED
9–10 A.M.	14
10–11	25
11–12	26
12–1 P.M.	38
1–2	55
2–3	60
3–4	51
4–5	29
5–6	14
6–7	9

BIBLIOGRAPHY

See Bibliography at the end of Chapter 2.