Student Instructions for the Use of Spreadsheets with Examples

All quantitative content in the book is supported with spreadsheets that students may use to better understand the material. For each quantitative example in the book, we describe how the corresponding spreadsheet may be used. You can view the following pages as a type of user's manual for the various spreadsheets. The goal is to allow students to potentially build each spreadsheet associated with quantitative discussion and also use these spreadsheets for some "what-if" analysis.

Contents

Chapter 5

Example for Phase II: Network Optimization Models

The example discussed in this subsection is shown in Figures 5-3 to 5-7 of the book.

Associated spreadsheet: *Figures 5-3 to 5-7*

The data in Figure 5-3 is provided as input in the associated spreadsheet. The area for ***Decision Variables*** (as shown in Figure 5-4) is set up in Cells A12:H18.

The next step is to understand how the constraints are set up. The constraint (5.2) can be rewritten as

$$K_i y_i - \sum_{j=1}^{m} x_{ij} \geq 0$$

In the spreadsheet, the left hand side of the constraint for supply region N. America is evaluated in Cell B22 as (see Figure 5-5)

G14*H4 + H14*J4 - SUM(B14:F14)

G14*H4 + H14*J4 evaluates the total available capacity in N. America based on the values of G14 and H14. SUM(B14:F14) evaluates the total supply out of N. America. The difference thus evaluates the unused capacity in N. America. When Solver is set up, we will require this cell to be "≥ 0" because the unused capacity must be at least 0. Similar constraints are set in Cells B23:B26 for the other supply cities.

The constraint (5.1) can be rewritten as

$$D_j - \sum_{i=1}^{n} x_{ij} = 0$$

In the spreadsheet, the left hand side of the constraint for demand region N. America is evaluated in Cell B28 as (see Figure 5-5)

B9 – SUM(B14:B18)

B9 is the demand in N. America and SUM(B14:B18) evaluates the total quantity shipped into N. America. Since all demand must be satisfied, when Solver is set up, we will require this cell to be "= 0". Similar constraints are set up in Cells C28:F28 for the other demand regions.

The objective function is evaluated in Cell B31 as (see Figure 5-5)

SUMPRODUCT(B14:F18,B4:F8)+SUMPRODUCT(G14:G18,G4:G8)+SUMPRODUCT(H14:H18,I4:I8)

SUMPRODUCT(B14:F18,B4:F8) evaluates the total cost of producing a transporting from supply regions to demand regions. SUMPRODUCT(G14:G18,G4:G8) evaluates the fixed cost of low capacity plants. SUMPRODUCT(H14:H18,I4:I8) evaluates the fixed costs of high capacity plants. The sum thus defines the total annual cost of the network.

To set up Solver we use Data | Analysis | Solver. In the Solver Dialog box we enter the objective, decision variables, and constraints as shown in Figure 5-6 (and detailed below).

Set Objective: $B$31 (Cell B31 contains the objective function)

To: Min (our goal is to minimize the total cost)

By changing variable cells: $B$14:$H$18 (these cells contain all the decision variables)

Subject to the constraints:

$B$14:$H$18 ≥ 0	(all variables are non-negative)
$B$22:$B$26 ≥ 0	(all locations must have unused capacity of at least 0)
$B$28:$F$28 = 0	(all market demand must be satisfied)
$G$14:$H$18 = binary	(the number of plants built can only take on values of 0 or 1)

Click on “Solve” to obtain the optimal solution shown in Figure 5-7.

Other scenarios that can be tried are as follows:

1. What if a plant must be built in some location (say Europe)? In this case, the cell I16 evaluates the total number of plants built in Europe. Adding the constraint “I16 ≥ 1” to Solver ensures that at least one plant is built in Europe.
2. What if plants must be built in every market? In this case we need to add the constraint “I14:I18 ≥ 0” to Solver.

Example for Phase III: Gravity Location Models

The example discussed in this subsection is shown in Figure 5-8 of the book.

Associated spreadsheet: *Figure 5-8*

The data in Table 5-1 is provided as input in the associated spreadsheet in Cells A3:F12. The ***Decision Variables*** (location of facility) is set up in Cells B16:B17.In Cells G5:G12, we calculate the distance from the facility to each source or destination using Equation 5.4. The calculation of the distance between Buffalo and the facility is shown in Cell G5 to be:

$d_n = \sqrt{(x - x_n)^2 + (y - y_n)^2}$ = SQRT(($B$16-E5)^2 + ($B$17-F5)^2)

The formula is then copied to cells G6:G12.

The *Objective function* is obtained in Cell B19 using Equation 5.5 to be

Cost = SUMPRODUCT(G5:G12,D5:D12,C5:C12)

The goal in this case is to find a facility location that minimizes total cost. To set up Solver we use Data | Analysis | Solver. In the Solver Dialog box we enter the objective, decision variables, and constraints as shown in Figure 5-8 (and detailed below).

Set Objective: $B$19 (Cell B19 contains the objective function)

To: Min (our goal is to minimize the total cost)

By changing variable cells: $B$16:$B$17 (these cells contain all the decision variables)

Subject to the constraints:

Here no constraints are needed because the optimal facility location may have negative coordinates. Click on "Solve" to obtain the optimal solution. The optimal location is shown by the pink dot on the chart.

Other scenarios that can be tried are as follows:

1. Change the quantity shipped from St. Louis (Cell D7) to 1,700. What does this change to the facility location?
2. Change the quantity shipped from St. Louis (Cell D7) to 2,700. What does this change to the facility location?

Example for Phase IV: Network Optimization Models

The example discussed in this subsection is shown in Tables 5-2 to 5-4 and Figures 5-9 to 5-12 of the book.

Associated spreadsheet: *Figures 5-9 to 5-12*

The data in Table 5-2 is provided as input in the associated spreadsheet (in all worksheets) in Cells A2:I9. The results in Table 5-3 are obtained using worksheets *Table 5-3 HighOptic* and *Table 5-3 TelecomOne*. In each case invoke Solver and click on Solve to obtain the results shown in Table 5-3.

The worksheet *Merged Network with All Plants* contains results if all plants are kept open in the merged network. Simply use Solver to obtain the results.

We now detail Figures 5-9 to 5-12 using the worksheet *Figure 5-12*. The ***Decision Variables*** (as shown in Figure 5-9) are set up in Cells A12:H18. Observe that the variables in Cells H144:H18 correspond to decisions regarding whether a plant is open (variable is 1) or shut (variable is 0).

Our next step is to build the objective function and constraints as shown in Figure 5-10. The constraint (5.2) can be rewritten as

$$K_i y_i - \sum_{j=1}^{m} x_{ij} \geq 0$$

In the spreadsheet, the left hand side of the constraint for supply Baltimore is evaluated in Cell B22 as (see Figure 5-10)

I4*H14 - SUM(B14:G14)

I4*H14 evaluates the total available capacity in Baltimore based on the values of I4 and H14. SUM(B14:G14) evaluates the total supply out of Baltimore. The difference thus evaluates the unused capacity in Baltimore. When Solver is set up, we will require this cell to be "≥ 0" because the unused capacity must be at least 0. Similar constraints are set in Cells B23:B26 for the other supply cities.

The constraint (5.1) can be rewritten as

$$D_j - \sum_{i=1}^{n} x_{ij} = 0$$

In the spreadsheet, the left hand side of the constraint for demand region Atlanta is evaluated in Cell B29 as (see Figure 5-10)

B9 – SUM(B14:B18)

B9 is the demand in N. America and SUM(B14:B18) evaluates the total quantity shipped into Atlanta. Since all demand must be satisfied, when Solver is set up, we will require this cell to be "= 0". Similar constraints are set up in Cells C29:G28 for the other demand regions.

