Chapter 4

Relevant Costs for Nonroutine Operating Decisions

Study Checklist – Monitor your progress

1. Read the chapter in the text
2. Review the learning objectives below
3. Read the overview of the chapter
4. Read the chapter review for learning objectives 1 - 4
5. Do Problem Set A and check your answers
6. Read the chapter review for learning objectives 5 - 7
7. Do Problem Set B and check your answers
8. Do the End of Chapter Exercises in this study guide
9. Do the homework assigned by your instructor

CHAPTER LEARNING OBJECTIVES
After studying this chapter, you should be able to answer the following questions:
Q1. What is the process for making nonroutine operating decisions?
Q2. How are decisions made to accept, reject, and price special orders?
Q3. How are decisions made to keep or drop products, segments, or whole businesses?
Q4. How are decisions made to insource or outsource an activity (make or buy)?
Q5. How are decisions made for product emphasis and constrained resources?
Q6. What qualitative factors are important to nonroutine operating decisions?
Q7. What limitations and uncertainties should be considered when making nonroutine operating decisions?

OVERVIEW OF CHAPTER
Managers rely on management accountants for assistance in making nonroutine operating decisions such as whether to accept a customer's special order, or whether to keep or eliminate a seemingly unprofitable business segment. Other examples of nonroutine operating decisions include whether or not to outsource a business activity (or the manufacture of a subcomponent) and how to allocate scarce resources to products. There are quantitative decision rules to use for these types of decisions, but the quality of the information used must be considered, as must any relevant qualitative factors, before a final decision is made.
CHAPTER REVIEW: Learning Objectives 1 - 4

Q1: What is the process for making nonroutine operating decisions?
The general rule is to choose the alternative that maximizes profits (subject to qualitative considerations). This general rule can be made more specific once the nature of the decision at hand is identified. The process for making nonroutine operating decisions is:

- Identify the type of decision to be made
- Identify the relevant quantitative analysis technique(s)
- Apply the relevant quantitative analysis technique(s)
  - Identify the variables that are required as input, and which of these are known versus unknown
  - Estimate the unknown input variables
  - Apply the general rule for this type of decision
  - Interpret the results, taking the quality of information into consideration
- Identify and analyze the qualitative factors
- Consider the quantitative and qualitative information and make a decision

Q2: How are decisions made to accept, reject, and price special orders?
The general decision rule for special order decisions depends on whether or not there is sufficient idle capacity to produce the order. If there is enough capacity, then the special order should be accepted when the price exceeds the relevant costs. The decision may include determining the price for the order, so the price must at least exceed these relevant costs. Quite often (but not always) variable costs are relevant and fixed costs are not relevant. The demonstration problem below includes examples of exceptions to this.

When there is not enough idle capacity to produce the order, and it can be accepted only by replacing regular business, then the opportunity cost of accepting the special order must be included as part of the relevant costs. The opportunity cost of a lost unit of regular business is the contribution margin per unit that this regular business would have provided.

Demonstration problem-Special order decisions
Lanam Co. has been producing and selling 10,000 units per month, with the following total costs:

Direct materials .......................................................... $20,000
Direct labor ................................................................. 35,000
Manufacturing overhead: Variable .................... 15,000
                  Fixed ................................ 24,000
Selling expenses: Variable .............. 10,000
                  Fixed ................................ 13,000

The normal selling price is $15 per unit. The company has received an offer from a special customer who would like to buy exactly 5,000 units of product for $9 per unit. This special order would incur none of the usual variable selling expenses. Additional administrative expenses specifically related to this special order would be $1,500.

Required:
a) Suppose plant capacity is 18,000 units. Should Lanam accept this special order?
b) Suppose plant capacity is 13,000 units. Should Lanam accept this special order?
Solution to demonstration problem

Note the variable costs are $8 per unit.

- Direct materials .......................................... $2.00
- Direct labor .............................................. 3.50
- Manufacturing overhead: Variable ......... 1.50
- Selling expenses: Variable ...................... 1.00

$8.00

In this case, not all variable costs are relevant because this special order will incur no variable selling expenses.

a) Here there is sufficient capacity to accept this order without replacing regular business because regular business of 10,000 units plus the special order of 5,000 units is less than capacity of 18,000 units.

Incremental revenue if accept (5,000 units @ $9) $45,000
Relevant variable costs (5,000 units @ $7) 35,000
Relevant fixed costs (additional admin costs) (1,500)

Increase in profit if accept special order $8,500

Here the quantitative analysis shows that the order should be accepted.

b) In this case, there is not sufficient capacity to accept this order without replacing regular business because regular business of 10,000 units plus the special order of 5,000 units exceeds capacity of 13,000 units. The order can only be accepted only if it replaces 2,000 units of regular business. The analysis for part (a) only needs to be changed to include the opportunity cost of accepting the order.

Increase in profit if accept special order when there was idle capacity $8,500
Less: opportunity cost: lost contribution margin on 2,000 units of regular business ($15 - $8) x 2,000 units 14,000

Effect on profit if accept special order $(5,500)

Here the quantitative analysis shows that the order should not be accepted.

Q3: How are decisions made to keep or drop products, segments, or whole businesses?
The general decision rule for keep or drop decisions is that the segment should be dropped if its contribution margin is less than the sum of the relevant fixed costs plus the opportunity costs of keeping the segment. The only fixed costs that are relevant are those that can be avoided if the business segment is dropped. The opportunity costs are the benefits forgone when the decision is made to keep the segment; these benefits stem from the opportunity to use the released capacity for other purposes.
Demonstration problem—Keep or drop decisions
Mikkee Corporation has three departments. Data for the most recent year is presented below. There are $20 in corporate headquarters fixed costs that are not traceable to individual departments.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>$400</td>
<td>$200</td>
<td>$80</td>
</tr>
<tr>
<td>Variable costs</td>
<td>128</td>
<td>52</td>
<td>34</td>
</tr>
<tr>
<td>Contribution margin</td>
<td>272</td>
<td>148</td>
<td>46</td>
</tr>
<tr>
<td>Department fixed costs:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unavoidable</td>
<td>96</td>
<td>52</td>
<td>12</td>
</tr>
<tr>
<td>Avoidable</td>
<td>60</td>
<td>104</td>
<td>54</td>
</tr>
<tr>
<td>Allocated fixed costs</td>
<td>12</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Operating income</td>
<td>$104</td>
<td>$(14)</td>
<td>$(22)</td>
</tr>
</tbody>
</table>

Required:

a) Should any department(s) be dropped? Which one(s) and why? What is the effect on operating income if your advice is followed?

b) Without regard to your answer for (a) above, suppose that Departments B and C are both eliminated. What is the new operating income for the Mikkee Corporation?

c) Suppose that a decision to drop Department B will free up capacity that can be used by Department A, and will save Mikkee $49 per year. Should Mikkee drop Department B in this case?

Solution to demonstration problem

a) First compute each department's contribution margin less avoidable fixed costs:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution margin</td>
<td>$272</td>
<td>$148</td>
<td>$46</td>
</tr>
<tr>
<td>Avoidable fixed costs</td>
<td>60</td>
<td>104</td>
<td>54</td>
</tr>
<tr>
<td>Effect on profit if keep</td>
<td>$212</td>
<td>$44</td>
<td>$(8)</td>
</tr>
</tbody>
</table>

Department C is the only department that should be dropped. Operating income will increase by $8 if it is dropped.

b) Dropping Department C will increase income by $8 and dropping Department B will decrease income by $44, so dropping both departments will decrease income by $44 - $8 = $32.

c) The opportunity cost of keeping Department B is $49.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution margin</td>
<td>$148</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoidable fixed costs</td>
<td></td>
<td>104</td>
<td>44</td>
</tr>
<tr>
<td>Opportunity cost of keeping Department B</td>
<td></td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>Effect on profit if keep</td>
<td></td>
<td>$(5)</td>
<td></td>
</tr>
</tbody>
</table>

In this case, Department B should be dropped (subject to qualitative considerations) because it will increase income by $5.
Q4: How are decisions made to insource or outsource an activity (make or buy)?
The general decision rule for make or buy decisions is to outsource (buy) if the acquisition cost is less than or equal to the sum of variable costs plus relevant fixed costs, minus opportunity costs. The only relevant fixed costs are those that will be avoided when the decision is made to buy. The opportunity costs are the benefits forgone when the decision is made to insource, or make, the subcomponent. As in Q3, these benefits stem from the opportunity to use the released capacity for other purposes.

Demonstration problem—Make (insource) or buy (outsource) decisions
Gibson, Inc. manufactures a subcomponent that it needs for the production of its main product. Gibson currently makes, and uses, 100,000 of these subcomponents per year. The per-unit production costs of the subcomponent follow:

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct materials</td>
<td>$2.60</td>
</tr>
<tr>
<td>Direct labor</td>
<td>$1.00</td>
</tr>
<tr>
<td>Manufacturing overhead: Variable</td>
<td>$1.20</td>
</tr>
<tr>
<td>Fixed</td>
<td>$1.60</td>
</tr>
<tr>
<td>Total cost per unit</td>
<td>$6.40</td>
</tr>
</tbody>
</table>

Quaid, Inc. has offered to sell Gibson all 100,000 units it will need during the coming year for $6.00 per unit. If Gibson accepts the offer from Quaid, the facilities used to manufacture the subcomponent could be used elsewhere in production. This change would save Gibson $90,000 in the fixed costs of producing its main product. In addition, a $50,000 cost item included in fixed factory overhead which is specifically related to producing this subcomponent (rental of special equipment not usable in the manufacture of other products) would be eliminated.

Required:
Determine whether Gibson should make the component or buy it from Quaid. What is the effect on operating income if your advice is followed?

Solution to demonstration problem
Note that the variable costs per unit of the subcomponent are $4.80, and the total fixed costs associated with producing the subcomponent are $1.60 x 100,000 = $160,000. This $160,000 includes $50,000 of avoidable fixed costs. This $50,000 is relevant but the remaining $110,000 is not relevant because it cannot be avoided, regardless of the decision.

