This is a decision-making-under-uncertainty case. There are two events: a favorable market (event 1) and an unfavorable market (event 2). There are four alternatives, which include do nothing (alternative 1), invest in corporate bonds (alternative 2), invest in preferred stock (alternative 3), and invest in common stock (alternative 4). The decision table is presented. Note that for alternative 2, the return in a good market is $30,000 \((1 + 0.13)^5\) = $55,273. The return in a good market is $120,000, \((4 \times $30,000)\) for alternative 3, and $240,000, \((8 \times $30,000)\) for alternative 4.

Payoff table

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Event 1</th>
<th>Event 2</th>
<th>Laplace Average Value</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Hurwicz Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>55,273</td>
<td>–</td>
<td>22,636.5</td>
<td>–</td>
<td>55,273</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>10,000</td>
<td>0</td>
<td>10,000</td>
<td>2,819.9</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Alternative 3</td>
<td>120,00</td>
<td>–</td>
<td>52,500.0</td>
<td>–</td>
<td>120,00</td>
<td>–150.00</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>15,000</td>
<td>15,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternative 4</td>
<td>240,00</td>
<td>–</td>
<td>105,000.0</td>
<td>–</td>
<td>240,00</td>
<td>–300.00</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>30,000</td>
<td>30,000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Regret table

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Event 1</th>
<th>Event 2</th>
<th>Maximum Regret</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1</td>
<td>240,000</td>
<td>0</td>
<td>240,000</td>
</tr>
<tr>
<td>Alternative 2</td>
<td>184,727</td>
<td>10,000</td>
<td>184,727</td>
</tr>
<tr>
<td>Alternative 3</td>
<td>120,000</td>
<td>15,000</td>
<td>120,000</td>
</tr>
<tr>
<td>Alternative 4</td>
<td>0</td>
<td>30,000</td>
<td>30,000</td>
</tr>
</tbody>
</table>

a. Sue Pansky is a risk avoider and should use the maximin decision approach. She should do nothing and not make an investment in Starting Right.
b. Ray Cahn should use a coefficient of realism of 0.11. The best decision is to do nothing.
c. Lila Battle should eliminate alternative 1 of doing nothing and apply the maximin criterion. The result is to invest in the corporate bonds.
d. George Yates should use the equally likely decision criterion. The best decision for George is to invest in common stock.
e. Pete Metarko is a risk seeker. He should invest in common stock.

f. Julia Day can eliminate the preferred stock alternative and still offer alternatives to risk seekers (common stock) and risk avoiders (doing nothing or investing in corporate bonds).

2. North–South Airline, Ch. 4, page 145

### Northern Airline Data

<table>
<thead>
<tr>
<th>Year</th>
<th>Airframe Cost per Aircraft</th>
<th>Engine Cost per Aircraft</th>
<th>Average Age (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>51.80</td>
<td>43.49</td>
<td>6,512</td>
</tr>
<tr>
<td>2002</td>
<td>54.92</td>
<td>38.58</td>
<td>8,404</td>
</tr>
<tr>
<td>2003</td>
<td>69.70</td>
<td>51.48</td>
<td>11,077</td>
</tr>
<tr>
<td>2004</td>
<td>68.90</td>
<td>58.72</td>
<td>11,717</td>
</tr>
<tr>
<td>2005</td>
<td>63.72</td>
<td>45.47</td>
<td>13,275</td>
</tr>
<tr>
<td>2006</td>
<td>84.73</td>
<td>50.26</td>
<td>15,215</td>
</tr>
<tr>
<td>2007</td>
<td>78.74</td>
<td>79.60</td>
<td>18,390</td>
</tr>
</tbody>
</table>

### Southeast Airline Data

<table>
<thead>
<tr>
<th>Year</th>
<th>Airframe Cost per Aircraft</th>
<th>Engine Cost per Aircraft</th>
<th>Average Age (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>13.29</td>
<td>18.86</td>
<td>5,107</td>
</tr>
<tr>
<td>2002</td>
<td>25.15</td>
<td>31.55</td>
<td>8,145</td>
</tr>
<tr>
<td>2003</td>
<td>32.18</td>
<td>40.43</td>
<td>7,360</td>
</tr>
<tr>
<td>2004</td>
<td>31.78</td>
<td>22.10</td>
<td>5,773</td>
</tr>
<tr>
<td>2005</td>
<td>25.34</td>
<td>19.69</td>
<td>7,150</td>
</tr>
<tr>
<td>2006</td>
<td>32.78</td>
<td>32.58</td>
<td>9,364</td>
</tr>
<tr>
<td>2007</td>
<td>35.56</td>
<td>38.07</td>
<td>8,259</td>
</tr>
</tbody>
</table>

Utilizing QM for Windows, we can develop the following regression equations for the variables of interest.