The objective function is evaluated in Cell B32 as (see Figure 5-10)

SUMPRODUCT(B14:G18,B4:G8) + SUMPRODUCT(H14:H18,H4:H8)

SUMPRODUCT(B14:G18,B4:G8) evaluates the total cost of producing a transporting from supply regions to demand regions. SUMPRODUCT(H14:H18,H4:H8) evaluates the fixed cost of plants. The sum thus defines the total annual cost of the network.

To set up Solver we use Data | Analysis | Solver. In the Solver Dialog box we enter the objective, decision variables, and constraints as shown in Figure 5-11 (and detailed below).

Set Objective: $B$32 (Cell B32 contains the objective function)

To: Min (our goal is to minimize the total cost)

By changing variable cells: $B$14:$H$18 (these cells contain all the decision variables)

Subject to the constraints:

$B$14:$G$18 ≥ 0	(all variables are non-negative)
$B$22:$B$26 ≥ 0	(all locations must have unused capacity of at least 0)
$B$29:$G$29 = 0	(all market demand must be satisfied)
$H$14:$H$18 = binary	(the number of plants built can only take on values of 0 or 1)

Click on “Solve” to obtain the optimal solution shown in Figure 5-12.

The Capacitated Plant Location Model With Single Sourcing

The associated worksheet is *Table 5-4 Single Sourcing*.

The main difference in this model is that the entire demand from each demand city must be served from a single source. The ***Decision Variables*** are set up in Cells A12:H18. Observe that the variables in Cells H14:H18 correspond to decisions regarding whether a plant is open (variable is 1) or shut (variable is 0) while the variables in Cells B14:G18 determine whether a given supply city serves a market (variable is 1) or not (variable is 0). Cells B23:G27 then evaluate the quantity shipped (resulting production allocation) from each supply city to each demand city. Cell B23 contains the formula "= B14*B9" which multiplies the decision variable with the demand in Atlanta. Thus, the quantity shipped equals demand if Cell B14 = 1 and 0 if Cell B14 = 0.

The constraints (5.8) are set up in Cells B38:G38. Cell B38 contains the constraint for the demand city Atlanta evaluated as "=SUM(B14:B18)". This cell is then to be set "= 0" when the Solver model is set up.

The constraints (5.9) are set up in Cells B31:B35. Cell B31 contains the constraint for supply city Baltimore evaluated as "=I4*H14-SUMPRODUCT(B14:G14,$B$9:$G$9)". This cell is then set to be "≥ 0" when the Solver model is set up.

The objective function is evaluated in Cell B41 as "=SUMPRODUCT(B23:G27,B4:G8) + SUMPRODUCT(H14:H18,H4:H8)". The first term SUMPRODUCT(B23:G27,B4:G8) evaluates the production and transportation cost of the production allocation. The second term SUMPRODUCT(H14:H18,H4:H8) evaluates the fixed cost of the open plants.

To set up Solver we use Data | Analysis | Solver. In the Solver Dialog box we enter the objective, decision variables, and constraints as detailed below.

Set Objective: $B$41 (Cell B41 contains the objective function)

To: Min (our goal is to minimize the total cost)

By changing variable cells: $B$14:$H$18 (these cells contain all the decision variables)

Subject to the constraints:

$B$14:$H$18 ≥ 0	(all variables are non-negative)
$B$31:$B$35 ≥ 0	(all locations must have unused capacity of at least 0)
$B$38:$G$38 = 1	(all market demand must be satisfied from a single supply city)
$B$14:$H$18 = binary	(all decision variables can only take on values of 0 or 1)

Click on "Solve" to obtain the optimal solution shown in Table 5-4.

Chapter 6

Example 6-1

Associated worksheet: *Discounted cash flow* in the spreadsheet *Chapter 6 example Trips Logistics*

The discount rate of 0.1 is in Cell B8 and the NPV of the lease in Cell B14. Change the discount rate in Cell B8 and see how it affects the NPV.

Section 6.5: Evaluating Network Design Decisions Using Decision Trees

The example discussed in this subsection is shown in Figure 6-2 and Tables 6-5 to 6-11 of the book. It focuses on the value of flexibility for Trips Logistics in the presence of uncertainty.

Associated spreadsheet: *Chapter 6 example Trips Logistics*

Evaluating the Spot Market Option

Associated worksheet: *Decision Tree – spot market*

The results in Table 6-5 are shown in Cells A3:E13.

The results in Table 6-6 are shown in Cells A19:D24.

Evaluating the Fixed Lease Option

Associated worksheet: *Decision Tree – Fixed Lease*

The results in Table 6-7 are shown in Cells A5:G15.

The results in Table 6-8 are shown in Cells A21:E26.

Evaluating the Flexible Lease Option

Associated worksheet: *Decision Tree – Flexible Lease*

The results in Table 6-9 are shown in Cells A5:G15.

The results in Table 6-10 are shown in Cells A21:E26.

Section 6.6: To Onshore or Offshore: Evaluation of Global Supply Chain Design Decisions Under Uncertainty

The example discussed in this subsection is shown in Figure 6-3 and Tables 6-12 to 6-17 of the book. It focuses on the evaluation of a plant location decision in the presence of uncertainty.

Associated spreadsheet: *Chapter 6 example D-Solar*

Evaluating the Onshore Option

Associated worksheet: *On-shore*

The results in Table 6-14 for Period 2 are shown in Cells A8:G17.

The transition probabilities from Period 1 to period 2 are shown in Cells E3:E6. The results in Table 6-15 for Period 1 are shown in Cells A21:E26 with the Expected profit column in Cells B26:E26.

The evaluation for period 0 is in Cells G21:H26 with the final expected profit calculation in Cell H26.

Evaluating the Offshore Option

Associated worksheet: *Off-shore*

The results in Table 6-16 for Period 2 are shown in Cells A8:G17.

The transition probabilities from Period 1 to period 2 are shown in Cells E3:E6. The results in Table 6-17 for Period 1 are shown in Cells A21:E26 with the Expected profit column in Cells B26:E26.

The evaluation for period 0 is in Cells G21:H26 with the final expected profit calculation in Cell H26.

Chapter 7

Static Methods (Time-Series Forecasting Methods) in Section 7.5

Associated spreadsheet: *Chapter 7-Tahoe-salt*

The data for Tahoe Salt in Table 7-1 and a graph with the demand in Figure 7-1 are shown in Cells A2:C14 in worksheet *Table 7.1*.

The next step is to evaluate the deseasonalized demand. This calculation is shown in worksheet *Figure 7-2 &7-3*. The deseasonalized demand for period 3 is calculated in Cell C4 using the formula

=(B2+B6+2*SUM(B3:B5))/8

This formula calculates the deseasonalized demand in period 3 as the average of the average demand in periods 1-4 and the average demand in periods 2-5. The formula is then copied down to Cells C5:C11 to obtain deseasonalized demand in periods 4 to 10. The results in Table 7-2 are shown Cells A1:C13. Figure 7-3 is shown around Cells A27 to F45.

The next step is to run a regression between the deseasonalized demand (Cells C4:C11) and time periods (Cells A4:A11). The results of the regression are on the worksheet *Regression-1*. The initial level L is shown in Cell B17 and the trend T in Cell B18.

If you want to set up the regression yourself, proceed as follows. Use Data | Data Analysis | Regression to bring up the regression dialog box. In the dialog box enter

Input Y range: C4:C11 (corresponds to deseasonalized demand)
Input X range: A4:A11 (corresponds to time periods)

Under "Output options" select "New Worksheet Ply" to get the results on a new worksheet.

The next step is to obtain the seasonal factors. The details of this step are provided in the worksheet *Figure7-4*. The first step is to obtain the deseasonalized demand for each period as shown in Cells C1:C13. Given the initial level L = 18,439 and trend T = 524, the deseasonalized demand for period t (t = 1 to 12) is obtained as 18,439 + 524 t. For period 1 the deseasonalized demand is in Cell C2 with the formula "=18439+524*A2". The formula is then copied down to Cells C3:C13.