The relevant cost to make the subcomponent is computed as follows:
- Incremental variable costs ($4.80 x 100,000) = $480,000
- Incremental (or avoidable, or relevant) fixed cost = $50,000
- Opportunity cost of making subcomponent (benefits forgone) = $90,000
- Relevant cost to make = $480,000 + $50,000 - $90,000 = $620,000

The relevant cost to buy is $6.00 x 100,000 = $600,000

Gibson should buy, not make, the subcomponent because income will increase by $20,000.
PROBLEM SET A (Learning Objectives 1 - 4)

**True-False:** Indicate whether each of the following is true (T) or false (F) in the space provided.

_____ 1. Fixed costs are always irrelevant in nonroutine decision making.

_____ 2. Avoidable costs are always relevant in nonroutine decisions.

_____ 3. When a company is operating at capacity, the minimum acceptable price for a customer’s special order is equal to the relevant variable and fixed costs associated with producing the order.

_____ 4. In a make or buy decision, the relevant cost to make the subcomponent is the sum of the variable and fixed costs that will be avoided if the component is purchased, plus the opportunity costs associated with not releasing the capacity for other uses.

_____ 5. Any business segment that has a negative contribution margin should be dropped.

_____ 6. Any business segment that has a negative operating income should be dropped.

_____ 7. Opportunity costs are always relevant in nonroutine decision making.

_____ 8. For a company with sufficient excess capacity to produce a customer’s special order, the opportunity cost of accepting the special order is zero.

_____ 9. For a company without sufficient excess capacity to produce a customer’s special order, the opportunity cost of the special order is equal to the contribution margin per unit of regular business times the number of units of regular business that will be replaced.

_____ 10. Variable costs are always relevant when making nonroutine decisions.

**Multiple choice:** Write the letter that represents the best choice in the space provided.

_____ 1. Each year Wright’s Widgets buys 10,000 subcomponents that it needs in the production of its widgets from an outside supplier for $15 each. If Wright instead used its existing idle capacity to produce it in-house, the variable production costs would be $8 per unit and $3 of fixed production overhead would be allocated to each unit. Additionally, Wright would need to hire one quality control technician for $28,000 per year. The excess capacity that would be required is currently leased to another company for $25,000 per year. What is the advantage or disadvantage if Wright continues to buy the subcomponent from the outside supplier?
   
a. $13,000 advantage  
b. $17,000 disadvantage  
c. $37,000 advantage  
d. $3,000 disadvantage
Use the following information for questions 2 - 4:

Taylor Enterprises sells its product for $40 per unit. Production costs per unit for regular sales are:
- Direct materials: $6
- Direct labor: $14
- Manufacturing overhead (2/3 variable): $12

Taylor recently received a special order from a customer for 20,000 units.

2. Suppose the special order price is $600,000 for all 20,000 units, and assume that Taylor has sufficient capacity to fill the special order. Should it be accepted?
   a. Yes, because profits will increase by $120,000
   b. No, because profits will decrease by $200,000
   c. No, because profits will decrease by $40,000
   d. Yes, because profits will increase by $40,000

3. Suppose that Taylor would like to earn $50,000 on this order and assume that there is sufficient capacity to fill the special order. What price per unit should Taylor charge for the special order?
   a. $34.50
   b. $42.50
   c. $30.50
   d. $26.50

4. Suppose that the special order price is $600,000 for all 20,000 units, but there is not sufficient capacity to fill the order; 8,000 units of regular business will be replaced by the special order if it is accepted. Should Taylor accept the special order?
   a. No, because profits will decrease by $56,000
   b. Yes, because profits will increase by $40,000
   c. No, because profits will decrease by $24,000
   d. No, because profits will decrease by $280,000

5. Moore Manufacturing has two major product lines, Gidgets and Gadgets.

   Income statements for the two product lines follow:

<table>
<thead>
<tr>
<th></th>
<th>Gidgets</th>
<th>Gadgets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenues</td>
<td>$400,000</td>
<td>$400,000</td>
</tr>
<tr>
<td>Variable expenses</td>
<td>225,000</td>
<td>150,000</td>
</tr>
<tr>
<td>Product line fixed expenses</td>
<td>130,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Allocated corporate fixed expenses</td>
<td>120,000</td>
<td>90,000</td>
</tr>
<tr>
<td>Net operating income (loss)</td>
<td>$(75,000)</td>
<td>$60,000</td>
</tr>
</tbody>
</table>

   If the Gidget product line were dropped, all of its product line fixed expenses could be avoided. Should the Gidget product line be dropped?
   a. Yes, because profits will increase by $75,000
   b. No, because profits will decrease by $45,000
   c. No, because profits will decrease by $55,000
   d. No, because profits will decrease by $175,000
Use the following information for questions 6 - 8:
Solo Co. made and sold 100,000 of its only product in 2004. Solo's income statement for 2004 follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>Direct materials</td>
<td>300,000</td>
</tr>
<tr>
<td>Direct labor</td>
<td>150,000</td>
</tr>
<tr>
<td>Variable manufacturing overhead</td>
<td>50,000</td>
</tr>
<tr>
<td>Fixed manufacturing overhead</td>
<td>100,000</td>
</tr>
<tr>
<td>Gross margin</td>
<td>400,000</td>
</tr>
<tr>
<td>Variable selling &amp; administrative expenses</td>
<td>75,000</td>
</tr>
<tr>
<td>Fixed selling &amp; administrative expenses</td>
<td>60,000</td>
</tr>
<tr>
<td>Operating income</td>
<td>$265,000</td>
</tr>
</tbody>
</table>

In 2005, Solo expects to produce and sell 80,000 units, and the selling price and variable costs per unit will remain unchanged. One third of the direct materials costs are for a subcomponent that Solo purchases from an outside supplier. In 2005, Solo will be producing the component internally for $0.75 per unit.

6. Compute the contribution margin per unit in 2005.
   a. $5.25
   b. $4.50
   c. $2.81
   d. $0.81

7. Compute the 2005 expected operating income.
   a. $232,000
   b. $90,000
   c. $200,000
   d. $105,000

8. What is the effect on 2005 profits of Solo’s decision to produce the component internally?
   a. The decision will increase 2005 profits by $25,000
   b. The decision will increase 2005 profits by $20,000
   c. The decision will decrease 2005 profits by $65,000
   d. The decision will decrease 2005 profits by $33,000

9. Relevant costs in a special order decision include all of the following except:
   a. direct materials costs of $3 per unit
   b. a fixed cost of $1500 for rental of a machine needed to produce the order
   c. the contribution margin per unit of regular sales when there is sufficient capacity to produce the order
   d. unusual shipping charges of $4 per unit for the special order
Use the following information for questions 10 - 12:
Loso Co. made and sold 100,000 of its only product in 2004 for $15 each. Loso's costs per unit for 2004 follow:

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Cost per Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct materials</td>
<td>$5.00</td>
</tr>
<tr>
<td>Direct labor</td>
<td>2.00</td>
</tr>
<tr>
<td>Variable manufacturing overhead</td>
<td>1.00</td>
</tr>
<tr>
<td>Fixed manufacturing overhead</td>
<td>1.50</td>
</tr>
<tr>
<td>Variable selling &amp; administrative expenses</td>
<td>0.80</td>
</tr>
<tr>
<td>Fixed selling &amp; administrative expenses</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>Total cost per unit</strong></td>
<td><strong>$10.80</strong></td>
</tr>
</tbody>
</table>

In 2005, Loso expects to produce and sell 80,000 units. The selling price and variable costs per unit will remain unchanged, as will total fixed costs. Early in 2005, a new customer approaches Loso and requests a one-time special order for 30,000 units.

10. **What are total budgeted fixed costs for 2005?**
   a. $160,000  
   b. $150,000  
   c. $120,000  
   d. $200,000  

11. **Suppose the special order will incur only half the regular variable selling & administrative expenses and will require the rental of a special grinding machine for $15,000. Assume the capacity of Loso is 120,000 units per year. What is the minimum price per unit for the special order that Loso should accept?**
   a. $9.00  
   b. $8.90  
   c. $11.00  
   d. $10.90  

12. **Suppose the special order will incur only half the regular variable selling & administrative expenses and will require the rental of a special grinding machine for $15,000. Assume the capacity of Loso is 100,000 units per year. What is the minimum price per unit for the special order that Loso should accept?**
   a. $10.97  
   b. $15.10  
   c. $11.10  
   d. $15.50
Use the following information for questions 13 - 15:
Ricardo Company has three products, A, B, and C. The following information is available:

<table>
<thead>
<tr>
<th></th>
<th>Product A</th>
<th>Product B</th>
<th>Product C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>$30,000</td>
<td>$70,000</td>
<td>$34,000</td>
</tr>
<tr>
<td>Variable costs</td>
<td>18,000</td>
<td>27,000</td>
<td>18,000</td>
</tr>
<tr>
<td>Contribution margin</td>
<td>12,000</td>
<td>43,000</td>
<td>16,000</td>
</tr>
<tr>
<td>Fixed costs:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoidable</td>
<td>4,500</td>
<td>12,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Unavoidable</td>
<td>3,000</td>
<td>10,000</td>
<td>6,200</td>
</tr>
<tr>
<td>Operating income</td>
<td>$4,500</td>
<td>$21,000</td>
<td>$(2,200)</td>
</tr>
</tbody>
</table>

13. If Ricardo drops Product C, then
   a. operating income will increase by $2,200
   b. operating income will decrease by $16,000
   c. operating income will decrease by $4,000
   d. operating income will decrease by $9,800

14. Suppose that eliminating Product C will free up warehouse space for Product A’s use, and will reduce the avoidable fixed costs of Product A by $1,500. If Ricardo drops Product C, then
   a. operating income will increase by $3,700
   b. operating income will decrease by $14,500
   c. operating income will decrease by $8,300
   d. operating income will decrease by $2,500

15. Suppose that eliminating Product C will reduce sales of Product B by 10%. If Ricardo drops Product C, then
   a. operating income will decrease by $11,000
   b. operating income will decrease by $6,100
   c. operating income will decrease by $4,300
   d. operating income will decrease by $8,300
CHAPTER REVIEW: Learning Objectives 5 - 7

Q5: How are decisions made for product emphasis and constrained resources?
Companies must determine how to allocate limited resources to their various products. When there is not enough of a resource (e.g. materials, labor hours, or machine hours), then this is known as a constraint, and the resource is known as a constrained, or scarce, resource. Any constrained resource that involves time is called a bottleneck.