**Northern Airline—airframe maintenance cost:**

\[
\text{Cost} = 36.10 + 0.0025 \text{ (airframe age)}
\]

Coefficient of determination = 0.7694

Coefficient of correlation = 0.8771

**Northern Airline—engine maintenance cost:**

\[
\text{Cost} = 20.57 + 0.0026 \text{ (airframe age)}
\]
Coefficient of determination = 0.6124
Coefficient of correlation = 0.7825

Southeast Airline—airframe maintenance cost:
Cost = 4.60 + 0.0032 (airframe age)
Coefficient of determination = 0.3904
Coefficient of correlation = 0.6248

Southeast Airline—engine maintenance cost:
Cost = −0.671 + 0.0041 (airframe age)
Coefficient of determination = 0.4599
Coefficient of correlation = 0.6782

The graphs below portray both the actual data and the regression lines for airframe and engine maintenance costs for both airlines. Note that the two graphs have been drawn to the same scale to facilitate comparisons between the two airlines.
**Northern Airline:** There seem to be modest correlations between maintenance costs and airframe age for Northern Airline. There is certainly reason to conclude, however, that airframe age is not the only important factor.

**Southeast Airline:** The relationships between maintenance costs and airframe age for Southeast Airline are much less well defined. It is even more obvious that airframe age is not the only important factor—perhaps not even the most important factor.

Overall, it would seem that:

1. Northern Airline has the smallest variance in maintenance costs, indicating that the day-to-day management of maintenance is working pretty well.
2. Maintenance costs seem to be more a function of airline than of airframe age.

3. The airframe and engine maintenance costs for Southeast Airline are not only lower but more nearly similar than those for Northern Airline, but, from the graphs at least, appear to be rising more sharply with age.

4. From an overall perspective, it appears that Southeast Airline may perform more efficiently on sporadic or emergency repairs, and Northern Airline may place more emphasis on preventive maintenance.

Ms. Jones’s report should conclude that:

1. There is evidence to suggest that maintenance costs could be made to be a function of airframe age by implementing more effective management practices.

2. The difference between maintenance procedures of the two airlines should be investigated.

3. The data with which she is presently working do not provide conclusive results.

3. Forecasting Attendance at SWU Football Games, Ch. 5, page 189

1. Because we are interested in annual attendance and there are six years of data, we find the average attendance in each year shown in the table below. A graph of this indicates a linear trend in the data. Using Trend Analysis in the forecasting module of QM for Windows we find the equation:

   \[ Y = 31,660 + 2,305.714X \]

   Where \( Y \) is attendance and \( X \) is the time period (\( X = 1 \) for 2005, 2 for 2006, etc.). For this model, \( r^2 = 0.98 \) which indicates this model is very accurate.

   Attendance in 2011 is projected to be
   \[ Y = 31,660 + 2,305.714(7) = 47,800 \]

   Attendance in 2012 is projected to be
   \[ Y = 31,660 + 2,305.714(8) = 50,105 \]

   At this rate, the stadium, with a capacity of 54,000, will be “maxed out” (filled to capacity) in 2014.

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Based upon the projected attendance and tickets prices of $20 in 2011 and $21 (a 5% increase) in 2012, the projected revenues are:

   \[ 47,800 \times 20 = 956,000 \text{ in 2010} \]
   \[ 50,105 \times 21 = 1,052,205 \text{ in 2012}. \]

3. The school might consider another expansion of the stadium, or raise the ticket prices more than 5% per year. Another possibility is to raise the prices of the best seats while leaving the end zone prices more reasonable.

4. Forecasting Monthly Sales, Ch. 5, page 190

The scatter plot of the data shows a definite seasonal pattern with higher sales in the winter months and lower sales in the summer and fall months. There is a slight upward trend as evidenced by the fact that for each month, the sales increased from the first year to the second, and again form the second year to the third.
2. A trend line based on the raw data is found to be:

\[ Y = 330.889 - 1.162X \]

The slope of the trend line is negative which would indicate that sales are declining over time. However, as previously noted, sales are increasing. The high seasonal index in January and February causes the trend line on the unadjusted data to appear to have a negative slope.