The seasonal factor for period 1 is obtained in Cell D2 as the ratio of actual demand to deseasonalized demand using the formula "= B2/C2". This formula is copied down to Cells D3:D13. To provide all seasonal factors in Cells D2:D13. The results in Figure 7-4 are shown in Cells A1:D13.

The next step is to obtain the seasonal factors as the average of the corresponding seasonal factor over the three years. Thus, the average seasonal factor for period 1 is the average of the seasonal factors in period 1 (Cell D2), period 5 (Cell D6), and period 9 (Cell D10) and is shown in Cell E2. All four seasonal factors are shown in Cells E2:E5.

The final step is to obtain the forecasts for periods 13 to 16. The forecasts are obtained in Cells C17:C20.

Example 7-1

Associated worksheet: *Example 7-1* in the spreadsheet *Examples 1-4 Chapter 7*

This example illustrates the use of moving average for forecasting. The demand data for weeks 1 to 4 is shown in Cells B2:B5. The level L_4 for period 4 is evaluated in Cell C4 as the average of demand over the first four periods. The forecast F_5 for period 5 is in Cell D5. Once demand in period 5 is observed, the forecast error E_5 is in Cell E6 and the level L_5 is in Cell C6.

Example 7-2

Associated worksheet: *Example 7-2* in the spreadsheet *Examples 1-4 Chapter 7*

This example illustrates the use of simple exponential smoothing for forecasting. The demand data for weeks 1 to 4 is shown in Cells B2:B5. The initial level is calculated in Cell C2 as the average of the four demands in Cells B3:B6. The forecast F_1 for period 1 is in Cell D3 as "= C2". The level L_1 for period 1 is evaluated in Cell C3 using Equation 7.13 as "=0.1*B3+0.9*C2". In this case we use $\alpha = 0.1$. The level for other periods is shown in Cells C4:C6 and is obtained by copying the formula in Cell C3 to Cells C4:C6. The forecast for other periods is shown in Cells D4:D7 and is obtained by copying the formula in Cell D3 down to Cells D4:D7.

Example 7-3

Associated worksheet: *Example 7-3* in the spreadsheet *Examples 1-4 Chapter 7*

This example illustrates the use of Holt's for forecasting. The demand data for months 1 to 6 is shown in Cells B3:B8. To obtain the initial level and trend we run a regression between demand and time. The results of the regression are shown in Cells K2:S19.

If you want to set up the regression yourself, proceed as follows. Use Data | Data Analysis | Regression to bring up the regression dialog box. In the dialog box enter

> Input Y range: B3:B8 (corresponds to demand)
> Input X range: A3:A8 (corresponds to time periods)

Under "Output options" select "Output Range" to be the Cell where the beginning of the results of the regression is to appear.

The initial level L_0 is obtained from the regression in Cell L18 and entered in Cell E2. The initial estimate of trend T_0 is obtained from the regression in Cell L19 and entered in Cell F2. The forecast F_1 for period 1 is obtained using Equation 7.14 in Cell C3 as "= E2 + F2".

The level L_1 for period 1 is evaluated in Cell E3 using Equation 7.15 as "=(G2*B3)+((1-G2)*(E2+F2))". G2 contains α and H2 contains β. The trend T_1 for period 1 is evaluated in Cell F3 using Equation 7.16 as "=(H2*(E3-E2))+((1-H2)*F2)". The level for other periods is shown in Cells E4:E8 and is obtained by copying the formula in Cell E3 to Cells E4:E8. The trend for other periods is shown in Cells F4:F8 and is obtained by copying the formula in Cell F3 to Cells F4:F8. The forecast for other periods is shown in Cells C4:C9 and is obtained by copying the formula in Cell C3 down to Cells C4:C9.

Example 7-4

Associated worksheet: *Example 7-4* in the spreadsheet *Examples 1-4 Chapter 7*

This example illustrates the use of Winter's for forecasting. The demand data for month 1 is shown in Cell B3. The initial level is shown in Cell E2, the initial trend is shown in Cell F2, and the seasonal factors are shown in Cells G3:G6. The forecast F_1 for period 1 is obtained using Equation 7.17 in Cell C3 as "=(E2+F2)*G3". The level L_1 for period 1 is evaluated in Cell E3 using Equation 7.18 as "=(H2*(B3/G3))+((1-H2)*(E2+F2))". In this case we use $\alpha = 0.1$, $\beta=0.2$ and $\gamma=0.1$ (Cells H2:J2).

The trend T_1 for period 1 is evaluated in Cell F3 using Equation 7.19 as "=((I2*(E3-E2))+((1-I2)*F2))". The seasonal factor S_5 for period 5 is evaluated in Cell G7 using Equation 7.20 as "=(J2*(B3/E3))+((1-J2)*G3)". The forecast F_2 for period 2 is obtained using Equation 7.17 in Cell C4.

Section 7.7: Selecting the best smoothing constant

Associated worksheet: *Figure7-5,6* in spreadsheet *Chapter 7-Tahoe-salt*

In this worksheet we illustrate how to select a smoothing constant by optimizing some error measure. For demand data in Cells B3:B12, we use simple exponential smoothing with a smoothing constant α in Cell B14 to build the forecast in Cells D3:D12. The errors are shown in Cells E3:E12. The mean squared error (MSE) after 10 periods is calculated in Cell F13 using Equation 7.21. The MAD after 10 periods is calculated in Cell G13 using Equation 7.22. The MAPE is calculated in Cell H13 using Equation 7.24.

Obtaining Figure 7-5

Our first goal is to find the smoothing constant α in Cell B14 that minimizes the MSE in Cell F13. To obtain Figure 7-5, invoke Solver (Data | Analysis | Solver). In the dialog box ensure the following (as shown in Figure 7-5):

Set Target Cell: F13

Equal to: Min

By Changing Cells: B14

Subject to the Constraints:
B14 ≤ 1 (α must be less than or equal to 1)

Click on Solve to obtain the value of α in Cell B14 that minimizes the MSE in Cell F13 (as shown in Figure 7-5).

Obtaining Figure 7-6

Our next goal is to find the smoothing constant α in Cell B14 that minimizes the MAD in Cell G13. To obtain Figure 7-6, invoke Solver (Data | Analysis | Solver). In the dialog box ensure the following (as shown in Figure 7-6):

Set Target Cell: G13

Equal to: Min

By Changing Cells: B14

Subject to the Constraints:
B14 ≤ 1 (α must be less than or equal to 1)

Click on Solve to obtain the value of α in Cell B14 that minimizes the MSE in Cell G13 (as shown in Figure 7-6).

Section 7.8 Forecasting Demand at Tahoe Salt

In this section we build forecasts for Tahoe Salt using four different forecasting methods.

Moving Average (Figure 7-7)

Associated worksheet: *Figure 7-7* in *Chapter 7-Tahoe-Salt*

Figure 7-7 is shown in Cells A1:K13. Given that we are using a 4-period moving average, the level in period 4 is obtained in Cell C5 using the formula "=AVERAGE(B2:B5)". The formula is copied to Cells C6:C13 to obtain the level for other periods.

The forecast for period 5 is obtained in Cell D6 as the level in period 5 (=C5). Forecasts for other periods are obtained by copying the Cell D6 to Cells D7:D13.

The error for period 5 is obtained in Cell E6 as the difference between the forecast and demand for period 5 (=D6-B6). Errors for other periods are obtained by copying the Cell E6 to Cells E7:E13.

The absolute error for period 5 is obtained in Cell F6 as the absolute value of the error for period 5 (=ABS(E6)). Absolute errors for other periods are obtained by copying the Cell F6 to Cells F7:F13.