Only one constrained resource, multiple products, unlimited customer demand
If there is only one constrained resource and customer demand for all products is unlimited, then it will be optimal to produce only one of the products. The general rule is to produce the product with the highest contribution margin per unit of the constrained resource.

- Note that this general rule is not “make the product with the highest contribution margin per unit”.

- The contribution margin per unit of the constrained resource is the product’s contribution margin per unit divided by the number of units of the scarce resource required to produce a unit of the product.
  - For example, suppose the constrained resource is machine hours. If the contribution margin per unit of Product A is $35, and it takes 2 machine hours to produce one Product A, then the contribution margin per unit of the constrained resource (machine hours) is $35/2 machine hours = $17.50/machine hour.

  - The shadow price shows how much (above the normal cost) that a company would be willing to pay in order to obtain one more unit of the scarce resource (assuming that it has not yet satisfied customer demand for the scarce resource). It is equal to the contribution margin per unit of the scarce resource for the product that the company is producing when the scarce resource is fully consumed.

Only one constrained resource, multiple products, limited customer demand
If there is a limit on customer demand for one or more of the products, the general rule is very similar to the above case with unlimited customer demand. First compute the contribution margin per unit of constrained resource for each product, then rank the products. The company should first make the product with the highest contribution margin per unit of the constrained resource, until customer demand for that product is satisfied. Then it should produce the product with the next-highest contribution margin per unit of the constrained resource, until customer demand for that product is satisfied, and so on.

- The shadow price for the constrained resource is the contribution margin per unit of the constrained resource for the product the company is producing when it runs out of the resource. Suppose a company sells 3 products, A, B & C and the contribution margin per machine hour for each of them is $12/hour, $15/hour, and $10/hour, respectively. The company should first produce B until customer demand is satisfied, then A, and then C. If the company runs out of machine hours while it is producing C, for example, the shadow price is $10/hour. The company would be willing to pay up to $10 (in addition to the normal cost of a machine hour) for each additional machine hour it could acquire.
**Demonstration problem-Constrained resource decisions (multiple products: 1 scarce resource)**

Bobshi Productions makes 3 products, X, Y, and Z. The only constrained resource is labor hours; there are only 100,000 labor hours available each year. You are given the following per-unit information:

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selling price</td>
<td>$9.00</td>
<td>$10.00</td>
<td>$33.00</td>
</tr>
<tr>
<td>Variable costs</td>
<td>1.00</td>
<td>6.00</td>
<td>17.00</td>
</tr>
<tr>
<td>Contribution margin</td>
<td>$8.00</td>
<td>$4.00</td>
<td>$16.00</td>
</tr>
<tr>
<td>Labor hrs required</td>
<td>1.25</td>
<td>0.80</td>
<td>20.00</td>
</tr>
</tbody>
</table>

**Required:**

a) Suppose there is unlimited customer demand for each product. Which product(s), and how many of each, should Bobshi produce? What is the total contribution margin if Bobshi follows your advice? What amount, above the normal cost for a labor hour, would Bobshi be willing to pay to acquire one more labor hour?

b) Suppose customer demand for X, Y, and Z is 40,000, 50,000, and 70,000 units, respectively. Which product(s), and how many of each, should Bobshi produce? What is the total contribution margin if Bobshi follows your advice? What amount, above the normal cost for a labor hour, would Bobshi be willing to pay to acquire one more labor hour?

**Solution to demonstration problem**

a) First compute the contribution margin per labor hour for each product:

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution margin per unit</td>
<td>$8.00</td>
<td>$4.00</td>
<td>$16.00</td>
</tr>
<tr>
<td>Labor hrs required</td>
<td>1.25</td>
<td>0.80</td>
<td>20.00</td>
</tr>
<tr>
<td>Contribution margin/hr</td>
<td>$6.40</td>
<td>$5.00</td>
<td>$0.80</td>
</tr>
</tbody>
</table>

With one scarce resource and unlimited customer demand, it will always be optimal to produce only one product. Since X has the highest contribution margin per labor hour, Bobshi should produce all Xs. Each X requires 1.25 labor hours, and 100,000 hours are available, so Bobshi can make 100,000/1.25 = 80,000 Xs. Total contribution margin is the $8.00 contribution margin per X times 80,000 Xs, or $640,000. The shadow price is the contribution margin per labor hour for the product that Bobshi is producing when it runs out of hours, which is of course, product X. Bobshi would be willing to pay up to $6.40 above the normal cost of a labor hour to acquire one more hour.

b) Use the contribution margin per direct labor hour for each product computed in part (a). Bobshi should produce Xs first, then Ys, and finally Zs until it runs out of direct labor hours. To produce the 40,000 units of X demanded by customers will use 40,000 units x 1.25 hrs/unit = 50,000 hours. To produce the 50,000 units of Y demanded by customers will use 50,000 units x 0.80 hrs/unit = 40,000 hours. This leaves 10,000 available hours to produce Z. The number of units of Z that can be produced with 10,000 hours is 10,000 hrs/20 hrs per unit, or 500 Zs, which is less than customer demand. Bobshi should make 40,000 Xs, 50,000 Ys, and 500 Zs.

Total contribution margin is 40,000 Xs times $8 + 50,000 Ys times $4 + 500 Zs times $16 = $528,000. Since Bobshi was making Zs when it ran out of labor hours, the shadow price is $0.80 per hour. Bobshi would be willing to pay up to $0.80 above the normal cost to acquire one more labor hour.
Multiple constrained resources, two products, limited or unlimited customer demand

When there are only two products, and multiple constrained resources, there is a solution technique that is useful in building your intuition for these types of problems, which are called linear programming problems. When there are two products the problem can be viewed graphically. If customer demand for any of the products is limited, it can be included as one of the constraints.

- With multiple products and multiple constraints, the problem is easier if you organize the information. A linear programming formulation is a method of organizing the data and includes an algebraic description of the objective function and of the constraints.
  
  - The objective function states what you are trying to achieve. In the product emphasis/constrained resource problems in this chapter, we are trying to maximize total contribution margin. The objective function for a company with two products, A and B, would be written as:

\[
\text{Max } \sum_{i=A,B} \text{CM}_i \cdot A + \text{CM}_B \cdot B,
\]

where \( A, B \) represent the number of units of products A and B produced and \( \text{CM}_i \) is the contribution margin per unit of product \( i \). If you were to read this aloud, you would say, "Max over your choice of A and B the total contribution margin from A and B".

- Each constraint is written as an inequality. If a company has two constrained resources, \( \alpha \) and \( \beta \), there would be two constraints:

\[
\alpha_A \cdot A + \alpha_B \cdot B \leq \text{Total amount of resource } \alpha \text{ available}, \quad \text{and}
\beta_A \cdot A + \beta_B \cdot B \leq \text{Total amount of resource } \beta \text{ available},
\]

where \( \alpha_i \) is the amount of resource \( \alpha \) it takes to make one unit of \( i \), and \( \beta_i \) is the amount of resource \( \beta \) it takes to make one unit of product \( i \).

- In this solution technique, draw a graph and label the axes as A and B. Then graph the constraint inequalities, remembering that graphing an inequality includes shading the area where the inequality is true. The area where all constraints are true (shaded) is the feasible set, and the optimal production of A and B will be at one of the corners of the set. An example is shown below:

The feasible set is the 4 sided object lined in bold. The optimal solution will be at one of the 3 circled corners. It is easy to compute total contribution margin at each corner, and then choose the corner with the highest total contribution margin.

[Diagram showing the feasible set and constraints]
Demonstration problem-Product emphasis/constrained resource decisions (2 products; 2 scarce resources)

Joseph’s Jewelry produces two products, silver rings (SR) and gold bracelets (GB). Production and contribution margin information is given below:

<table>
<thead>
<tr>
<th></th>
<th>SR</th>
<th>GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution margin per unit</td>
<td>$40</td>
<td>$70</td>
</tr>
<tr>
<td>Direct labor hours required per unit</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Machine hours required per unit</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>

Required:

a) Suppose DL hours are limited to 180 hours a week, but machine hours are unlimited. How many of each product should the company make? What is the total contribution margin for this production plan? What is the shadow price for direct labor hours? for machine hours?
b) Suppose machine hours are limited to 90 hours a week, but DL hours are unlimited. How many of each product should the company make? What is the total contribution margin for this production plan? What is the shadow price for direct labor hours? for machine hours?
c) Suppose that DL hours are limited to 180 hours a week and machine hours are limited to 90 hours a week. Formulate this as a linear programming problem. Draw a graph of the trade-offs between SR and GB, putting SR on the y axis. Put both constraints on the graph, labeling them and the values where they intersect the GB or SR axis. How many of each product should the company make? What is the total contribution margin for this production plan?

Solution to demonstration problem

First compute the contribution margin per direct labor hour and the contribution margin per machine hour for each product, because parts (a) and (b) are actually problems with only one scarce resource.