3. There is a definite seasonal pattern and a definite trend in the data. Using the decomposition method in QM for Windows, the trend equation (based on the deseasonalized data) is

\[ Y = 294.069 + 0.859X \]

The table below gives the seasonal indices, the unadjusted forecasts found using the trend line, and the final (adjusted) forecasts for the next year.

<table>
<thead>
<tr>
<th>Month</th>
<th>Unadjusted forecast</th>
<th>Seasonal index</th>
<th>Adjusted forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>325.852</td>
<td>1.447</td>
<td>471.5</td>
</tr>
<tr>
<td>February</td>
<td>326.711</td>
<td>1.393</td>
<td>455.1</td>
</tr>
<tr>
<td>March</td>
<td>327.57</td>
<td>1.379</td>
<td>451.7</td>
</tr>
<tr>
<td>April</td>
<td>328.429</td>
<td>1.074</td>
<td>352.7</td>
</tr>
<tr>
<td>May</td>
<td>329.288</td>
<td>1.039</td>
<td>342.1</td>
</tr>
<tr>
<td>June</td>
<td>330.147</td>
<td>0.797</td>
<td>263.1</td>
</tr>
<tr>
<td>July</td>
<td>331.006</td>
<td>0.813</td>
<td>269.1</td>
</tr>
<tr>
<td>August</td>
<td>331.865</td>
<td>0.720</td>
<td>238.9</td>
</tr>
<tr>
<td>September</td>
<td>332.724</td>
<td>0.667</td>
<td>221.9</td>
</tr>
<tr>
<td>October</td>
<td>333.583</td>
<td>0.747</td>
<td>249.2</td>
</tr>
<tr>
<td>November</td>
<td>334.442</td>
<td>0.891</td>
<td>298.0</td>
</tr>
<tr>
<td>December</td>
<td>335.301</td>
<td>1.033</td>
<td>346.4</td>
</tr>
</tbody>
</table>

5. Mexicana Wire Works, Ch. 7, page 300

1. Maximize \( P = 34W75C + 30W33C + 60W5X + 25W7X \)

subject to:

- \( W75C \leq 1,400 \)
- \( W33C \leq 250 \)
- \( W5X \leq 1,510 \)
- \( W7X \leq 1,116 \)
- \( W75C + 2W33C + 0W5X + 1W7X \leq 4,000 \)
- \( W75C + 1W33C + 4W5X + 1W7X \leq 4,200 \)
- \( W75C + 3W33C + 0W5X + 0W7X \leq 2,000 \)
- \( W75C + 0W33C + 3W5X + 2W7X \leq 2,300 \)
- \( W75C \geq 150 \)
- \( W7X \geq 600 \)
Solution: Produce:

1,100 units of W75C—backorder 300 units
250 units of W33C—backorder 0 units
0 units of W5X—backorder 1,510 units
600 units of W7X—backorder 516 units

Maximized profit will be $59,900. By addressing quality problems listed earlier, we could increase our capacity by up to 3% reducing our backorder level.

2. Bringing in temporary workers in the Drawing Department would not help. Drawing is not a binding constraint. However, if these former employees could do rework, we could reduce our rework inventory and fill some of our backorders thereby increasing profits. We have about a third of a month’s output in rework inventory. Expediting the rework process would also free up valuable cash.

3. The plant layout is not optimum. When we install the new equipment, an opportunity for improving the layout could arise. Exchanging the locations for packaging and extrusion would create a better flow of our main product. Also, as we improve our quality and reduce our rework inventory, we could capture some of the space now used for rework storage and processing and put it to productive use.

Our machine utilization of 63% is quite low. Most manufacturers strive for at least an 85% machine utilization. If we could determine the cause(s) of this poor utilization, we might find a key to a dramatic increase in capacity.