The mean squared error for period 5 is obtained in Cell G6 as the average squared error between periods 5 and 5(=SUMSQ($F$6:F6)/(A6-4)). Observe that Cell A6 contains the period value (in this case 5) and A6-4 gives the number of errors so far. Mean squared errors for other periods are obtained by copying the Cell G6 to Cells G7:G13.

The mean absolute deviation (MAD) for period 5 is obtained in Cell H6 as the average absolute error between periods 5 and 5 (=SUM($F$6:F6)/(A6-4)). Observe that Cell A6 contains the period value (in this case 5) and A6-4 gives the number of errors so far. Mean absolute deviations for other periods are obtained by copying the Cell H6 to Cells H7:H13.

The % error for period 5 is obtained in Cell I6 as the absolute error in Cell F6 as a percentage of demand in Cell B6 (=100*F6/B6). % errors for other periods are obtained by copying the Cell I6 to Cells I7:I13.

The mean absolute percent error (MAPE) for period 5 is obtained in Cell J6 as the average percent error between periods 5 and 5 (=AVERAGE($I$6:I6)). Mean absolute percent errors for other periods are obtained by copying the Cell J6 to Cells J7:J13.

The tracking signal (TS) for period 5 is obtained in Cell K6 as the ratio of the total error between periods 5 and 5 and the Mad in period 5 (=SUM($E$6:E6)/H6). Tracking signals for other periods are obtained by copying the Cell K6 to Cells K7:K13.

Simple Exponential Smoothing (Figure 7-8)

Associated worksheet: *Figure 7-8* in *Chapter 7-Tahoe-Salt*

Figure 7-8 is shown in Cells A1:K14. Given that we are using simple exponential smoothing, the level in period 0 is obtained in Cell C2 using the formula "=AVERAGE(B3:B14)" as the average of all demand from period 1 to 12.

The forecast for period 1 is obtained in Cell D3 as the level in period 0 (=C2). Forecasts for other periods are obtained by copying the Cell D3 to Cells D4:D14.

The level for period 1 is obtained using Equation 7.13 in Cell C3 using the formula "=$B$20*B3+(1-$B$20)*C2". The Cell B20 contains the value of α = 0.1. The level for other periods is obtained by copying Cell C3 to Cells C4:C14.

The error for period 1 is obtained in Cell E3 as the difference between the forecast and demand for period 1 (=D3-B3). Errors for other periods are obtained by copying the Cell E3 to Cells E4:E14.

The absolute error for period 1 is obtained in Cell F3 as the absolute value of the error for period 1 (=ABS(E3)). Absolute errors for other periods are obtained by copying the Cell F3 to Cells F4:F14.

The mean squared error for period 1 is obtained in Cell G3 as the average squared error between periods 1 and 1(=SUMSQ($E$3:E3)/A3). Observe that Cell A3 contains the period value (in this case 1) and gives the number of errors so far. Mean squared errors for other periods are obtained by copying the Cell G3 to Cells G4:G14.

The mean absolute deviation (MAD) for period 1 is obtained in Cell H3 as the average absolute error between periods 1 and 1 (=SUM($F$3:F3)/A3). Observe that Cell A3 contains the period value (in this case 1) and gives the number of errors so far. Mean absolute deviations for other periods are obtained by copying the Cell H3 to Cells H4:H14.

The % error for period 1 is obtained in Cell I3 as the absolute error in Cell F3 as a percentage of demand in Cell B3 (=100*F3/B3). % errors for other periods are obtained by copying the Cell I3 to Cells I4:I14.

The mean absolute percent error (MAPE) for period 1 is obtained in Cell J3 as the average percent error between periods 1 and 1 (=AVERAGE($I$3:I3)). Mean absolute percent errors for other periods are obtained by copying the Cell J3 to Cells J4:J14.

The tracking signal (TS) for period 1 is obtained in Cell K3 as the ratio of the total error between periods 1 and 1 and the Mad in period 1 (=SUM($E$3:E3)/H3). Tracking signals for other periods are obtained by copying the Cell K3 to Cells K4:K14.

Trend Corrected Exponential Smoothing (Figure 7-9)

Associated worksheet: *Figure 7-9* in *Chapter 7-Tahoe-Salt*

Figure 7-9 is shown in Cells A1:L14. Given that we are using trend corrected exponential smoothing, we need to obtain the initial level and trend in period 0. This is done using a regression (Data | Analysis | regression). The results of this regression are shown in worksheet *holts-regression*. To build the regression worksheet, invoke regression and in the dialog box enter

Input Y range: B3:B14
Input X range: A3:A14

And select New Worksheet Ply.

The initial level in period 0 is obtained in Cell B17 of the worksheet *holts-regression* and the initial trend in period 0 is obtained in Cell B18 of the worksheet *holts-regression.*

Return to worksheet *Figure 7-9*.

The forecast for period 1 is obtained in Cell E3 as the sum of the level and trend in period 0 (=C2 + D2). Forecasts for other periods are obtained by copying the Cell E3 to Cells E4:E14.

The level for period 1 is obtained using Equation 7.15 in Cell C3 using the formula "=$B$20*B3+(1-$B$20)*(C2+D2)". The Cell B20 contains the value of $\alpha = 0.1$. The level for other periods is obtained by copying Cell C3 to Cells C4:C14.

The trend for period 1 is obtained using Equation 7.16 in Cell D3 using the formula "=$B$21*(C3-C2)+(1-$B$21)*D2". The Cell B21 contains the value of $\beta = 0.2$. The trend for other periods is obtained by copying Cell D3 to Cells D4:D14.

The error for period 1 is obtained in Cell F3 as the difference between the forecast and demand for period 1 (=E3-B3). Errors for other periods are obtained by copying the Cell F3 to Cells F4:F14.

The absolute error for period 1 is obtained in Cell G3 as the absolute value of the error for period 1 (=ABS(F3)). Absolute errors for other periods are obtained by copying the Cell G3 to Cells G4:G14.

The mean squared error for period 1 is obtained in Cell H3 as the average squared error between periods 1 and 1(=SUMSQ($F$3:F3)/A3). Observe that Cell A3 contains the period value (in this case 1) and gives the number of errors so far. Mean squared errors for other periods are obtained by copying the Cell H3 to Cells H4:H14.

The mean absolute deviation (MAD) for period 1 is obtained in Cell I3 as the average absolute error between periods 1 and 1 (=SUM($G$3:G3)/A3). Observe that Cell A3 contains the period value (in this case 1) and gives the number of errors so far. Mean absolute deviations for other periods are obtained by copying the Cell I3 to Cells I4:I14.

The % error for period 1 is obtained in Cell J3 as the absolute error in Cell G3 as a percentage of demand in Cell B3 (=100*G3/B3). % errors for other periods are obtained by copying the Cell J3 to Cells J4:J14.

The mean absolute percent error (MAPE) for period 1 is obtained in Cell K3 as the average percent error between periods 1 and 1 (=AVERAGE($J$3:J3)). Mean absolute percent errors for other periods are obtained by copying the Cell K3 to Cells K4:K14.

The tracking signal (TS) for period 1 is obtained in Cell L3 as the ratio of the total error between periods 1 and 1 and the MAD in period 1 (=SUM($F$3:F3)/I3). Tracking signals for other periods are obtained by copying the Cell L3 to Cells L4:L14.