<table>
<thead>
<tr>
<th></th>
<th>SR</th>
<th>GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution margin per direct labor hour</td>
<td>$3.33</td>
<td>$3.89</td>
</tr>
<tr>
<td>Contribution margin per machine hour</td>
<td>8.00</td>
<td>7.00</td>
</tr>
</tbody>
</table>

a) Since direct labor hours is the only constrained resource, Joseph will make only the product with the highest contribution margin per direct labor hour, which is GB. If there are 180 direct labor hours available each week, Joseph can make 180 hours/18 hours per GB = 10 GB per week. The total contribution margin per week is 10 GB times $70/GB = $700. Since Joseph has unlimited machine hours, he would be willing to pay $0 for an extra machine hour. However, he’d be willing to pay up to $3.89 over his normal cost of a direct labor hour to acquire one more direct labor hour.

b) Since machine hours is the only constrained resource, Joseph will make only the product with the highest contribution margin per machine hour, which is SR. If there are 90 machine hours available each week, Joseph can make 90 hours/5 hours per SR = 18 SR per week. The total contribution margin per week is 18 SR times $40/SR = $720. Since Joseph has unlimited direct labor hours, he would be willing to pay $0 for an extra direct labor hour. However, he’d be willing to pay up to $8 over his normal cost of a machine hour to acquire one more machine hour.

solution continues on next page →
Solution to demonstration problem continued

c) The linear programming formulation is:

\[
\begin{align*}
\text{Max} & \quad 40SR + 70GB, \text{ subject to:} \\
\text{SR,GB} \quad & \quad 12SR + 18GB \leq 180 \quad \text{direct labor hour constraint} \\
& \quad 5SR + 10GB \leq 90 \quad \text{machine hour constraint}
\end{align*}
\]

The graph for this problem is:

The constraints are easy to graph. For the direct labor hour constraint, note that when GB = 0, SR = 180/12 = 15 and when SR = 0, GB = 180/18 = 10. For the machine hour constraint, note that when GB = 0, SR = 90/5 = 18 and when SR = 0, GB = 90/10 = 9.

To find the number of SR and GB where the constraints intersect, either use substitution (solve the first constraint as an equality for SR, substitute this into the second constraint and solve for GB) or “cleverly” subtract one constraint from the other, like this:

\[
\begin{align*}
12SR + 18GB &= 180 \\
5SR + 10GB &= 90 \quad \text{multiply both sides of this by 1.8 to get} \\
3SR + 0GB &= 18, \text{ or } SR = 6.
\end{align*}
\]

If SR = 6, then 12SR + 18GB = 180, or 12 x 6 + 18GB = 180, or 18GB = 180 – 72 = 108, or GB = 6.

Now, what is the total contribution margin (TCM) at each of the 3 corners?

- Point A: TCM = 15($40) + 0($70) = $600
- Point B: TCM = 6($40) + 6($70) = $660
- Point C: TCM = 0($40) + 9($70) = $630

Point B is optimal. Joseph should produce 6 SR and 6 GB each week to earn a TCM of $660 per week.
Multiple constrained resources, multiple products, limited or unlimited customer demand

When there are two products and more than two constraints, you can still use the graphing solution approach shown above; there will just be more corners of the feasible set that could be optimal solutions. However, when there are more than two products, the graphing approach will not work. The problem can still be solved mathematically, but it is tedious. There are several software packages that can solve linear programming problems quickly, and the output from the software packages provides useful information beyond just the optimal production plan.

The text and this study guide discuss how to use an Excel add-in called Excel Solver to solve linear programming problems. The demonstration problem below shows how to interpret the Excel Solver output, and Exhibit 4A.2 of the text, shows how to put data into the Excel dialog boxes. The output provides information about which constraints are binding (i.e. all of the resource is consumed), and which constraints are not binding, or slack (i.e. there are resources remaining after the production of the optimal plan).

The output shown in this study guide is from Excel 2000, version 9.0. The output may appear slightly different under different versions of Excel.

### Demonstration problem-Constrained resource decisions & Excel Solver (3 products; 2 scarce resources)

Misha Manufacturing makes 3 products, A, B, and C. Each year, Misha has 6,000 direct labor hours and 10,000 machine hours available. Production and contribution margin information is given below:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>$100</td>
<td>$8</td>
<td>$40</td>
</tr>
<tr>
<td>labor</td>
<td>10</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>machine</td>
<td>20</td>
<td>10</td>
<td>4</td>
</tr>
</tbody>
</table>

**Required:**

a) Use Excel Solver to find the optimal number of each product that Misha should make. In the Solver Results dialog box, request the answer and sensitivity reports. Interpret the answer report.

b) Use the Sensitivity Report to determine and interpret the shadow prices for the direct labor and machine hour constraints. What does the shadow price on the nonnegativity of Product C mean?

**Solution to demonstration problem**

The formulas entered into the Excel worksheet are the objective function in cell C7 and the left hand sides (LHS) of the constraints in cells B10 and B11. The right hand side (RHS) of the constraints are entered into cells C10 and C11. After Solver is run, the optimal production plan will appear in cells B6, C6 and D6. The nonnegativity constraints are needed for most problems so that Excel Solver doesn’t allow a negative quantity of As, Bs, or Cs to be chosen. The formulas are shown on the next page.

solution continues on next page →
Solution to demonstration problem continued

```
<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Misha</td>
<td>Manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Product</td>
<td>Mix</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Changing</td>
<td>Cells</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Target Cell:</td>
<td>=100<em>B5+80</em>C5+40*D5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Constraints:</td>
<td>Used</td>
<td>Maximum</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Direct labor</td>
<td>=10<em>B5+10</em>C5+8*D5</td>
<td>6000</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Machine hours</td>
<td>=20<em>B5+10</em>C5+4*D5</td>
<td>10000</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Nonnegativity</td>
<td>constraints:</td>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>A</td>
<td>=B5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>B</td>
<td>=C5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>C</td>
<td>=D5</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

a) The Excel Solver Answer Report is shown below:

Microsoft Excel 9.0 Answer Report

<table>
<thead>
<tr>
<th>Cell</th>
<th>Name</th>
<th>Original Value</th>
<th>Final Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C7</td>
<td>Target Cell: B</td>
<td>0</td>
<td>$56,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cell</th>
<th>Name</th>
<th>Original Value</th>
<th>Final Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B5</td>
<td>Changing Cells: A</td>
<td>0</td>
<td>400</td>
</tr>
<tr>
<td>$C5</td>
<td>Changing Cells: B</td>
<td>0</td>
<td>200</td>
</tr>
<tr>
<td>$D5</td>
<td>Changing Cells: C</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cell</th>
<th>Name</th>
<th>Cell Value</th>
<th>Formula</th>
<th>Status</th>
<th>Slack</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B$10</td>
<td>Direct labor hours Used</td>
<td>6000</td>
<td>$B$10&lt;=$C$10</td>
<td>Binding</td>
<td>0</td>
</tr>
<tr>
<td>$B$11</td>
<td>Machine hours Used</td>
<td>10000</td>
<td>$B$11&lt;=$C$11</td>
<td>Binding</td>
<td>0</td>
</tr>
<tr>
<td>$B$14</td>
<td>A Used</td>
<td>400</td>
<td>$B$14&lt;=$C$14</td>
<td>Not Binding</td>
<td>400</td>
</tr>
<tr>
<td>$B$15</td>
<td>B Used</td>
<td>200</td>
<td>$B$15&lt;=$C$15</td>
<td>Not Binding</td>
<td>200</td>
</tr>
<tr>
<td>$B$16</td>
<td>C Used</td>
<td>0</td>
<td>$B$16&lt;=$C$16</td>
<td>Binding</td>
<td>0</td>
</tr>
</tbody>
</table>
```

solution continues on next page →
Solution to demonstration problem continued

The optimal production plan is to produce 400 As, 200 Bs, and zero Cs. This will yield a total contribution margin of $56,000. All of the direct labor hours and all of the machine hours are consumed by this production plan; these constraints are binding. The nonnegativity constraints for products B and C are not binding because the optimal plan includes a positive quantity of these products. Since the optimal plan includes zero product C, the nonnegativity constraint for product C is binding.

b) The Excel Solver Sensitivity Report is shown below:

<table>
<thead>
<tr>
<th>Adjustable Cells</th>
<th>Final Value</th>
<th>Reduced Gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B$5 Changing Cells: A</td>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>$C$5 Changing Cells: B</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td>$D$5 Changing Cells: C</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constraints</th>
<th>Final Value</th>
<th>Shadow Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B$10 Direct labor hours Used</td>
<td>6000</td>
<td>6</td>
</tr>
<tr>
<td>$B$11 Machine hours Used</td>
<td>10000</td>
<td>2</td>
</tr>
<tr>
<td>$B$14 A Used</td>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>$B$15 B Used</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td>$B$16 C Used</td>
<td>0</td>
<td>-15.99995565</td>
</tr>
</tbody>
</table>

This report provides information about the shadow prices for the constraints. Misha would be willing to pay up to $6 above the normal cost of a direct labor hour to obtain one more direct labor hour.

Misha would be willing to pay up to $2 above the normal cost of a machine hour to obtain one more machine hour.

The optimal plan includes no units of Product C. Misha would have to be given nearly $16 in order to produce one unit of C because the production of a unit of C uses resources that are more profitably used to produce Products A and B.

Q6: What qualitative factors are important to nonroutine operating decisions?

Qualitative information is information that cannot be expressed quantitatively. Examples include the effects of decisions on employee morale or the company’s reputation, and the quality of products or services obtained from suppliers. Qualitative information can sometimes have more effect on a decision than quantitative information. Examples of qualitative concerns (for which a company might attempt to gather qualitative information) for the types of nonroutine operating decisions covered in this chapter follow.

- Special order decisions
  - Will regular customers have concerns about the company selling products to their competitors at a lower price?
  - Will accepting the special order forge a valuable relationship with a new customer?
  - If the special order replaces regular business, what is the effect on the company’s reputation when regular orders are not filled in a timely fashion?
• Keep or drop decisions
  o What will be the effect on the morale of remaining employees if a business segment is dropped?
  o What is the effect of on the company’s reputation of dropping (or keeping) the business segment?
  o Will dropping the business segment increase or decrease sales of the remaining business segments?