6. Chase Manhattan Bank, Ch. 8, page 339

This very advanced and challenging scheduling problem can be solved most expeditiously using linear programming, preferably integer programming. Let $F$ denote the number of full-time employees. Some number, $F_1$, of them will work 1 hour of overtime between 5 P.M. and 6 P.M. each day and some number, $F_2$, of the full-time employees will work overtime between 6 P.M. and 7 P.M. There will be seven sets of part-time employees; $P_j$ will be the number of part-time employees who begin their workday at hour $j$, $j = 1, 2, \ldots, 7$, with $P_1$ being the number of workers beginning at 9 A.M., $P_2$ at 10 A.M., $P_7$ at 3 P.M. Note that because part-time employees must work a minimum of 4 hours, none can start after 3 P.M. since the entire operation ends at 7 P.M. Similarly, some number of part-time employees, $Q_j$, leave at the end of hour $j$, $j = 4, 5, \ldots, 9$.

The workforce requirements for the first two hours, 9 A.M. and 10 A.M., are:

$F + P_1 \geq 14$

$F + P_1 + P_2 \geq 25$

At 11 A.M. half of the full-time employees go to lunch; the remaining half go at noon. For those hours:

$0.5F + P_1 + P_2 + P_3 \geq 26$

$0.5F + P_1 + P_2 + P_3 + P_4 \geq 38$

Starting at 1 P.M., some of the part-time employees begin to leave. For the remainder of the straight-time day:
\[
F + P_1 + P_2 + P_3 + P_4 + P_5 - Q_4 \geq 55
\]
\[
F + P_1 + P_2 + P_3 + P_4 + P_5 + P_6 - Q_4 - Q_5 \geq 60
\]
\[
F + P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7 - Q_4 - Q_5 - Q_6 \geq 51
\]
\[
F + P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7 - Q_4 - Q_5 - Q_6 - Q_7 \geq 29
\]

For the two overtime hours:

\[
F_1 + P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7 - Q_4 - Q_5 - Q_6 - Q_7 - Q_8 \geq 14
\]
\[
F_2 + P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7 - Q_4 - Q_5 - Q_6 - Q_7 - Q_8 - Q_9 \geq 9
\]

If the left-hand sides of these 10 constraints are added, one finds that 7\(F\) hours of full-time labor are used in straight time (although 8\(F\) are paid for), \(F_1 + F_2\) full-time labor hours are used and paid for at overtime rates, and the total number of part-time hours is

\[
10P_1 + 9P_2 + 8P_3 + 7P_4 + 6P_5 + 5P_6 + 4P_7 - 6Q_4 - 5Q_5 - 4Q_6 - 3Q_7 - 2Q_8 - Q_9 \leq 128.4
\]

which is 40\% of the day’s total requirement of 321 person-hours.
This also leads to the objective function. The total daily labor cost which must be minimized is
\[ Z = 8(10.11)F + 8.08(F_1 + F_2) + 7.82(10P_1 + 9P_2 + 8P_3 + 7P_4 + 6P_5 + 5P_6 + 4P_7 - 6Q_4 - 5Q_5 - 4Q_6 - 3Q_7 - 2Q_8 - Q_9) \]

Total overtime for a full-time employee is restricted to 5 hours or less, an average of 1 hour or less per day per employee. Thus the number of overtime hours worked per day cannot exceed the number of full-time employees:
\[ F_1 + F_2 \leq F \]

Since part-time employees must work at least 4 hours per day,
\[ Q_4 \leq P_1 \]

for those leaving at the end of the fourth hour. At the end of the fifth hour, those leaving must be drawn from the \( P_1 - Q_4 \) remaining plus the \( P_2 \) that arrived at the start of the second hour:
\[ Q_5 \leq P_1 + P_2 - Q_4 \]

Similarly, for the remainder of the day,
\[
\begin{align*}
Q_6 & \leq P_1 + P_2 + P_3 - Q_4 - Q_5 \\
Q_7 & \leq P_1 + P_2 + P_3 + P_4 - Q_4 - Q_5 - Q_6 \\
Q_8 & \leq P_1 + P_2 + P_3 + P_4 + P_5 - Q_4 - Q_5 - Q_6 - Q_7 \\
Q_9 & \leq P_1 + P_2 + P_3 + P_4 + P_5 + P_6 - Q_4 - Q_5 - Q_6 - Q_7 - Q_8
\end{align*}
\]

To ensure that all part-timers who began at 9 A.M. do not work more than 7 hours:
\[ Q_4 + Q_5 + Q_6 + Q_7 \geq P_1 \]

Similarly,
\[
\begin{align*}
Q_4 + Q_5 + Q_6 + Q_7 + Q_8 & \geq P_1 + P_2 \\
Q_4 + Q_5 + Q + Q_7 + Q_8 + Q_9 & \geq P_1 + P_2 + P_3
\end{align*}
\]

