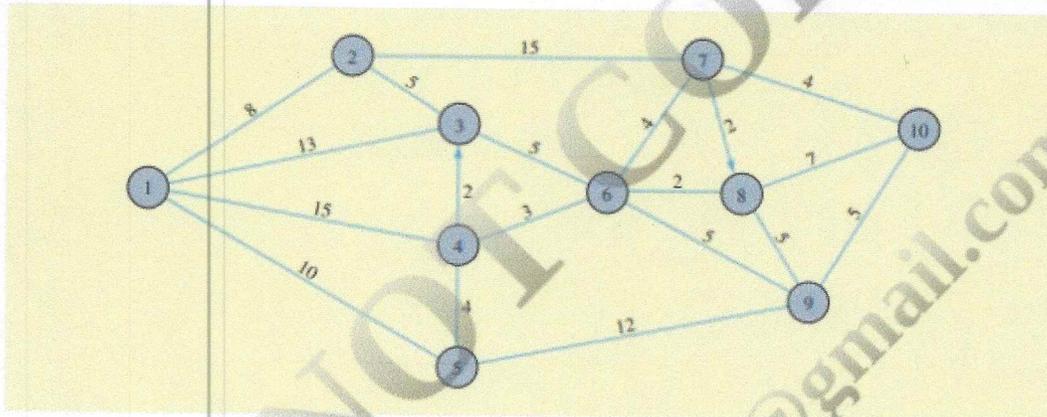
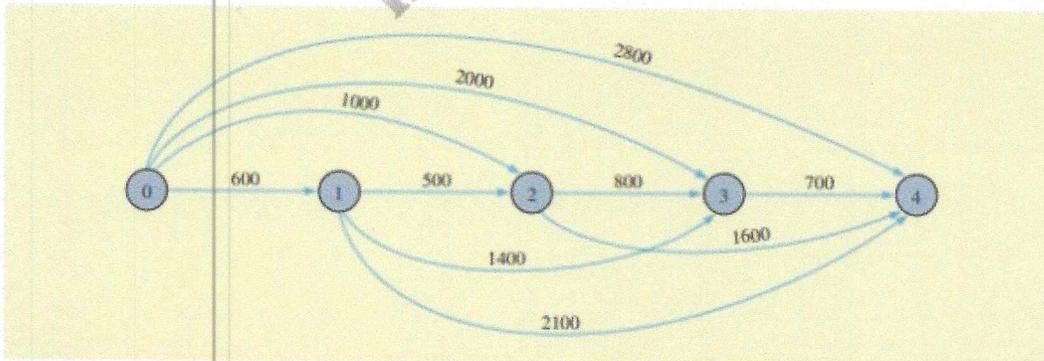


27. **Taxi Cab Routing.** City Cab Company identified 10 primary pickup and drop locations for cab riders in New York City. In an effort to minimize travel time and improve customer service and the utilization of the company's fleet of cabs, management would like the cab drivers to take the shortest route between locations whenever possible. Using the following network of roads and streets, what is the route a driver beginning at location 1 should take to reach location 10? The travel times in minutes are shown on the arcs of the network. Note that there are two one-way streets and that the direction is shown by the arrows. **LO 4**



28. **Minimizing the Cost of Replacement Computer Equipment.** The five nodes in the following network represent points one year apart over a four-year period. Each node indicates a time when a decision is made to keep or replace a firm's computer equipment. If a decision is made to replace the equipment, a decision must also be made as to how long the new equipment will be used. The arc from node 0 to node 1 represents the decision to keep the current equipment one year and replace it at the end of the year. The arc from node 0 to node 2 represents the decision to keep the current equipment two years and replace it at the end of year 2. The numbers above the arcs indicate the total cost associated with the equipment replacement decisions. These costs include discounted purchase price, trade-in value, operating costs, and maintenance costs. Use a shortest-route model to determine the minimum cost equipment replacement policy for the four-year period. **LO 4**



Ch. 7

Problems

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of shifts 1 through 5. Also, assume that the projected required number of nurses factors in time for each nurse to have a meal break.

Formulate and solve the nurse scheduling problem as an integer program for one day for the data given below.