• Insource or outsource (make or buy) decisions
  o Will the supplier be able to provide sufficient quantities of satisfactory quality of the item? (make or buy)
  o Is the business activity one of the core competencies of the company? (insource or outsource)

• Product emphasis/constrained resource decisions
  o Is the quantitative analysis’ optimal production plan in agreement with the company’s long-term strategic plans?
  o Will relaxing a labor hour or machine hour constraint affect product quality?
  o How would customers respond to a price change?
  o Can a constraint on the availability of materials be relaxed by changing suppliers, without reducing product quality?

Q7: What limitations and uncertainties should be considered when making nonroutine operating decisions?
In all decision making, the quality of the quantitative and qualitative information available should be considered. This is especially true for nonroutine operating decisions, because a company may have less experience gathering this type of information than it does for routine decisions.

• There are always uncertainties accompanying the information; suppliers may change their prices, future market forces may require a change in the product’s price, or competitors may introduce a product that makes the company’s product obsolete.

• The quality of the information may be lower if the information is not up-to-date or if the accounting system is not aggregating and summarizing cost and revenue information in an appropriate way.

• The information used in making the decision is only useful input to a quantitative analysis technique if the assumptions of the technique are not violated. Companies need to consider whether linear cost and revenue assumptions hold for any range of activity. If the assumptions do hold for some relevant range of activity, then companies need to make sure they plan to operate within this relevant range.

The quality of the decision-making process must also be taken into consideration.

• Companies must watch for decision-maker bias. Decision-makers may have a stake in a decision. A product line manager most likely does not want his product discontinued, and a supervisor of a particular business process will not want this activity outsourced. Since these individuals are so close to the necessary information, they frequently cannot be removed from the decision-making process.
• The decision-making process can be improved by performing sensitivity analyses, which show how the decision might change if the input data changes.

• The decision-making process should include the consideration of the company’s long-term strategic plans. Even if the analysis shows that a particular business segment should be eliminated, for example, keeping the segment may be more in line with the company’s goals.
PROBLEM SET B (Learning Objectives 5 - 7)

True-False: Indicate whether each of the following is true (T) or false (F) in the space provided.

_____ 1. The qualitative information in a decision may override the quantitative analysis.

_____ 2. The shadow price is the same thing as the contribution margin per unit of the constrained resource.

_____ 3. The shadow price for a resource that has a slack constraint is zero.

_____ 4. In all product emphasis/constrained resource decisions the company should make the product with the highest contribution margin per unit.

_____ 5. In a product emphasis/constrained resource decision with unlimited customer demand and one constrained resource, it will always be optimal to produce only one product.

_____ 6. In a product emphasis/constrained resource decision with limited customer demand and one constrained resource, it will always be optimal to produce more than one product.

_____ 7. In a product emphasis/constrained resource decision with two products and four constrained resources, the problem can be solved by graphing the constraints.

_____ 8. The quality of information used for nonroutine decisions is most likely higher than the quality of information used for routine decisions.

_____ 9. Sensitivity analysis is used to see how the changes in the input data for a decision might change the results of the quantitative analysis.

_____ 10. Since the quality of the decision-making process is reduced by decision-maker bias, all persons with a stake in the decision should be removed from the process.
Multiple choice: Write the letter that represents the best choice in the space provided.

Use the following information for questions 1 - 3:
Clark, Inc. makes 3 products, B, C, and D. Clark only has 110 machine hours available each week. Contribution margin, machine hour requirements, and weekly customer demand information is as follows:

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>8</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>0.6</td>
<td>0.4</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>600</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

1. In what order should the products be produced?
   a. B, C, D
   b. C, D, B
   c. D, B, C
   d. B, D, C

2. Determine the number of units of each product that should be produced.
   a. 200 Bs, 0 Cs, and 100 Ds
   b. 150 Bs, 0 Cs, and 100 Ds
   c. 0 Bs, 600 Cs, and 0 Ds
   d. 200 Bs, 100 Cs, and 100 Ds

3. Determine the maximum amount that Clark would be willing to pay, above the normal cost, for one more machine hour per week.
   a. $10.00
   b. $13.33
   c. $35.00
   d. $0.00

4. Quantitative factors in a nonroutine operating decision
   a. include nonfinancial information
   b. could never include product quality considerations
   c. are always relevant to a nonroutine operating decision
   d. are of a higher quality than qualitative factors

5. Qualitative information used in a make or buy decision is least likely to include
   a. the reliability of the supplier
   b. the quality of the supplier’s product
   c. the effect of purchasing a component on the company’s long-term strategic plan
   d. all of the above are good examples of qualitative factors that may be considered in a make or buy decision
Use the following information for questions 6 - 8:
Karl, Inc. makes 2 products, W and X. Karl only has 100 machine hours and 400 labor hours available each week. Customer demand for both products is unlimited. Contribution margin and machine and direct labor hour requirements are as follows:

<table>
<thead>
<tr>
<th></th>
<th>W</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contribution margin per unit</strong></td>
<td>$12</td>
<td>$28</td>
</tr>
<tr>
<td><strong>Machine hours required per unit</strong></td>
<td>1.2</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>Labor hours required per unit</strong></td>
<td>2.4</td>
<td>4.4</td>
</tr>
</tbody>
</table>

6. Which of the following statements is true?
   a. The machine hour constraint is slack.
   b. The labor hour constraint is binding.
   c. Karl should only produce one product.
   d. This problem cannot be solved without using software or tedious mathematical computations not covered in this chapter.

7. What is the optimal production plan?
   a. Produce 83 Ws and no units of X.
   b. Produce 45 Xs and no units of W.
   c. Produce 83 Ws and 45 Xs.
   d. This problem cannot be solved without using software or tedious mathematical computations not covered in this chapter.

8. How much would Karl be willing to pay, above the normal cost, to obtain one more machine hour and one more labor hour, respectively?
   a. $12.73 and $6.36
   b. $12.73 and $0
   c. $10.00 and $0
   d. This problem cannot be solved without using software or tedious mathematical computations not covered in this chapter.

9. Which of the following is considered a bottleneck in a product emphasis/constrained resource decision?
   a. Suppliers can only provide 1,000 pounds of direct material each month.
   b. The company’s 12 machines can only operate 18 hours per day.
   c. Customer demand for product A is limited to 1200 units per month.
   d. All of the above are considered bottlenecks.

10. Which of the following is true?
    a. In a product emphasis/constrained resource decision with 2 products and 2 constraints, it will always be optimal to make both products.
    b. In a product emphasis/constrained resource decision with 2 products and 1 constraint, it will always be optimal to make only one product.
    c. Product emphasis/constrained resource decisions with more than 2 products and more than 2 constraints cannot be solved without software.
    d. All of the above are true.
END OF CHAPTER EXERCISES

Exercises: Write your answer in the space provided.
1. The Maxwell Company, your client, has asked for your assistance in analyzing the mix of their board game sales. Their objective is to increase profits without expanding capacity. The company gathered the following data for your use:

<table>
<thead>
<tr>
<th>Game</th>
<th>Estimated customer demand</th>
<th>Selling price per unit</th>
<th>Materials cost per unit</th>
<th>Labor costs per unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligopoly</td>
<td>100,000</td>
<td>$6.00</td>
<td>$2.00</td>
<td>$1.50</td>
</tr>
<tr>
<td>War of the Moons</td>
<td>60,000</td>
<td>4.75</td>
<td>0.50</td>
<td>1.20</td>
</tr>
<tr>
<td>Money</td>
<td>70,000</td>
<td>3.25</td>
<td>1.25</td>
<td>0.50</td>
</tr>
<tr>
<td>Risky</td>
<td>80,000</td>
<td>2.50</td>
<td>0.25</td>
<td>0.50</td>
</tr>
</tbody>
</table>

The above information is based on a labor rate of $5.00 per hour. The factory has an annual capacity of 35,000 labor hours. Fixed costs average $10,000 per month. Variable administrative costs are estimated at 50% of the labor cost.

a) Determine the order that the games should be produced.
   Produce first ______________
   Produce second _____________
   Produce third ______________
   Produce fourth _____________

b) Determine the quantity of each game that should be produced.
   Oligopoly _________________
   War of the Moons __________
   Money _________________
   Risky _________________

c) What is the shadow price for labor? ___________________
2. Gamma Company is considering the feasibility of purchasing from a nearby supplier a subcomponent that it currently makes. Gamma produces and uses 10,000 of the subcomponents each year. The supplier will furnish the subcomponent for $4.50 per unit, including shipping costs. Currently, Gamma incurs materials costs of $1.06/unit when producing the subcomponent. Other costs assigned to the production of the subcomponent are direct labor costs of $3/unit and fixed manufacturing overhead of $2/unit. The machine used to produce the subcomponent is on a month-to-month lease for $100/month.

Determine whether Gamma should make or buy the subcomponent. What is the advantage of your chosen alternative over the other one?

Make or Buy (Circle one) Advantage ____________________________

3. Beta Company expects to produce 30,000 units next year, which is 50% of its capacity. The selling price of each unit is $20. The variable costs per unit are $6.50, and fixed manufacturing overhead of $0.60 will be assigned to each unit. Another company asks Beta for a one-time special order of 10,000 units at a selling price of $8 per unit.

a) Should Beta accept or reject the special order? What is the effect on profit if Beta follows your advice?

Accept or Reject (Circle one) Advantage ____________________________

b) Assume instead that 30,000 units is 80% of capacity. In this case what is the effect on profit if Beta follows accepts the special order?

Effect on profit ____________________________
4. Foix Industries has 3 divisions. Income statements for last year are shown below. Since no changes in revenues or expenses are expected this year, Foix is considering the elimination of South Division. In the South Division, 40% of its division fixed costs are unavoidable. If South is eliminated, the North Division will lose the volume discounts from a supplier to both divisions; this lost amount is estimated at $60,000 per year. However, this elimination would allow West Division to save $80,000 per year in travel expenses for its salespersons because they could use the abandoned offices of South Division. Since South and West produce related products, the elimination of South means that West would lose approximately $100,000 of sales revenue.