Finally, to ensure that all part-time employees leave at some time:
\[ P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7 = Q_4 + Q_5 + Q_6 + Q_7 + Q_8 + Q_9 \]

The resulting problem has 16 integer variables and 22 constraints. If integer programming software is not available, the linear programming problem can be solved and the solution rounded, making certain that none of the constraints have been violated. Note that the integer programming solution might also need to be adjusted—if \( F \) is an odd integer, \( 0.5F \) will not be an integer and the requirement that “half” of the full-time employees go to lunch at 11 A.M. and the other half at noon will have to be altered by assigning the extra employee to the appropriate hour.

1. The least-cost solution requires 29 full-time employees, 9 of whom work two hours of overtime per day. In actuality, 18 of the full-time employees would work overtime on two different days and 9 would work overtime on one day. Fourteen of the full-time workers would take lunch at 11 A.M. and the other 15 would take it at noon. Eleven part-timers would begin at 11 A.M., with 9 of them leaving at 3 P.M. and the other 2 at 4 P.M. Fifteen part-time employees would work from noon until 4 P.M., and 5 would work from 2 P.M. until 6 P.M. The resulting cost of 232 hours of straight
time, 18 hours of overtime, and 126 hours of part-time work is $3,476.28 per day.

This solution is not unique—other work assignments can be found that result in this same cost.

2. The same staffing would be used every day. In fact, one would expect different patterns to present themselves on different days; for example, Fridays are usually much busier bank days than the others. In addition, the person-hours required for each hour of the day are assumed to be deterministic. In a real situation, wide fluctuations will be experienced in a stochastic manner.

The optimal solution results in a considerable amount of idle time, partly caused by the restriction that employees can start at the beginning of an hour and leave at the end. Eliminating this restriction might yield better results at the risk of increasing the problem size.

7. Andrew–Carter, Inc., Ch. 9, page 391
This case presents some of the basic concepts of aggregate planning by the transportation method. The case involves solving a rather complex set of transportation problems. Four different configurations of operating plants have to be tested. The solutions, although requiring relatively few iterations to optimality, involve degeneracy if solved manually. The costs are:
<table>
<thead>
<tr>
<th>Configuration</th>
<th>Total Variable Cost</th>
<th>Total Fixed Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>All plants operating</td>
<td>$179,730</td>
<td>$41,000</td>
<td>$220,730</td>
</tr>
<tr>
<td>1 and 2 operating, 3 closed</td>
<td>188,930</td>
<td>33,500</td>
<td>222,430</td>
</tr>
<tr>
<td>1 and 3 operating, 2 closed</td>
<td>183,430</td>
<td>34,000</td>
<td>217,430</td>
</tr>
<tr>
<td>2 and 3 operating, 1 closed</td>
<td>188,360</td>
<td>33,000</td>
<td>221,360</td>
</tr>
</tbody>
</table>

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

The optimum producing and shipping pattern is

<table>
<thead>
<tr>
<th>From</th>
<th>To (Amount)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant 1 (R.T.)</td>
<td>W2 (13,000); W4 (14,000)</td>
</tr>
<tr>
<td>Plant 3 (R.T.)</td>
<td>W1 (5,000); W3 (11,000); W4 (1,000); W5 (8,000)</td>
</tr>
<tr>
<td>Plant 3 (O.T.)</td>
<td>W1 (4,000)</td>
</tr>
</tbody>
</table>

There are three alternative optimal producing and shipping patterns, where R.T. = regular time, O.T. = overtime, and W = warehouse.

Getting the solution manually should not be attempted using the northwest corner rule. It will take eight tableaux to do the “all plants” configuration, with degeneracy appearing in the seventh tableau; the “1 and 2” configuration takes five tableaux; and so on. It is strongly suggested that software be used.
The assignment algorithm can be utilized to yield the fastest time to complete a table with each person assigned one task.