Hint: Note that exceeding the minimum number of needed nurses in each shift is acceptable so long as the total number of nurses over all shifts is minimized. **LO 4**

 **DATAfile**
NurseSchedule

| Shift | Time | Minimum Number of Nurses Needed |
|-------|------------------------|---------------------------------|
| 1 | 12:00 A.M. – 4:00 A.M. | 10 |
| 2 | 4:00 A.M. – 8:00 A.M. | 24 |
| 3 | 8:00 A.M. – 12:00 P.M. | 18 |
| 4 | 12:00 P.M. – 4:00 P.M. | 10 |
| 5 | 4:00 P.M. – 8:00 P.M. | 23 |
| 6 | 8:00 P.M. – 12:00 A.M. | 17 |

- 8. Investment Net Present Value.** Spencer Enterprises must choose among a series of new investment alternatives. The potential investment alternatives, the net present value of the future stream of returns, the capital requirements, and the available capital funds over the next three years are summarized as follows. **LO 5, 7**

| Alternative | Net Present Value (\$) | Capital Requirements (\$) | | |
|-------------------------------|------------------------|---------------------------|--------|--------|
| | | Year 1 | Year 2 | Year 3 |
| Limited warehouse expansion | 4,000 | 3,000 | 1,000 | 4,000 |
| Extensive warehouse expansion | 6,000 | 2,500 | 3,500 | 3,500 |
| Test market new product | 10,500 | 6,000 | 4,000 | 5,000 |
| Advertising campaign | 4,000 | 2,000 | 1,500 | 1,800 |
| Basic research | 8,000 | 5,000 | 1,000 | 4,000 |
| Purchase new equipment | 3,000 | 1,000 | 500 | 900 |
| Capital funds available | | 10,500 | 7,000 | 8,750 |

- Develop and solve an integer programming model for maximizing the net present value.
 - Assume that only one of the warehouse expansion projects can be implemented. Modify your model of part (a).
 - Suppose that, if test marketing of the new product is carried out, the advertising campaign also must be conducted. Modify your formulation of part (b) to reflect this new situation.
- 9. Connecting Rods Production.** Hawkins Manufacturing Company produces connecting rods for 4- and 6-cylinder automobile engines using the same production line. The cost required to set up the production line to produce the 4-cylinder connecting rods is \$2000, and the cost required to set up the production line for the 6-cylinder connecting rods is \$3500. Manufacturing costs are \$15 for each 4-cylinder connecting rod and \$18 for each 6-cylinder connecting rod. Hawkins makes a decision at the end of each week as to which product will be manufactured the following week. If a production changeover is necessary from one week to the next, the weekend is used to reconfigure the production line. Once the line has been set up, the weekly production capacities are 6000 6-cylinder connecting rods and 8000 4-cylinder connecting rods. **LO 6**

Let

x_4 = the number of 4-cylinder connecting rods produced next week

x_6 = the number of 6-cylinder connecting rods produced next week

s_4 = 1 if the production line is set up to produce the 4-cylinder connecting rods;
0 if otherwise

s_6 = 1 if the production line is set up to produce the 6-cylinder connecting rods;
0 if otherwise

- Using the decision variables x_4 and s_4 , write a constraint that limits next week's production of the 4-cylinder connecting rods to either 0 or 8000 units.
 - Using the decision variables x_6 and s_6 , write a constraint that limits next week's production of the 6-cylinder connecting rods to either 0 or 6000 units.
 - Write three constraints that, taken together, limit the production of connecting rods for next week.
 - Write an objective function for minimizing the cost of production for next week.
10. **Locating Police Substations.** Grove City is considering the relocation of several police substations to obtain better enforcement in high-crime areas. The locations under consideration together with the areas that can be covered from these locations are given in the following table. **LO 5**

| Potential Locations for Substations | Areas Covered |
|-------------------------------------|---------------|
| A | 1, 5, 7 |
| B | 1, 2, 5, 7 |
| C | 1, 3, 5 |
| D | 2, 4, 5 |
| E | 3, 4, 6 |
| F | 4, 5, 6 |
| G | 1, 5, 6, 7 |

- Formulate an integer programming model that could be used to find the minimum number of locations necessary to provide coverage to all areas.
 - Solve the problem in part (a).
11. **Multi-product Production Planning.** Hart Manufacturing makes three products. Each product requires manufacturing operations in three departments: A, B, and C. The labor-hour requirements, by department, are as follows:

| Department | Product 1 | Product 2 | Product 3 |
|------------|-----------|-----------|-----------|
| A | 1.50 | 3.00 | 2.00 |
| B | 2.00 | 1.00 | 2.50 |
| C | 0.25 | 0.25 | 0.25 |