<table>
<thead>
<tr>
<th></th>
<th>South</th>
<th>North</th>
<th>West</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenues</td>
<td>$220,000</td>
<td>$600,000</td>
<td>$320,000</td>
<td>$1,140,000</td>
</tr>
<tr>
<td>Variable costs</td>
<td>$140,000</td>
<td>$285,000</td>
<td>$160,000</td>
<td>$585,000</td>
</tr>
<tr>
<td>Contribution margin</td>
<td>$80,000</td>
<td>$315,000</td>
<td>$160,000</td>
<td>$555,000</td>
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<tr>
<td>Division fixed costs</td>
<td>$100,000</td>
<td>$115,000</td>
<td>$85,000</td>
<td>$300,000</td>
</tr>
<tr>
<td>Allocated corporate fixed costs</td>
<td>$40,000</td>
<td>$100,000</td>
<td>$65,000</td>
<td>$205,000</td>
</tr>
<tr>
<td>Operating income</td>
<td>($60,000)</td>
<td>$100,000</td>
<td>$10,000</td>
<td>$50,000</td>
</tr>
</tbody>
</table>

a) What is the effect on profit if the South Division is dropped? ___________________

b) List some of the concerns that Foix might have about uncertainties and the quality of the information it is using to make this decision.

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

c) List some examples of the qualitative factors that Foix might have to consider in this decision.

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________
5. Anderson Enterprises manufactures 2 products that require both machine processing and labor operations. There is unlimited demand for both products. Unit prices, cost data, and processing requirements are shown below. There are only 160,000 machine hours and 780,000 DL hours available.

<table>
<thead>
<tr>
<th></th>
<th>Product A</th>
<th>Product M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit selling price</td>
<td>$80</td>
<td>$220</td>
</tr>
<tr>
<td>Unit variable costs</td>
<td>$40</td>
<td>$90</td>
</tr>
<tr>
<td>Machine hours per unit</td>
<td>0.4</td>
<td>1.4</td>
</tr>
<tr>
<td>DL hours per unit</td>
<td>2.0</td>
<td>6.0</td>
</tr>
</tbody>
</table>

a) Formulate this as a linear programming problem.

b) Draw a graph with M on the y axis and A on the x axis.

c) Find the optimal production plan, and determine the total contribution margin for that plan.

Number of units of M

Number of units of A

Total contribution margin
6. Cowboy Hats, Inc. sells custom felt cowboy hats in 3 sizes: 2 gallon hats, 5 gallon hats, and 10 gallon hats for the real rancher who rides the range for days and uses his hat for a wash basin. There are 3 resource constraints; Cowboy can only obtain a limited quantity of the special compressed, waterproof felt it requires, and the cutting and steaming machines have a limited number of hours available. There is limited customer demand for all 3 products. The contribution margin and constraint data for all 9 constraints (3 scarce resources, 3 customer demand limits, and 3 nonnegativity) were entered into Excel Solver. The answer and sensitivity reports are shown below this text. Use this output to answer the questions on the next page. It’s acceptable to report the production of partial units because partial units of this period can be completed next period.

<table>
<thead>
<tr>
<th>Target Cell (Max)</th>
<th>Cell</th>
<th>Name</th>
<th>Original Value</th>
<th>Final Value</th>
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<tbody>
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<td>$C7</td>
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<table>
<thead>
<tr>
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<th>Cell</th>
<th>Name</th>
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<th>Final Value</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>$C5</td>
<td>Changing Cells: 5 Gallon</td>
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<td>400</td>
<td></td>
</tr>
<tr>
<td>$D5</td>
<td>Changing Cells: 10 Gallon</td>
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<table>
<thead>
<tr>
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<th>Cell</th>
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<th>Slack</th>
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<tr>
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<td>Felt Used</td>
<td>773</td>
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<tr>
<td>$B11</td>
<td>Cutting hours Used</td>
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<tr>
<td>$B12</td>
<td>Steaming hours Used</td>
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<td>Binding</td>
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<tr>
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<td>Demand for 2 Gallon Used</td>
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<td>$B$13&lt;=$C$13</td>
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<tr>
<td>$B14</td>
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<td>Binding</td>
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</tr>
<tr>
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</tr>
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<td>$B$16&lt;=$C$16</td>
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</tr>
<tr>
<td>$B17</td>
<td>5 Gallon Used</td>
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<td>$B$17&lt;=$C$17</td>
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</tr>
<tr>
<td>$B18</td>
<td>10 Gallon Used</td>
<td>26.6666</td>
<td>$B$18&lt;=$C$18</td>
<td>Not Binding</td>
<td>26.6666</td>
<td></td>
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<table>
<thead>
<tr>
<th>Microsoft Excel 9.0 Sensitivity Report</th>
<th>Adjusted Cells</th>
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<tbody>
<tr>
<td>$B5</td>
<td>Changing Cells: 2 Gallon</td>
<td>125.3333</td>
<td>0</td>
</tr>
<tr>
<td>$C5</td>
<td>Changing Cells: 5 Gallon</td>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>$D5</td>
<td>Changing Cells: 10 Gallon</td>
<td>26.6666</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constraints</th>
<th>Cell</th>
<th>Name</th>
<th>Final Value</th>
<th>Shadow Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B10</td>
<td>Felt Used</td>
<td>773</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>$B11</td>
<td>Cutting hours Used</td>
<td>600</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>$B12</td>
<td>Steaming hours Used</td>
<td>400</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>$B13</td>
<td>Demand for 2 Gallon Used</td>
<td>125</td>
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<td></td>
</tr>
<tr>
<td>$B14</td>
<td>Demand for 5 Gallon Used</td>
<td>400</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>$B15</td>
<td>Demand for 10 Gallon Used</td>
<td>27</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>$B16</td>
<td>2 Gallon Used</td>
<td>125.3333</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>$B17</td>
<td>5 Gallon Used</td>
<td>400</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>$B18</td>
<td>10 Gallon Used</td>
<td>26.6666</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
a) What is the optimal production plan? Round your answers to the nearest whole hat.

2 Gallon __________ 5 Gallon __________ 10 Gallon __________

b) What is the RHS of each of the 3 resource constraints?

Felt __________ Cutting hours __________ Steaming hours __________

c) What is the RHS of each of the 3 customer demand constraints?

2 Gallon __________ 5 Gallon __________ 10 Gallon __________

d) The supplier of the felt told Cowboy that it could obtain more felt than it currently purchases if Cowboy would be willing to pay only 3% more for the additional square yards of felt. Should Cowboy consider this? Why or why not?

e) Cowboy recently located a steaming machine that it could rent for $30 per hour. Should Cowboy consider renting this machine? Why or why not? What is the effect on profit if Cowboy rented this machine for an additional 20 hours per period?

f) Cowboy recently located a cutting machine that it could rent for $30 per hour. Should Cowboy consider renting this machine? Why or why not? What is the effect on profit if Cowboy rented this machine for an additional 20 hours per period?

g) Cowboy’s sales manager is considering a special advertising campaign targeted at increasing customer demand for 10 gallon hats. The campaign will cost $800 and is expected to increase demand for the 10 gallon hats by 100 hats. Should Cowboy consider this campaign? Why or why not? What is the effect on profit if Cowboy begins this campaign?

h) Cowboy’s sales manager is considering a special advertising campaign targeted at increasing customer demand for 5 gallon hats. The campaign will cost $800 and is expected to increase demand for the 5 gallon hats by 100 hats. Should Cowboy consider this campaign? Why or why not? What is the effect on profit if Cowboy begins this campaign?
SOLUTION TO PROBLEM SET A

True-False:

1. F Although fixed costs are often irrelevant, any fixed cost that differs across the alternatives is relevant.
2. T Some people use the terms relevant, avoidable and incremental cost interchangeably.
3. F This is false because the opportunity cost of the regular business replaced by the special order was not included.
4. T
5. T The general rule is to drop the segment if contribution margin less avoidable fixed costs is negative. If contribution margin is negative, then contribution margin less avoidable fixed costs will also be negative.
6. F This is false; see the statement about the general rule for keep or drop decisions in #5 above.
7. T Opportunity costs are the benefits forgone when one alternative is chosen over another. By definition, then, this differs across the alternatives and is hence relevant.
8. T The opportunity cost of accepting a special order includes the lost contribution margin on regular business when that business is replaced. If the company has idle capacity, no regular business is replaced.
9. T This is true; see the discussion for #8 above.
10. F Although variable costs are often relevant, any variable cost that does not differ across the alternatives is irrelevant.

Multiple choice:

1. B The variable costs per unit if Wright makes the subcomponent are $8/unit, or $80,000 annually. Add to this cost the $28,000 salary for the technician that is required when the subcomponent is produced and the $25,000 opportunity cost of not leasing out the released capacity to arrive at a relevant cost to make of $133,000. The cost to buy is $15 x 10,000 = $150,000. The cost to buy exceeds the relevant cost to make by $17,000, so Wright should really be making the subcomponent.

If you chose A, then you used the cost to make the product of $11/unit ($8/unit variable cost + $3/unit fixed cost). This is incorrect – fixed costs are not relevant in this decision.
2. D The manufacturing overhead cost per unit is $8 variable and $4 fixed, and the $4 is not relevant. The total variable costs to produce a unit are $6 + $14 + $8 = $28. This exceeds the special order price of $30/unit ($600,000/20,000 units) by $2 per unit. The special order will increase profits by $40,000.

If you chose A, then you computed the incremental cost of producing the special order as $6 + $14 + $4; you used fixed manufacturing overhead as an incremental cost instead of variable manufacturing overhead.

If you chose B, then you used the difference in the regular and special order prices of $10 ($40 - $30) times 20,000 units. This ignores relevant costs of producing the special order.