Trend- and Seasonality Corrected Exponential Smoothing (Figure 7-10)

Associated worksheet: *Figure 7-10* in *Chapter 7-Tahoe-Salt*

Figure 7-10 is shown in Cells A1:M14. Given that we are using trend and seasonality corrected exponential smoothing, we need to obtain the initial level and trend in period 0, and initial seasonal factors for periods 1-4. This is done in two steps. In the first step we build deseasonalized demand as shown on worksheet *deseasonalized*. This is done exactly as we discussed in the creation of worksheet *Figure 7-4*. The initial estimates of seasonal factors for periods 1-4 are obtained in Cells F4:F7 of the worksheet *deseasonalized*. The next step is to obtain the initial estimates for level and trend in period 0. This is done using a regression (Data | Analysis | regression) on deseasonalized demand. The results of this regression are shown in worksheet *winters-regression*. To build the regression worksheet, invoke regression (in the worksheet *deseasonalized*) and in the dialog box enter

Input Y range: C6:C13
Input X range: A6:A13

And select New Worksheet Ply.

The initial level in period 0 is obtained in Cell B17 of the worksheet *winters-regression* and the initial trend in period 0 is obtained in Cell B18 of the worksheet *winters-regression.*

Return to worksheet *Figure 7-10*.

The forecast for period 1 is obtained in Cell F3 using Equation 7.17 (=(C2+D2)*E3). Forecasts for other periods are obtained by copying the Cell F3 to Cells F4:F14.

The level for period 1 is obtained using Equation 7.18 in Cell C3 using the formula "=$B$20*(B3/E3)+(1-$B$20)*(C2+D2)". The Cell B20 contains the value of $\alpha = 0.05$. The level for other periods is obtained by copying Cell C3 to Cells C4:C14.

The trend for period 1 is obtained using Equation 7.19 in Cell D3 using the formula "=$B$21*(C3-C2)+(1-$B$21)*D2". The Cell B21 contains the value of $\beta = 0.1$. The trend for other periods is obtained by copying Cell D3 to Cells D4:D14.

The seasonal factor for period 5 is obtained using Equation 7.20 in Cell E7 using the formula "=$B$22*(B3/C3)+(1-$B$22)*E3". The Cell B22 contains the value of $\gamma = 0.1$. The seasonal factor for other periods is obtained by copying Cell E7 to Cells E8:E14.

The error for period 1 is obtained in Cell G3 as the difference between the forecast and demand for period 1 (=F3-B3). Errors for other periods are obtained by copying the Cell G3 to Cells G4:G14.

The absolute error for period 1 is obtained in Cell H3 as the absolute value of the error for period 1 (=ABS(G3)). Absolute errors for other periods are obtained by copying the Cell H3 to Cells H4:H14.

The mean squared error for period 1 is obtained in Cell I3 as the average squared error between periods 1 and 1(=SUMSQ($G$3:G3)/A3). Observe that Cell A3 contains the period value (in this case 1) and gives the number of errors so far. Mean squared errors for other periods are obtained by copying the Cell I3 to Cells I4:I14.

The mean absolute deviation (MAD) for period 1 is obtained in Cell J3 as the average absolute error between periods 1 and 1 (=SUM($H$3:H3)/A3). Observe that Cell A3 contains the period value (in this case 1) and gives the number of errors so far. Mean absolute deviations for other periods are obtained by copying the Cell J3 to Cells J4:J14.

The % error for period 1 is obtained in Cell K3 as the absolute error in Cell H3 as a percentage of demand in Cell B3 (=100*H3/B3). % errors for other periods are obtained by copying the Cell K3 to Cells K4:K14.

The mean absolute percent error (MAPE) for period 1 is obtained in Cell L3 as the average percent error between periods 1 and 1 (=AVERAGE($K$3:K3)). Mean absolute percent errors for other periods are obtained by copying the Cell L3 to Cells L4:L14.

The tracking signal (TS) for period 1 is obtained in Cell M3 as the ratio of the total error between periods 1 and 1 and the MAD in period 1 (=SUM($G$3:G3)/J3). Tracking signals for other periods are obtained by copying the Cell M3 to Cells M4:M14.

Chapter 8

Identifying Aggregate Units if Production in Section 8.2

Associated spreadsheet: *Chapter 8-Table 8-1*

This spreadsheet is uses data in Table 8-1to identify an aggregate unit and its revenue and production time characteristics. The data is provided in Cells A1:E7, G1:G7, and I1:I7.

The first step is to take the setup time given per batch (column D) for each product family and convert into per unit. This is done in Cells F2:F7 where the setup time per unit = setup time per batch (Column D) / average batch size (Column E). The formula in Cell F2 (=D2/E2) is copied down to Cells F3:F7. The Net Production Time per unit (Column H) is then obtained as a sum of setup time / unit (Column F) and Production time per unit (Column G).

The aggregate unit is defined as the weighted average (by percent share of sales) of all product families.

The material cost / unit for the aggregate unit is calculated in Cell B9 using the formula "=SUMPRODUCT(B2:B7,$I$2:$I$7)" as the weighted average of material cost

The revenue / unit for the aggregate unit is calculated in Cell C9 using the formula "=SUMPRODUCT(C2:C7,$I$2:$I$7)" as the weighted average of revenue

The net production time / unit for the aggregate unit is calculated in Cell H9 using the formula "=SUMPRODUCT(H2:H7,$I$2:$I$7)" as the weighted average of production time

Building a Basic Aggregate Planning Spreadsheet – Section 8.6

Associated Spreadsheet: *Chapter 8–trial-aggplan*

This spreadsheet takes the data for the Red Tomato Tools example in Section 8.4 and allows a student to build an aggregate plan using trial-and error. The data for Red Tomato Tools in Table 8-2 and 8-3 is provided on worksheet *Table 8-2, 8-3* in Cells A5:B11 and Cells A15:B24 respectively.

The analytical portion is on the worksheet *Planning* whose construction is detailed in Table 8-8. The periodic demand is shown in Cells J5:J10. The decision variables for the planner are the number hired each period (Cells B5:B10), the number laid off each period (Cells C5:C10), the amount of overtime each period (Cells E5:E10) and the quantity subcontracted each period (Cells H5:H10). Based on the values entered for each of these decision variables, the spreadsheet builds the aggregate plan. The overtime entered in Cells E5:E10 must be such that it is less than or equal to the maximum available overtime evaluated in Cells M5:M10 (based on the fact that each worker can do at most 10 hours of overtime each period).

The workforce in each period is calculated in Cells D5:D10. The workforce in period 1 in Cell D5 is calculated using the formula "=D4+B5-C5". Here D4 is the workforce in period 1, B5 the number hired in period 1 and C5 the number laid off in period 1.

The production in each period is calculated in Cells I5:I10. The production in period 1 in Cell I5 is calculated using the formula "=40*D5+(E5/'Tables 8-2, 8-3'!$B$21)". 40*D5 comes from the fact that each worker can product 40 units a period and D5 is the number of workers available in period 1. E5/'Tables 8-2, 8-3'!$B$21 comes from the fact that E5 is the number of overtime hours in the period and 'Tables 8-2, 8-3'!$B$21 is the number of labor hours required per unit.

The inventory and stockout in each period is calculated in Cells F5:F10 and Cells G5:G10 respectively. The inventory in period 1 is calculated using the formula "=MAX(I5+F4+H5-G4-J5,0)". I5+F4+H5 is the number of units available this period from production (I5), previous period inventory (F4), or subcontracting (H5). G4+J5 is the total supply needed to serve last period stockout (G4) or current period demand (J5). If I5+F4+H5-G4-J5 ≥ 0, we have excess inventory for this period that shows up in Cell F5. If I5+F4+H5-G4-J5 < 0, we have a stockout that shows up in Cell G5 which has the formula "=MAX(0,J5+G4-I5-H5-F4)".

Obtaining the results in Table 8-4

Make sure the entry in Cell E14 is 0 (implies no promotion).

To obtain these results, enter values in Cells B5:B10 (# Hired), C5:C10 (# Laid Off), E5:E10 (Overtime), and H5:H10 (subcontract) as follows:

Cells B5:B10	C5:C10	E5:E10	H5:H10
0	16	0	0
0	0	0	0
0	0	0	0
0	0	0	140
0	0	0	0
0	0	0	0

Example 8-1: Obtaining the Results in Table 8-6

First change the demand in Cells B6:B11 of the worksheet *Tables 8-2, 8-3* to equal that shown in Table 8-5.