During the next production period, the labor-hours available are 450 in department A, 350 in department B, and 50 in department C. The profit contributions per unit are \$25 for product 1, \$28 for product 2, and \$30 for product 3. **LO 6**

- Formulate a linear programming model for maximizing total profit contribution.
- Solve the linear program formulated in part (a). How much of each product should be produced, and what is the projected total profit contribution?
- After evaluating the solution obtained in part (b), one of the production supervisors noted that production setup costs had not been taken into account. She noted that

setup costs are \$400 for product 1, \$550 for product 2, and \$600 for product 3. If the solution developed in part (b) is to be used, what is the total profit contribution after taking into account the setup costs?

- d. Management realized that the optimal product mix, taking setup costs into account, might be different from the one recommended in part (b). Formulate a mixed-integer linear program that takes setup costs into account. Management also stated that we should not consider making more than 175 units of product 1, 150 units of product 2, or 140 units of product 3.
- e. Solve the mixed-integer linear program formulated in part (d). How much of each product should be produced, and what is the projected total profit contribution? Compare this profit contribution to that obtained in part (c).
12. **Carrier Selection.** Offhaus Manufacturing produces office supplies but outsources the delivery of its products to third-party carriers. Offhaus ships to 20 cities from its Dayton, Ohio, manufacturing facility and has asked a variety of carriers to bid on its business. Seven carriers have responded with bids. The resulting bids (in dollars per truckload) are shown in the table. For example, the table shows that carrier 1 bid on the business to cities 11–20. The right side of the table provides the number of truckloads scheduled for each destination in the next quarter.

| Bid \$/Truckload | Carrier 1 | Carrier 2 | Carrier 3 | Carrier 4 | Carrier 5 | Carrier 6 | Carrier 7 | Destination | Demand (Truckloads) |
|---------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-------------|------------------------|
| City 1 | | | | | \$2188 | \$1666 | \$1790 | City 1 | 30 |
| City 2 | | \$1453 | | | \$2602 | \$1767 | | City 2 | 10 |
| City 3 | | \$1534 | | | \$2283 | \$1857 | \$1870 | City 3 | 20 |
| City 4 | | \$1687 | | | \$2617 | \$1738 | | City 4 | 40 |
| City 5 | | \$1523 | | | \$2239 | \$1771 | \$1855 | City 5 | 10 |
| City 6 | | \$1521 | | | \$1571 | | \$1545 | City 6 | 10 |
| City 7 | | \$2100 | | \$1922 | \$1938 | | \$2050 | City 7 | 12 |
| City 8 | | \$1800 | | \$1432 | \$1416 | | \$1739 | City 8 | 25 |
| City 9 | | \$1134 | | \$1233 | \$1181 | | \$1150 | City 9 | 25 |
| City 10 | | \$672 | | \$610 | \$669 | | \$678 | City 10 | 33 |
| City 11 | \$724 | | \$723 | \$627 | \$657 | | \$706 | City 11 | 11 |
| City 12 | \$766 | | \$766 | \$721 | \$682 | | \$733 | City 12 | 29 |
| City 13 | \$741 | | \$745 | | \$682 | | \$733 | City 13 | 12 |
| City 14 | \$815 | \$800 | \$828 | | \$745 | | \$832 | City 14 | 24 |
| City 15 | \$904 | | \$880 | | \$891 | | \$914 | City 15 | 10 |
| City 16 | \$958 | | \$933 | | \$891 | | \$914 | City 16 | 10 |
| City 17 | \$925 | | \$929 | | \$937 | | \$984 | City 17 | 23 |
| City 18 | \$892 | | \$869 | \$822 | \$829 | | \$864 | City 18 | 25 |
| City 19 | \$927 | | \$969 | | \$967 | | \$1008 | City 19 | 12 |
| City 20 | \$963 | | \$938 | | \$955 | | \$995 | City 20 | 10 |
| Number of Bids | 10 | 10 | 10 | 7 | 20 | 5 | 18 | | |



Because dealing with too many carriers can be cumbersome, Offhaus would like to limit the number of carriers it uses to three. Also, for customer relationship reasons, Offhaus wants each city to be assigned to only one carrier (that is, there is no splitting of the demand to a given city across carriers). **LO 5, 8**

- a. Develop a model that will yield the three selected carriers and the city-carrier assignments that minimize the cost of shipping. Solve the model and report the solution.