If you chose C, then you used the total manufacturing cost per unit of $32 ($6 + $14 + $12) and compared it to the special order price of $30. This is not correct because the $32 cost includes irrelevant fixed costs.

If you got this question wrong, then you got the next one wrong. Stop now, go back and re-do #3 and #4. Then come back and check your answers.

3. C Taylor would like a profit of $50,000, which is $50,000/20,000 units = $2.50 per unit. The minimum price per unit must cover variable costs of $28 plus the required profit of $2.50.

If you chose A then you added the $32 total production cost per unit to the required profit per unit of $2.50. The $32 includes irrelevant fixed costs.

If you chose B then you added the required profit of $2.50 to the selling price of a regular unit, which makes no sense at all (sorry!).

If you chose D, then you took the correct incremental (relevant) production cost of $28 and subtracted the required profit per unit on the special order. It may seem that costs and profit are “opposites”, but in this case you add them; you want the special order price to cover costs and the required profit.

4. A The opportunity cost of accepting the order is the lost contribution margin on the 8,000 units of replaced regular business, or ($40 - $28) x 8,000 = $96,000. The increase in profit under idle capacity was $40,000; $40,000 - $96,000 = a $56,000 decrease in profits if the order is accepted.

If you chose B, you forgot the opportunity cost for the lost regular business.

If you chose C, you included the opportunity cost but you incorrectly computed the opportunity cost as $40 - $32 production cost. The $32 includes irrelevant fixed costs.

If you chose D, then you included the opportunity cost but incorrectly computed it as the $40 of lost revenue. When Taylor loses a unit of regular business, it does not lose the $40 in revenue, it loses the contribution margin of $12 ($40 - $28).
5. B Gidget’s contribution margin is $400,000 = $225,000 = $175,000. 
Contribution margin less avoidable fixed costs = $175,000 - $130,000 = 
$45,000 increase in profit if Moore keeps the Gidget product line, or a 
$45,000 decrease if it drops the Gidget product line.
If you chose A or D then you forgot the general rule for keep or drop 
decisions.
If you chose C, you subtracted allocated corporate fixed expenses from 
the contribution margin, instead of avoidable fixed expenses.

6. B This problem is really here to remind you that contribution margin per unit is 
selling price per unit less all variable costs per unit, not just production 
variable costs. The selling price is $10/unit, and the per unit variable costs 
are $2.75 for direct materials (because in 2005 Solo will make a 
subcomponent for $0.75 per unit, and in 2004 it purchased the 
subcomponent for $1.00), $1.50 for direct labor, $0.50 for variable 
manufacturing overhead, and $0.75 for variable selling & admin. expenses, 
or $5.50 total. The contribution margin/unit is $10.00 - $5.50 = $4.50.
If you chose A then you forgot to include the variable selling & 
administrative expenses.
If you chose C then you took the total variable costs from 2004, adjusted 
for the decrease in materials costs for 2005, then divided this by 80,000 
units of production in 2005. Remember that the total variable costs shown 
for 2004 are based on 100,000 units of production.
If you chose D then your error was similar to the one described for 
answer choice C but you compounded the error by including fixed costs in 
the numerator.
If you got this one wrong, you probably got #7 and #8 wrong. Go back 
and re-do your answers for #7 and #8. Then come back and check your 
answers.

7. C The contribution margin per unit in 2005 is $4.50, so the total contribution 
margin is $4.50 x 80,000 units = $360,000. Fixed costs in 2005 will be the 
same as 2004: $100,000 + $60,000 = $160,000. Therefore, expected 
operating income in 2005 = $360,000 - $160,000 = $200,000.
If you chose A then you incorrectly assumed that the fixed costs in 2005 
would be 80% times the fixed costs in 2004 because 2005 activity was only 
80% of 2004 activity. Remember that total fixed costs don’t change as 
activity within the relevant range changes.
If you chose B you used correct 2005 revenue, but you used 2004 cost 
information and updated it for the decrease in materials costs but not for the 
change in activity level.
If you chose D then you were just guessing!
8. **B** To answer this, you cannot compare the income of 2004 to the income of 2005 because of the difference in volume. Instead, note that the subcomponent cost $1 in 2004 but only $0.75 in 2005. This $0.25 savings times 80,000 units = an increase of $20,000.
   
   If you chose A then you were on the right track but you multiplied the $0.25 savings times 100,000 units instead of 80,000 units.
   
   If you chose C you compared the 2004 income to the 2005 income. The difference between these two figures is attributable to the volume difference as well as the decision to produce the component internally.
   
   If you chose D, then you chose A for #7, and carried the error through to #8.

9. **C** Answers A, B and D are all relevant to a special order decision. The contribution margin per unit of regular business is only relevant if some regular business needs to be replaced.

10. **D** This question is here to remind you to beware of per-unit fixed costs. The fixed cost per unit of $2 ($1.50 + $0.50) is only valid for 100,000 units of activity. Total fixed costs do not change as activity changes.
   
   If you chose A then you multiplied the $2/unit fixed cost times the new level of activity of 80,000 units.
   
   If you chose B then you correctly used the 100,000 units of activity but included only fixed manufacturing overhead and forgot fixed selling & administrative expenses.
   
   If you chose C then you used only the fixed manufacturing overhead, ignoring fixed selling & administrative overhead, and multiplied it by the 80,000 units of activity for 2005.

11. **B** The capacity of Loso is sufficient to produce the special order without replacing regular business. Variable costs for the special order are $5 for materials, $2 for labor, $1 for variable manufacturing overhead, plus $0.40 (50% x $0.80) for variable selling & administrative expenses, or $8.40 total. If a special machine is rented for the special order at a cost of $15,000, this is an extra $0.50 ($15,000/30,000 units) that must be covered by the special order price. The minimum acceptable price is $8.40 + $0.50 = $8.90.
   
   If you chose A then you incorrectly computed the variable selling & administrative expenses associated with the special order.
   
   If you chose C then you computed the variable costs incorrectly. You first multiplied the given per-unit information by the 100,000 units of activity in 2004, adjusted for the change in variable selling & administrative expenses, and then divided by 80,000 units of activity in 2005.
   
   If you chose D then you included irrelevant fixed costs in your computation of the relevant cost of producing the special order.
12. A  The order can only be accepted if 10,000 units of regular business are replaced (80,000 regular units + 30,000 special order units = 110,000, which exceeds capacity by 10,000 units). The contribution margin per unit of regular business is $15.00 – variable costs per unit of $8.80 = $6.20. The opportunity cost of accepting the order is $6.20 x 10,000 replaced regular units = $62,000. Each unit is the special order must cover the $8.90 discussed in #11 plus its share of this opportunity cost. $8.90 + $62,000/30,000 units = $10.97.

If you chose B then you added the contribution margin of a regular unit to the $8.90. This would be correct if every special order unit replaced a regular unit (i.e. if 30,000 units of regular business were replaced).

If you chose C then you were close, but you incorrectly computed the contribution margin per unit on regular units to be $6.60. You did this by assuming that regular units had 50% of the variable selling & administrative expenses listed in the given information.

If you chose D then you made both of the mistakes mentioned in B and C.

13. C  The general rule is to keep the segment if the contribution margin exceeds the avoidable fixed cost. $16,000 - $12,000 = $4,000, so Product C should not be dropped. If it is, this $4,000 will be lost.

If you chose A then you included irrelevant unavoidable fixed costs.

If you chose B then you forgot the general rule for keep or drop decisions.

If you chose D then you were confused about the general rule and used unavoidable fixed costs instead of avoidable fixed costs.

If you got this one wrong, you probably got #14 and #15 wrong. Stop now and go back to re-do your answers for #14 and #15. Then come back and check your answers.

14. D  In #13 we determined that profit will decrease by $4,000 if Product C is dropped. Now, dropping Product C will save $1,500, so the net effect on profit is a decrease of $4,000 less this $1,500 savings.

If you chose A then you included irrelevant unavoidable fixed costs (and you chose A for #13).

If you chose B then you chose B for #13 and carried the error to #14.

If you chose C then you chose C for #13 and carried the error to #14.

15. D  If Product B’s sales decrease by 10%, then Product B loses 10% of its contribution margin (it loses 10% of its revenue but saves 10% of its variable costs). This amounts to $43,000 x 10% = $4,300. In # 13 we determined that profit will decrease by $4,000 if Product C is dropped. Now we add the lost contribution margin from the effect on Product B’s sales to get a decrease in profit of $4,000 + $4,300 = $8,300.

If you chose A then you thought that a 10% loss of Product B’s sales would be 10% x $70,000 = $7,000.

If you chose B then you thought that a 10% loss of Product B’s sales would be a 10% loss of B’s income: 10% x $21,000 = $2,100.

If you chose C then you made the same error as B but also did not use the $4,000 decrease in income if C is dropped. You must have chosen A for #13. That’s why you were supposed to stop after your error in #13 and re-do your answers to #14 and #15!
SOLUTION TO PROBLEM SET B

True-False:

1. T
2. F This is not always true. We can compute the contribution margin per unit of scarce resource, but the shadow price will be $0 if the optimal production plan does not consume all of the resource. Why would a company pay extra to obtain something if it can't even use what it has available?
3. T This is true for the same reason that #2 is false.
4. F No, this is never the general rule, regardless of the number of constraints.
5. T If you got this wrong, re-read page 4-11.
6. F It may be optimal to produce more than one product, but not always.
7. T You can always use the graphing approach when there are 2 products.
8. F The information gathering process for routine decisions is likely to be more reliable than for nonroutine decisions because of the frequency of routine decisions.
9. T
10. F Persons with a stake in the decision are likely to have much of the necessary information so they most likely cannot be removed from the process.