Now go to worksheet *Planning* and enter the following values in Cells B5:B10 (# Hired), C5:C10 (# Laid Off), E5:E10 (Overtime), and H5:H10 (subcontract):

Cells B5:B10	C5:C10	E5:E10	H5:H10
0	16	0	0
0	0	0	0
0	0	0	0
0	0	0	140
0	0	0	0
0	0	0	0

Example 8-2: Obtaining the Results in Table 8-7

First change the demand in Cells B6:B11 of the worksheet *Tables 8-2, 8-3* to equal that shown in Table 8-2.

Now go to worksheet *Planning* and enter the following values in Cells B5:B10 (# Hired), C5:C10 (# Laid Off), E5:E10 (Overtime), and H5:H10 (subcontract):

Cells B5:B10 C5:C10 E5:E10 H5:H10

0	35	0	0
0	0	0	0
42	0	0	0
1	0	0	0
0	27	0	0
0	0	0	20

Building a Basic Aggregate Planning Spreadsheet Using Solver – Section 8.6

Associated Spreadsheet: *Chapter 8, 9 - examples*

This spreadsheet takes the data for the Red Tomato Tools example in Section 8.4 and allows a student to build an aggregate plan using Solver. The data for Red Tomato Tools in Table 8-2 and 8-3 is provided on worksheet *Table 8-2, 8-3* in Cells A5:B11 and Cells A15:B24 respectively.

The Solver model is built on worksheet *Planning*. We now discuss how this worksheet can be built and used. The decision variables for the Solver model are in Cells B5:I10.

The constraints from Equations 8.2 to 8.5 are formed in Cells M5:P10.

Cell M5 contains the formula "=+D5-D4-B5+C5" and corresponds to Equation 8.2. In the Solver model this Cell should be "=0".

Cell N5 contains the formula "=40*D5+(E5/4)-I5" and corresponds to Equation 8.3. In the Solver model the Cell should be "≥" 0.

Cell O5 contains the formula "=+F4-G4+I5+H5-J5-F5+G5" and corresponds to Equation 8.4. In the Solver model this Cell should be "=0".

Cell P5 contains the formula "=-E5+10*D5" and corresponds to Equation 8.5. In the Solver model the Cell should be "≥" 0.

All constraints in Cells M5:P5 are copied down to rows 6 to 10.

All costs are evaluated in Cells B15:I20 (these cells are hidden in the worksheet but can be seen using "unhide"). The total cost of the aggregate plan is calculated in Cell C22 as the sum of all costs in Cells B15:I20.

Invoke Solver to show the Solver dialog box where the Solver model is setup as follows:

Set Objective: C22 (Total cost)

To: Min (Goal is to minimize total cost)

By changing variable cells: B5:I10

Subject to the constraints:

B5:C10 = integer (only an integer number of workers may be hired or laid off)
B5:I10 ≥ 0 (all variables are non-negative)
F10 ≥ 500 (At least 500 units of inventory at the end of period 6)
G10 = 0 (No stockouts at the end of period 6)
M5:M10 = 0 (Constraint corresponding to Equation 8.2)
N5:N10 ≥ 0 (Constraint corresponding to Equation 8.3)
O5:O10 = 0 (Constraint corresponding to Equation 8.4)
P5:P10 ≥ 0 (Constraint corresponding to Equation 8.5)

Make sure the entry in Cell E24 is 0 (corresponding to no promotion). Clicking on Solve results in the aggregate plan corresponding to Table 8-4.

To obtain Table 8-6, change the demand in Cells B6:B11 in worksheet *Tables 8-2, 8-3* to be as shown in Table 8-5. Then run Solver.

To obtain Table 8-7, return the demand in Cells B6:B11 in worksheet *Tables 8-2, 8-3* to be as shown in Table 8-2. Change the Cells B19 and B20 in worksheet *Tables 8-2, 8-3* to $50 each. Then run Solver.

Building a Rough Master Production Schedule in Section 8.7

Associated spreadsheet: *Chapter 8-Table 8-9*

This spreadsheet is uses data in Table 8-1to go from the aggregate plan in Table 8-4 to a rough Master Production Schedule (MPS) in terms of the various product families. The aggregate plan (in terms of aggregate units) must be converted to production for each family to see if the MPS is feasible. The data is provided in Cells A3:E9.

For period 1, the aggregate production quantity is 2,560 (Cell B10). The first step is to evaluate the production quantity for each family. This is done in Cells F4:F9 by multiplying the total production quantity (Cell B10) by the percent share of sales of each product family (Cells E4:E9).

The next step is to obtain the number of setups required for the average batch size specified in Cells C4:C9. The number of setups for family A are evaluated in Cell G4 using the formula "=INT(F4/C4)". The idea is to eliminate the fractional part in the setups because there will an integer number of setups in each period.

The next step is to obtain the total setup time for each product family in Cells H4:H9. The total setup time is a product of the number of setups in Cells G4:G9 with the corresponding Setup time / batch in Cells B4:B9. The formula in Cell H4 is "=G4*B4".

The next step is to obtain the total production time for each product family in Cells I4:I9. The total production time for family A is evaluated in Cell I4 using the formula "=F4*D4".

The total setup time across all families is evaluated in Cell H10, the total production time across all families is calculated in Cell I10 and the total production and setup time across all families is then calculated in Cell J10.

This time is compared with the total available production time to see if the MPS is feasible. In this instance, the MPS turns out to be feasible. In case the MPS is infeasible, the number of setups will have to be decreased for some product families (fewer batches that are larger) to make the MPS feasible.

Chapter 9

Sales and Operations Planning at Red Tomato in Section 9.4

Associated spreadsheet: *Chapter 8,9-examples* for solutions with Solver
Chapter8-trial-aggplan for trial and error solutions without Solver

We first discuss how Figures 9-1 to 9-5 can be obtained using the spreadsheet *Chapter 8,9-examples*. The details of this spreadsheet have already been discussed earlier in the context of Chapter 8 (see pages 18, 19). So we focus on how the spreadsheet can be used to obtain the various cases discussed in Chapter 9.

The Base case – Figure 9-1

Associated worksheet: *Planning* in spreadsheet *Chapter 8,9-examples*

Set Cell E24 to 0. This corresponds to the case of "No promotion".

Use Data | Analysis | Solver | Solve to obtain Figure 9-1.

Figure 9-2: Impact of offering a promotion in January from $40 to $39

Associated worksheet: *Planning* in spreadsheet *Chapter 8,9-examples*

Set Cell E24 to 1. This corresponds to the case of when a promotion is offered. Set Cell E 25 to 1. This corresponds to a promotion in January. Ensure that Cell H24 = 0.1 (10 percent growth) and Cell H25 = 0.2 (20 percent forward buy).

Use Data | Analysis | Solver | Solve to obtain Figure 9-2.

Figure 9-3: Impact of offering a promotion in April from $40 to $39

Associated worksheet: *Planning* in spreadsheet *Chapter 8,9-examples*

Set Cell E24 to 1. This corresponds to the case of when a promotion is offered. Set Cell E 25 to 4. This corresponds to a promotion in April. Ensure that Cell H24 = 0.1 (10 percent growth) and Cell H25 = 0.2 (20 percent forward buy).

Use Data | Analysis | Solver | Solve to obtain Figure 9-3.