- b. Offhaus is not sure whether three is the correct number of carriers to select. Run the model you developed in part (a) for allowable carriers varying from 1 up to 7. Based on your results, how many carriers would you recommend and why?
13. **Martin-Beck Company (revisited).** Recall the Martin-Beck Company distribution system example in Section 7.3. **LO 7**
- Modify the formulation shown in Section 7.3 to account for the policy restriction that one plant, but not two, must be located either in Detroit or in Toledo.
 - Modify the formulation shown in Section 7.3 to account for the policy restriction that no more than two plants can be located in Denver, Kansas City, and St. Louis.
14. **Cloud Services Capacity Planning.** Galaxy Cloud Services operates several data centers across the United States containing servers that store and process the data on the Internet. Suppose that Galaxy Cloud Services currently has five outdated data centers: one each in Michigan, Ohio, and California and two in New York. Management is considering increasing the capacity of these data centers to keep up with increasing demand. Each data center contains servers that are dedicated to Secure data and to Super Secure data. The cost to update each data center and the resulting increase in server capacity for each type of server are as follows:

| Data Center | Cost (\$ millions) | Secure Servers | Super Secure Servers |
|-------------|--------------------|----------------|----------------------|
| Michigan | 2.5 | 50 | 30 |
| New York 1 | 3.5 | 80 | 40 |
| New York 2 | 3.5 | 40 | 80 |
| Ohio | 4.0 | 90 | 60 |
| California | 2.0 | 20 | 30 |

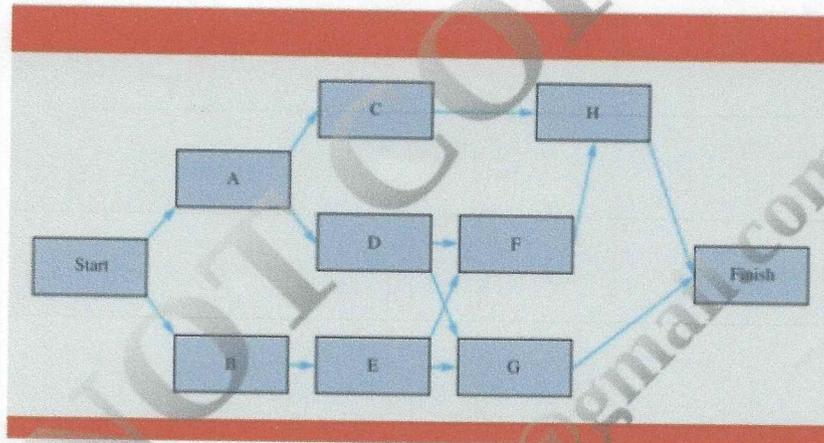
The projected needs are for a total increase in capacity of 90 Secure servers and 90 Super Secure servers. Management wants to determine which data centers to update to meet projected needs and, at the same time, minimize the total cost of the added capacity. **LO 6**

- Formulate a binary integer programming model that could be used to determine the optimal solution to the capacity increase question facing management.
 - Solve the model formulated in part (a) to provide a recommendation for management.
15. **Ohio Trust Bank Location (revisited).** Consider again the Ohio Trust bank location problem discussed in Section 7.3. The file *OhioTrustFull* contains data for all of Ohio's 88 counties. The file contains an 88×88 matrix with the rows and columns each being the 88 counties. The entries in the matrix are zeros and ones and indicate if the county of the row shares a border with the county of the column (1 = yes and 0 = no). **LO 5**
- Create a model to find the location of required principal places of business (PPBs) to minimize the number of PPBs needed to open all counties to branches.
 - Solve the model constructed in part (a). What is the minimum number PPBs needed to open up the entire state to Ohio Trust branches?
16. **Bank Teller Scheduling.** The Northshore Bank is working to develop an efficient work schedule for full-time and part-time tellers. The schedule must provide for efficient operation of the bank including adequate customer service, employee breaks, and so on. On Fridays the bank is open from 9:00 A.M. to 7:00 P.M. The number of tellers necessary to provide adequate customer service during each hour of operation is summarized here.