Multiple choice:

1. C Produce the products in the order of the highest contribution margin per machine hour:
   Product B: $8.00/0.6 hrs = $13.33/hr
   Product C: $4.00/0.4 hrs = $10.00/hr
   Product D: $7.00/0.2 hrs = $35.00/hr
   The order to produce is Product D first, then Product B, then Product C.
   If you got this wrong, you probably got #2 and #3 wrong. Go back and re-do your answers for #2 and #3, then come back and check your answers.
2. B First Clark should produce all the Ds it can sell. This is 100 Ds, and this uses 100 x 0.2 hr/unit, or 20 hours. There are 90 hours remaining. Next produce all the Bs that can be sold, if there are enough hours. Customer demand for Bs is 200 units, which requires 200 x 0.6 hrs, or 120 hours. There were only 90 hours available after Ds were produced, so customer demand for Bs won’t be fully satisfied. With the remaining 90 hours, Clark can produce 90/0.6 hrs = 150 Bs. There are no hours left to make any Cs.
3. B Since Clark was producing Bs when it ran out of machine hours, the shadow price is $13.33.
4. A Answer B isn’t right because product quality could be measured quantitatively (e.g. tensile strength measures). Answer C ignores that the quantitative information may include irrelevant cost information. Answer D is silly – just because information is stated numerically does not mean that it is somehow better than information that is not stated in quantitative terms.
5. D
6. C Since there are only two products, we can graph the constraints. 
   The machine hour constraint is $1.2W + 2.2X \leq 100$. 
   The labor hour constraint is $2.4W + 4.4X \leq 400$.

   ![Diagram showing constraints]

   When there is only one binding constraint, it is always true that it will be 
   optimal to produce only one product.

7. B The contribution margin per machine hour for a W is $12/1.2 \text{ hrs} = $10/hr. 
   The contribution margin per machine hour for an X is $28/2.2 \text{ hrs} = 
   $12.73/hr. Karl should produce all Xs. There are 100 machine hours 
   available, so Karl can produce $100/2.2 \text{ hrs per unit} = 45.5 \text{ Xs}$.

8. B Karl would pay $0 for a labor hour because he already has labor hours 
   available that he can’t use because machine hours are constrained. He 
   would pay $12.73 for a machine hour, the contribution margin per machine 
   hour for an X.

9. B A bottleneck is a constraint that involves time.

10. B A is not correct because it won’t always be optimal to make both products. 
    C is not correct because there are mathematical methods for solving these 
    problems, even though we didn’t cover them in this text or this study guide.
SOLUTION TO END OF CHAPTER EXERCISES

Exercises:

1. First compute the contribution margin per unit and the contribution margin per hour. The hours required per unit is computed as the labor costs per unit divided by $5/hour. Don’t forget the variable administrative costs!

<table>
<thead>
<tr>
<th>Game</th>
<th>Estimated customer demand</th>
<th>Selling price per unit</th>
<th>Materials cost per unit</th>
<th>Labor costs per unit</th>
<th>Variable admin costs per unit</th>
<th>Contribution margin per unit</th>
<th>Hours required per unit</th>
<th>Contribution margin per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligopoly</td>
<td>100,000</td>
<td>$6.00</td>
<td>$2.00</td>
<td>$1.50</td>
<td>$0.75</td>
<td>$1.75</td>
<td>0.30</td>
<td>$5.83</td>
</tr>
<tr>
<td>War of the Moons</td>
<td>60,000</td>
<td>4.75</td>
<td>0.5</td>
<td>1.2</td>
<td>0.60</td>
<td>2.45</td>
<td>0.24</td>
<td>$10.21</td>
</tr>
<tr>
<td>Money</td>
<td>70,000</td>
<td>3.25</td>
<td>1.25</td>
<td>0.5</td>
<td>0.25</td>
<td>1.25</td>
<td>0.10</td>
<td>$12.50</td>
</tr>
<tr>
<td>Risky</td>
<td>80,000</td>
<td>2.5</td>
<td>0.25</td>
<td>0.5</td>
<td>0.25</td>
<td>1.50</td>
<td>0.10</td>
<td>$15.00</td>
</tr>
</tbody>
</table>

a) The games are produced in the order of the highest contribution margin per hour: Risky first, then Money, then War of the Moons, then Oligopoly.

b) Risky is produced first. It takes 80,000 x 0.10 = 8,000 hours to satisfy customer demand, leaving 35,000 – 8,000 = 27,000 hours for remaining products.

Money is produced next. It takes 70,000 x 0.10 = 7,000 hours to satisfy customer demand, leaving 27,000 – 7,000 = 20,000 hours for remaining products.

War of the Moons is produced next. It takes 60,000 x 0.24 = 14,400 hours to satisfy customer demand, leaving 20,000 – 14,400 = 5,600 hours for Oligopoly.

Oligopoly is produced last. There are only 5,600 hours remaining. These 5,600 hours can produce 5,600/0.3 hours per unit = 18,667 units of Oligopoly.

Maxwell should produce 18,667 units of Oligopoly, 60,000 units of War of the Moons, 70,000 units of Money, and 80,000 units of Risky.

c) The shadow price is $5.83, since Maxwell ran out of labor hours while it was producing Oligopoly.
2. The variable costs associated with making the subcomponent are $1.06 materials + $3.00 labor = $4.06 per unit.

The incremental cost of producing the subcomponent is $4.06 \times 10,000 + $1,200 for renting the required machine (for 12 months) = $40,600 + $1,200 = $41,800. The cost to buy is $4.50 \times 10,000 = $45,000. The advantage of the make alternative over the buy alternative is $45,000 - $41,800 = $3,200.

3. a) If the variable costs of producing the unit are $6.50 and the special order price is $8, the special order will increase profit by $1.50 per unit. There is sufficient capacity to produce the units for the special order without losing regular business, so Gamma should accept the special order. It will increase profit by $1.50 \times 10,000 = $15,000.

b) If 30,000 units is 80% of Gamma’s capacity, then Gamma’s capacity is $30,000/0.8 = 37,500$ units. In order to accept the special order, Gamma will lose 2,500 regular units. The opportunity cost of accepting then is $2,500 \times ($20.00 - $6.50) = $33,750. The increase in profit before considering a capacity constraint was $15,000, so the effect on profit of accepting the order, including the opportunity cost, is a $15,000 increase less $33,750, or an $18,750 decrease if Gamma accepts the special order.

4. a) The effect on profits if South is eliminated is the $80,000 contribution margin less the avoidable fixed costs of 60% x $100,000, or $20,000, before the effects on the other Divisions are considered. The net effect on profits if South Division is dropped is this $20,000 increase less the $60,000 lost volume discounts for North Division plus the $80,000 travel expense savings of West Division, less the lost contribution margin for West Division of $50,000, or a net increase in profits of $10,000 if South Division is dropped. [Note that the West Division has a 50% contribution margin ratio ($320,000/$160,000 = 50%). A loss of $100,000 in West Division revenue is a loss of $50,000 of West Division contribution margin.]

b) Foix cannot be sure that the revenue and cost information from last year will hold for the upcoming year. The 40%/60% split between unavoidable and avoidable fixed costs for the South Division is probably just an estimate. Foix should investigate the reliability of this estimate. Also, the lost volume discounts for North Division is probably just an estimate. However, this estimate is likely to be more reliable than the estimated travel expense savings and the lost revenue for West Division. Foix can look into the details of these estimates; some are probably more reliable than others.

c) Examples of qualitative factors that Foix should consider include:
- employee morale for the North and West Divisions
- the company’s reputation in the regions where the South Division operates
- whether elimination of South Division is in line with Foix’s long-term strategic plans
- the effect on the elimination of South Division on the reputation of the company in the regions in which it operates the North and West divisions
5. a) First note that the contribution margin per unit of A is $80 - $40 = $40, and the contribution margin per unit of B is $220 - $90 = $130. The linear programming formulation is:

$$\text{Max } 40A + 130B, \text{ subject to: } 0.4A + 1.4M \leq 160,000 \text{ (machine hour constraint)}$$

$$2A + 6M \leq 780,000 \text{ (DL hour constraint)}$$

b&c) The graph of this problem is shown below:

The optimal production plan is A=330,000 and M=20,000. The total contribution margin at this point is $15,800,000.

6. a) The optimal production plan is 125 2 Gallons hats, 400 5 Gallon hats, and 27 10 Gallon hats. This is rounded from 125.3 2 Gallon hats and 26.7 10 Gallon hats.

b) The RHS of the felt constraint is the 773 used plus the 27 slack, or 800. The RHS of the cutting hours constraint is the 600 used plus the 0 slack, or 600. The RHS of the steaming hour constraint is the 400 used plus the 0 slack, or 400.

c) The RHS of the 2 Gallon hat customer demand constraint is the 125.3 used plus the 374.7 slack, or 500. The RHS of the 5 Gallon hat customer demand constraint is the 400 used plus the 0 slack, or 400. The RHS of the 10 Gallon hat customer demand constraint is the 26.7 used plus the 23.3 slack, or 50.

d) No, Cowboy should not increase its purchases of felt, because the felt constraint is slack.
e) If Cowboy rents the machine for 20 hours, the increase in profit is $20 \times ($37 \text{ shadow price, or per-hour value of increasing the resource} - $30 \text{ per hour cost of the resource}) = $140 increase in profits. Cowboy should rent the steaming machine.

f) If Cowboy rents the machine for 20 hours, the decrease in profit is $20 \times ($21 \text{ shadow price, or per-hour value of the increasing the resource} - $30 \text{ per hour cost of the resource}) = $180 decrease in profits. Cowboy should not rent the cutting machine.

g) Cowboy should not consider an advertising campaign to increase sales of 10 Gallon hats, because the customer demand constraint for 10 Gallon hats is slack. If Cowboy does begin this campaign, then profits will decrease by $800, the cost of the campaign.

h) The campaign costs Cowboy $800/100 hats, or $8 per hat. The shadow price shows that it is worth $9/hat to increase customer demand for the 5 Gallon hats. The $8 cost is lower than this value by $1 per hat. Cowboy should begin this advertising campaign; it will increase profits by $1 \times 100 \text{ hats, or } $100.