Figure 9-4: Impact of offering a promotion in January from $40 to $39 if discount leads to a large increase in consumption

Associated worksheet: *Planning* in spreadsheet *Chapter 8,9-examples*

Ensure that Cell H24 = 1 (100 percent growth which is larger than the 10 percent growth assumed earlier) and Cell H25 = 0.2 (20 percent forward buy). Set Cell E24 to 1. This corresponds to the case of when a promotion is offered. Set Cell E 25 to 1. This corresponds to a promotion in January.

Use Data | Analysis | Solver | Solve to obtain Figure 9-4.

Figure 9-5: Impact of offering a promotion in April from $40 to $39 if discount leads to a large increase in consumption

Associated worksheet: *Planning* in spreadsheet *Chapter 8,9-examples*

Ensure that Cell H24 = 1 (100 percent growth which is larger than the 10 percent growth assumed earlier) and Cell H25 = 0.2 (20 percent forward buy). Set Cell E24 to 1. This corresponds to the case of when a promotion is offered. Set Cell E 25 to 4. This corresponds to a promotion in April.

Use Data | Analysis | Solver | Solve to obtain Figure 9-5.

Building Table 9-3

Associated worksheet: *Planning* in spreadsheet *Chapter 8,9-examples*

Set the various Cells as shown in the Table below and run Solver in each case to obtain the profit values shown in Table 9-3:

Regular Price (Cell H23)	Promotion Price	Cell E24	Promotion Period	Cell E25	% Increase in Demand	Cell H24	% of Forward Buy	Cell H25
$40	$40	0	NA		NA			
$40	$39	1	January	1	10	0.1	20	0.2
$40	$39	1	April	4	10	0.1	20	0.2
$40	$39	1	January	1	100	1	20	0.2
$40	$39	1	April	4	100	1	20	0.2
$31	$31	0	NA		NA			
$31	$30	1	January	1	100	1	20	0.2
$31	$30	1	April	4	100	1	20	0.2

Replicating the Results Using the Spreadsheet Chapter8-trial-aggplan

All the results discussed above can be replicated using the trial and error spreadsheet as well. In each case we identify the values to be entered in Cells B5:B10 (# Hired), C5:C10 (# Laid Off), E5:E10 (Overtime), and H5:H10 (subcontract) in the appropriate worksheet.

The Base case – Figure 9-1

Associated worksheet: *Planning* in spreadsheet *Chapter8-trial-aggplan*

Make sure the entry in Cell E14 is 0 (implies no promotion) and Cell H13 is $40.

To obtain these results, enter values in Cells B5:B10 (# Hired), C5:C10 (# Laid Off), E5:E10 (Overtime), and H5:H10 (subcontract) as follows:

Cells B5:B10	C5:C10	E5:E10	H5:H10
0	16	0	0
0	0	0	0
0	0	0	0
0	0	0	140
0	0	0	0
0	0	0	0

Figure 9-2: Impact of offering a promotion in January from $40 to $39

Associated worksheet: *Figure 9-2* in spreadsheet *Chapter8-trial-aggplan*

Set Cell E14 to 1. This corresponds to the case of when a promotion is offered. Set Cell E15 to 1. This corresponds to a promotion in January. Ensure that Cell H14 = 0.1 (10 percent growth) and Cell H15 = 0.2 (20 percent forward buy).

To obtain these results, enter values in Cells B5:B10 (# Hired), C5:C10 (# Laid Off), E5:E10 (Overtime), and H5:H10 (subcontract) as follows:

Cells B5:B10	C5:C10	E5:E10	H5:H10
0	15	0	0
0	0	0	0
0	0	0	0
0	0	0	60
0	0	0	0
0	0	0	0

Figure 9-3: Impact of offering a promotion in April from $40 to $39

Associated worksheet: *Figure 9-3* in spreadsheet *Chapter8-trial-aggplan*

Set Cell E14 to 1. This corresponds to the case of when a promotion is offered. Set Cell E15 to 4. This corresponds to a promotion in April. Ensure that Cell H14 = 0.1 (10 percent growth) and Cell H15 = 0.2 (20 percent forward buy).

To obtain these results, enter values in Cells B5:B10 (# Hired), C5:C10 (# Laid Off), E5:E10 (Overtime), and H5:H10 (subcontract) as follows:

Cells B5:B10	C5:C10	E5:E10	H5:H10
0	14	0	0
0	0	0	0
0	0	0	0
0	0	0	40
0	0	0	0
0	0	0	0

Figure 9-4: Impact of offering a promotion in January from $40 to $39 if discount leads to a large increase in consumption

Associated worksheet: *Figure 9-4* in spreadsheet *Chapter8-trial-aggplan*

Set Cell E14 to 1. This corresponds to the case of when a promotion is offered. Set Cell E15 to 1. This corresponds to a promotion in January. Ensure that Cell H14 = 1 (100 percent growth) and Cell H15 = 0.2 (20 percent forward buy).

To obtain these results, enter values in Cells B5:B10 (# Hired), C5:C10 (# Laid Off), E5:E10 (Overtime), and H5:H10 (subcontract) as follows:

Cells B5:B10	C5:C10	E5:E10	H5:H10
0	0	0	100
0	11	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

Figure 9-5: Impact of offering a promotion in April from $40 to $39 if discount leads to a large increase in consumption

Associated worksheet: *Figure 9-5* in spreadsheet *Chapter8-trial-aggplan*

Set Cell E14 to 1. This corresponds to the case of when a promotion is offered. Set Cell E15 to 4. This corresponds to a promotion in April. Ensure that Cell H14 = 1 (100 percent growth) and Cell H15 = 0.2 (20 percent forward buy).

To obtain these results, enter values in Cells B5:B10 (# Hired), C5:C10 (# Laid Off), E5:E10 (Overtime), and H5:H10 (subcontract) as follows:

Cells B5:B10	C5:C10	E5:E10	H5:H10
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	100
0	0	0	0
0	0	0	0

Chapter 11

Example 11-1 Economic Order Quantity

Associated spreadsheet: Worksheet *Example 11-1* in the workbook *Chapter11-examples1-6*

The input data is provided in Cells A4:B7.

Using Equation 11.5, the economic order quantity is obtained in Cell F4 with the formula "=SQRT(2*C4*C5/(C6*C7))".

The results in Cells A11:D97 show how the Annual Order Cost (Column B), Annual Holding Cost (Column C), and Total Cost (Column D) change with the lot size (Column A). The Chart of the changing costs with Lot Size is shown in the worksheet *Example 11-1 Chart*.

To understand how changing demand affects the EOQ, change values in Cell C4 to 24000, 48000, and 96000. How does the EOQ (Cell F4) change relative to demand (Cell C4)?

To understand the impact of fixed cost S on EOQ, change values in Cell C5 to 1000 and 16000. How does the EOQ (Cell F4) change relative to fixed cost S (Cell C5)?

Example 11-2 Relationship between desired lot size and ordering cost

Associated spreadsheet: Worksheet *Example 11-2* in the workbook *Chapter11-examples1-6*

The input data is provided in Cells A4:B7.

Using Equation 11.5, the required order cost / lot is obtained in Cell F4 with the formula "=C5^2*(C6*C7)/(2*C4)". Cell C5 contains the desired lot size.

To understand how the desired lot size affects required order cost / lot S, change the desired lot size in Cell C5 to 100, 400 and 800. How does the required S (Cell F4) change relative to the desired lot size (Cell C5)?

Example 11-3 Multiple Products with Lots Ordered and Delivered Independently

Associated spreadsheet: Worksheet *Example 11-3* in the workbook *Chapter11-examples1-6*

The input data is provided in Cells A2:D12.

The results in Table 11-1 are shown in Cells A15:F18.

The first step is to evaluate the optimal number of orders per year using Equation 11.6. For Litepro the optimal number of orders per year is evaluated in Cell B16 using the formula

"=SQRT((D2*$D$12*D8)/(2*($D$11+D5)))".