| Time | Number of Tellers | Time | Number of Tellers |
|-----------------------|-------------------|---------------------|-------------------|
| 9:00 A.M.–10:00 A.M. | 6 | 2:00 P.M.–3:00 P.M. | 6 |
| 10:00 A.M.–11:00 A.M. | 4 | 3:00 P.M.–4:00 P.M. | 4 |
| 11:00 A.M.–Noon | 8 | 4:00 P.M.–5:00 P.M. | 7 |
| Noon–1:00 P.M. | 10 | 5:00 P.M.–6:00 P.M. | 6 |
| 1:00 P.M.–2:00 P.M. | 9 | 6:00 P.M.–7:00 P.M. | 6 |

5. **Updating Progress on the Western Hills Project.** Consider the Western Hills Shopping Center project summarized by Figure 9.6 and Table 9.2. Suppose the project has been underway for seven weeks. Activities A and E have been completed. Activity F has commenced but has three weeks remaining. Activities C and D have not started yet. Activity B has one week remaining (it was not started until week 2). Update the activity schedule for the project. In particular, how has the slack for each activity changed? **LO 1, 2**

6. **Critical Path for Wedding Plans.** To help with preparations, a couple has devised a project network to describe the activities that must be completed by their wedding date. In addition, they have estimated the time of each activity (in weeks). **LO 2**



| Activity | A | B | C | D | E | F | G | H |
|----------|---|---|---|---|---|---|----|---|
| Time | 5 | 3 | 7 | 6 | 7 | 3 | 10 | 8 |

- Identify the critical path.
 - How much time will be needed to complete this project?
 - Can activity D be delayed without delaying the entire project? If so, by how many weeks?
 - Can activity C be delayed without delaying the entire project? If so, by how many weeks?
 - What is the schedule for activity E?
7. **Apartment Building Renovation.** Jefferson Park Apartments is undertaking a summer renovation of its main building. The project is scheduled to begin May 1, and a September 1 (17-week) completion date is desired. The manager identified the following renovation activities and their estimated times. **LO 1, 2**

| Activity | Immediate Predecessor | Time |
|----------|-----------------------|------|
| A | — | 3 |
| B | — | 1 |
| C | — | 2 |
| D | A, B, C | 4 |
| E | C, D | 5 |
| F | A | 3 |
| G | D, F | 6 |
| H | E | 4 |

MGMT 651 – Analytics for Managerial Decision-Making
Homework 5

Worth 100 points

DO NOT FORGET TO TYPE YOUR NAME ON THE FIRST PAGE OF YOUR HOMEWORK SUBMISSION DOCUMENT

1. (10 points) Chapter 6 Problem 28
2. (15 points) A company is considering 4 locations to open warehouses: *New York*, *Los Angeles*, *Chicago* and *Atlanta*. Each warehouse can ship up to 100 units per week. The weekly fixed cost of keeping each warehouse open is \$400 for NY, \$500 for LA, \$300 for Chicago, and \$150 for Atlanta. The company's customers are spread across three well-defined regions across the country. Region 1 requires 80 units per week, region 2 requires 70 units per week and region 3 requires 40 units per week. The unit transportation costs for each warehouse to a region are shown in the following table:

| Table of Unit Transportation Costs | | | |
|------------------------------------|-----------------|-----------------|-----------------|
| FROM | TO | | |
| | <i>Region 1</i> | <i>Region 2</i> | <i>Region 3</i> |
| <i>New York</i> | \$20 | \$40 | \$50 |
| <i>Los Angeles</i> | 48 | 15 | 26 |
| <i>Chicago</i> | 26 | 35 | 18 |
| <i>Atlanta</i> | 24 | 50 | 35 |

The company wants to meet weekly demands at minimum cost, subject to the preceding information and the following strategic criteria:

- If the NY warehouse is opened, then the LA warehouse must be opened.
- At most two warehouses can be opened.
- Either the Atlanta or LA warehouse must be opened.

Formulate a mixed integer linear program (MILP) for this problem and solve using POM/OM (Integer and Mixed Integer Programming). Interpret your results: (a) which warehouse locations are selected? (b) What is the transportation schedule and what is the total transportation cost?

3. (15 points) Chapter 7 Problem 8. You may want to review the *Capital Budgeting* example in Chapter 7 of the textbook.
4. (10 points) Chapter 7 Problem 9
5. (20 points) Chapter 7 Problem 11. Solve part "e" using POM/OM (Integer and Mixed Integer Programming).
6. (15 points) Chapter 7 Problem 14
7. (15 points) Chapter 9 Problem 6