<table>
<thead>
<tr>
<th>Person</th>
<th>Job</th>
<th>Time (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tom</td>
<td>Preparation</td>
<td>100</td>
</tr>
<tr>
<td>Cathy</td>
<td>Assembly</td>
<td>70</td>
</tr>
<tr>
<td>George</td>
<td>Finishing</td>
<td>60</td>
</tr>
<tr>
<td>Leon</td>
<td>Packaging</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total time</td>
<td>240</td>
</tr>
</tbody>
</table>

2. If Randy is used, the assignment problem becomes unbalanced and a dummy job must be added. The optimum assignment would be

<table>
<thead>
<tr>
<th>Person</th>
<th>Job</th>
<th>Time (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>George</td>
<td>Preparation</td>
<td>80</td>
</tr>
<tr>
<td>Tom</td>
<td>Assembly</td>
<td>60</td>
</tr>
<tr>
<td>Leon</td>
<td>Finishing</td>
<td>80</td>
</tr>
<tr>
<td>Randy</td>
<td>Packaging</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total time</td>
<td>230</td>
</tr>
</tbody>
</table>

This is a savings of 10 minutes with Cathy becoming the backup.

3. If Cathy is given the preparation task, the solution of the assignment with the remaining three workers assigned to the remaining three tasks is

<table>
<thead>
<tr>
<th>Person</th>
<th>Job</th>
<th>Time (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cathy</td>
<td>Preparation</td>
<td>120</td>
</tr>
<tr>
<td>Tom</td>
<td>Assembly</td>
<td>60</td>
</tr>
<tr>
<td>George</td>
<td>Finishing</td>
<td>60</td>
</tr>
<tr>
<td>Leon</td>
<td>Packaging</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total time</td>
<td>250</td>
</tr>
</tbody>
</table>

If Cathy is assigned to the finishing task, the optimum assignment is

<table>
<thead>
<tr>
<th>Person</th>
<th>Job</th>
<th>Time (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>George</td>
<td>Preparation</td>
<td>80</td>
</tr>
<tr>
<td>Tom</td>
<td>Assembly</td>
<td>60</td>
</tr>
<tr>
<td>Cathy</td>
<td>Finishing</td>
<td>100</td>
</tr>
<tr>
<td>Leon</td>
<td>Packaging</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total time</td>
<td>250</td>
</tr>
</tbody>
</table>

4. One possibility would be to combine the packaging operation with finishing. Then, George could build an entire table by himself (in 230 minutes) and Tom could do preparation (100 minutes), Randy the assembly (80 minutes), and Leon the finishing and packaging (90 minutes). This crew could build 4.8 tables in a 480-minute workday, while George himself could build 2.09 tables—a total of almost 7 tables per day.
To utilize all five workers, George and Tom could each build entire tables, 2.09 and 1.75 per day, respectively. Letting Randy do preparation (110 minutes), Cathy the assembly (70 minutes), and Leon the finishing and packaging (90 minutes) allows an additional 4.36 tables per day for a total of 8.2 per day.

Nine tables per day could be achieved by having Tom prepare and assemble 3 tables, George prepare and finish 3 tables, Cathy assemble 6 tables, Leon finish 6 tables, and Randy prepare 3 tables and package all 9. George, Cathy, and Randy would each have 60 minutes per day unutilized and could build 0.6 table having George do preparation (80 minutes), Cathy assembly and packaging (95 minutes), and Randy the finishing (100 minutes).

8. New England Foundry, Ch. 13, page 530
1. To determine how much time the new layout would save, the present system must be compared to the new system. The amount of time that an employee spends traveling to the maintenance department added to the time that he or she spends in the system being serviced and waiting for service presently, compared to this value under the proposed system, will give the savings in time.

Under the present system, there are two service channels with a single line \((M = 2)\). The number of arrivals per hour is \(7 (\lambda = 7)\). The number of employees that can be serviced in an hour by each channel is \(5 (\mu = 5)\). The average time that a person spends in the system is

\[
W = \frac{\mu (\lambda / \mu)^M}{(M-1)! (M \mu - \lambda)^2} P_0 + \frac{1}{\mu}
\]

where

\[
P_0 = \frac{1}{\sum_{n=0}^{M-1} \frac{\lambda^n}{n! \mu^M} + \frac{1}{M! \mu^M} \frac{M \mu}{M \mu - \lambda}}
\]

In this case

\[
P_0 = \frac{1}{\left[1 + \frac{1}{5} \left(\frac{7}{5}\right)^1 + \frac{1}{2} \left(\frac{7}{5}\right)^2\right]} = \frac{2(5)}{5(2) - 7} = 0.18
\]

Therefore,

\[
W = \frac{5(7/5)^2}{1(10-7)^2} (0.18) + 1/5
\]

= 0.396 hour, or 23 minutes and 45 seconds

Added to the travel times involved (6 minutes total for maintenance personnel and 2 minutes total for molding personnel), the total trip takes:

For maintenance—29 minutes and 45 seconds
For molding—25 minutes and 45 seconds

Under the new system, waiting lines are converted to single-channel, single-line
operations. Bob will serve the maintenance personnel and Pete will serve the molding personnel.

Bob can now service 6 people per hour ($\mu = 6$). Four people arrive from the maintenance department every hour ($\lambda = 4$). The time spent in Bob’s department is

$$W = \frac{1}{\mu - \lambda} = \frac{1}{6 - 4} = \frac{1}{2} \text{ hour, or 30 minutes}$$

The reduced travel time is equal to 2 minutes, making the total trip time equal to 32 minutes. This is an increase in time of 2 minutes and 15 seconds for the maintenance personnel.

Pete can now service 7 people per hour ($\mu = 7$). Three people arrive from the molding department every hour ($\lambda = 3$). The time in Pete’s department is

$$W = \frac{1}{7 - 3} = \frac{1}{4} \text{ hour, or 15 minutes}$$

The travel time is equal to 2 minutes, making the total trip time equal to 17 minutes. This is a decrease in time of 8 minutes and 45 seconds per trip for the molding personnel.

2. To evaluate systemwide savings, the times must be monetized. For the maintenance personnel who are paid $9.50 per hour, the 2 1/4 minutes lost per trip costs the company 36 cents per trip [2 1/4 / 60 = 0.0375 of an hour; 0.0375($9.50) = $0.36]. For the molding personnel who are paid $11.75 per hour, the 8 minutes and 45 seconds per trip saved saves in monetary terms $1.71 per trip. The net savings is $1.71 - 0.36 = $1.35 per trip. (Students may also find the cost savings on an hourly or daily basis.)

Because the net savings for the new layout is small, other factors should be considered before a final decision is made. For example, the cost of changing from the old layout to the new layout could completely eliminate the advantages of operating the new layout. In addition, there may be other factors, some noneconomic, that were not discussed in the case that could cause you to want to stay with the old layout. In general, when the cost savings of a new approach (a new layout in this case) is small, careful analysis should be made of other factors.

9. Winter Park Hotel, Ch. 13, Page 531

1. Which of the two plans appears to be better? The current system has five clerks each with his or her own waiting line. This can be treated as five independent queues each with an arrival time of $\lambda = 90/5 = 18$ per hour. The service rate is one every 3 minutes, or $\mu = 20$ per hour. Assuming Poisson arrivals and exponential service times, the average amount of time that a guest spends waiting and checking in is given by

$$W = \frac{1}{\mu - \lambda} = \frac{1}{20 - 18} = 0.5 \text{ hour, or 30 minutes}$$

If 30% of the arrivals [that is, $\lambda = 0.3(90) = 27$ per hour] are diverted to a quick-
serve clerk who can register them in an average of 2 minutes ($\mu = 30$ per hour) their average time in the system will be 20 minutes. The remaining 63 arrivals per hour would distribute themselves equally among the four remaining clerks ($\lambda = 63/4 = 15.75$ per hour), each of whose mean service time is 3.4 minutes (or 0.05667 hour), so that $\mu = 1/0.05667 = 17.65$ per hour. The average time in the system for these guests will be 0.53 hour or 31.8 minutes. The average time for all arrivals would be $0.3(20) + 0.7(31.8) = 28.3$ minutes.

A single waiting line for the five clerks yields an $M/M/5$ queue with $\lambda = 90$ per hour, $\mu = 20$ per hour. The calculation of average time in the system gives $W = 7.6$ minutes. This plan is clearly faster.

Use of an ATM with the same service rate as the clerks (20 per hour) by 20 percent of the arrivals (18 per hour) gives the same average time for these guests as the current systems—30 minutes. The remaining $\lambda = 72$ per hour form an $M/M/4$ or $M/M/5$ queuing system. With four servers, the average time in the system is 8.9 minutes, resulting in an overall average of:

$0.2 \times 30 + 0.8 \times 8.9 = 13.1$ minutes

With five servers, the average time is 3.9 minutes resulting in an overall average of:

$0.2 \times 30 + 0.8 \times 3.9 = 9.1$ minutes