Given that each product is ordered independently, $D$11+D5 is the fixed cost of placing an order for Litepro. The formulae in Cells B17 and B18 are obtained by copying Cell B16 down to each of these cells.

The EOQ in Cells C16:C18 is obtained as "demand / order per year". The EOQ for Litepro is evaluated in Cell C16 using the formula "=D2/B16". The annual order cost for Litepro is evaluated in Cell D16 using the formula "=B16*($D$11+D5)" as the product of the number of orders per year and the fixed cost per order. The annual holding cost for Litepro is calculated using the formula "=(C16/2)*D8*$D$12".

Example 11-4 Products Ordered and Delivered Jointly

Associated spreadsheet: Worksheet *Example 11-4* in the workbook *Chapter11-examples1-6*

The input data is provided in Cells A2:D12.

The results in Table 11-2 are shown in Cells A16:F19.

Given that all products are ordered and delivered jointly, the joint fixed order cost is given in Cell D12 (=SUM(D5:D7)+D11). With this fixed cost, the optimal number of orders per year (for all products) is evaluated using Equation 11.8 in Cell B17 with the Excel formula "=SQRT((D2*D13*D8+D3*D9*D13+D4*D10*D13)/(2*D12))".

The number of orders per year for all products are the same as shown in Cells B17:B19. The order size is obtained in Cells C17:C19 as "demand / order per year". The annual order cost is obtained as the product of the fixed order cost (across all products) and the number of order per year in Cell D20 "=B17*(D11+SUM(D5:D7))".

The annual holding costs are obtained for each products as $\frac{Q}{2}hC$, where Q is the order size. The annual holding cost for Litepro is obtained in Cell E17 using the formula "=(C17/2)*D8*$D$13".

Example 11-5 Aggregation with Capacity Constraints

Associated spreadsheet: Worksheet *Example 11-5* in the workbook *Chapter11-examples1-6*

The input data is provided in Cells B3:D9. The number of suppliers on a truck in Cell B8 can be changed.

The combined order cost for all suppliers on the truck are calculated in Cell B11 to equal "=B6+B7*B8".

The results ignoring capacity constraints are shown in Cells A14:B18.

The results with capacity constraints are shown in Cells A21:B25. Cell B21 contains the total amount on the truck if the capacity constraint is included. This is calculated as Min{Desired quantity if capacity is ignored, Truck capacity} = min(B16, B9).

The quantity ordered from each supplier is obtained in Cell B22 (=Cell B21 / Number of suppliers = B21/B8) and the order frequency in Cell B23 (=Demand per product / quantity ordered from each supplier).

Change the number of suppliers in Cell B8 to see how the results change.

Example 11-6 Lot Sizing with Multiple Products

Associated spreadsheet: Worksheet *Example 11-6* in the workbook *Chapter11-examples1-6*

The input data is provided in Cells A2:D12. The results in Table 11-3 are shown in Cells A22:F26.

The evaluation of these results is done in two stages. The results of the first stage are shown in Cells A15:E19. Cells B17:B19 contain the outcome of Step 1 (of the 5 step procedure outlined on page 284 of the book). These cells contain the optimal order frequency if each product were ordered individually but incurred both the Common order cost (Cell D11) and the product specific order cost (Cells D5:D7).

Cells C17:C19 contain the outcome of Step 2 – the optimal order frequency if each product were ordered individually but only incurred the product specific order cost (Cells D5:D7).

Cells D17:D19 contain the ratio of Cells B17:B19 and Cells C17:C19 rounded up. Cells D17:D19 contain the number of deliveries of the most frequently ordered product for each delivery of this product. Thus, Cell D18 shows that Medpro should be included in every other delivery of Litepro. Cell D19 shows that Heavypro should be included in every 5^{th} delivery of Litepro.

Cell E17 then contains the optimal frequency of Litepro (the most frequently ordered product) using Equation 11.9.

Example 11-7 All Unit Quantity Discounts

Associated spreadsheet: Worksheet *Example 11-7 check* in the workbook *Chapter11-examples7-8* (see also worksheets *Example 11-7* and *Example 11-7 chart*)

The input data is provided in Cells A3:C11.

The first step is to calculate the desired order size for each price range in Cells B14:B16 using Equation 11.10. The next step is to adjust it to the appropriate size (based on whether the desired quantity is in the price range or not) in Cells C14:C16. For example, even though the desired order quantity in Cell B16 for a price of $2.92 is 6,411, it is adjusted up to 10,000 in Cell C16 because the discounted price of $2.92 is only available if at least 10,000 units are ordered.

Total cost for each range is then calculated in Cells E14:E16 using Equation 11.11.

Change the fixed order cost in Cell C3 and see how it affects the optimal order quantity without discounts in Cell C20 as well as the optimal order quantity with discounts obtained from Cells A13:E16.

The worksheet *Example 11-7* shows annual cost for different order quantities. These are then charted in the worksheet *Example 11-7 chart*.

Example 11-8 Marginal Unit Quantity Discounts

Associated spreadsheet: Worksheet *Example 11-8 check* in the workbook *Chapter11-examples7-8* (see also worksheets *Example 11-8* and *Example 11-8 chart*)

The input data is provided in Cells A3:C11.

The first step is to calculate the quantity V_i using Equation 11.12 in Cells B14:B16 for each price range. The next step is to calculate the desired order size for each price range in Cells C14:C16 using Equation 11.13. The next step is to adjust it to the appropriate size (based on whether the desired quantity is in the price range or not) in Cells D14:D16. For example, even though the desired order quantity in Cell B14 for a price of $3 is 6,325, it is adjusted down to 5,000 in Cell D14 because the price of $3 is applicable only for orders of 5,000 or less.

Total cost for each range is then calculated in Cells F14:F16 using Equation 11.14.

Change the fixed order cost in Cell C3 and see how it affects the optimal order quantity without discounts in Cell C20 as well as the optimal order quantity with discounts obtained from Cells A13:E16.

The worksheet *Example 11-8* shows annual cost for different order quantities. These are then charted in the worksheet *Example 11-8 chart*.

Example 11-9 The Impact of Locally Optimal Lot Sizes on a Supply Chain

Associated spreadsheet: Worksheet *Example 11-9* in the workbook *Chapter11-quantity discounts*

The input data is provided in Cells A3:D8.

Cell D9 contains the optimal lot size desired by the retailer based on its ordering and holding cost (calculated using the EOQ formula in Equation 11.5). For this lot size the manufacturer's costs are evaluated in Cells B10 while the retailers costs are evaluated in Cell D10. The total supply chain inventory related costs are evaluated in Cell D12 as the sum of the manufacturer and retailer costs.

Cell D15 calculates the desired optimal lot size considering both the manufacturer and retailer costs using the formula on page 293.

Cell D15 $= Q^* = \sqrt{\dfrac{2D(S_R + S_M)}{h_R C_R + h_M C_M}}$ =SQRT(2*D4*12*(D5+B5)/(B7*B6+D7*D6))

Cell B16 contains the manufacturer's cost and Cell D16 contains the retailers cost for the lot size in Cell D15. Cell D17 contains the total cost for the lot size in Cell D15.

Cell B19 contains the change in manufacturer's cost if the retailer changes order size from that in Cell D9 to that in Cell D15. Cell D19 contains the change in retailer's cost if the retailer changes order size from that in Cell D9 to that in Cell D15. Cell D20 contains the change in total supply chain cost if the retailer changes order size from that in Cell D9 to that in Cell D15.

Example 11-10 Designing a Suitable All Unit Discount

Associated spreadsheet: Worksheet *Example 11-9* and *Example 11-10* in the workbook *Chapter11-quantity discounts*

The input data is provided in Cells C3:C5.

Cell C9 (in worksheet *Example 11-10*) contains the required discount price such that the retailer is compensated the increase in cost (over a year) from Cell D19 in worksheet *Example 11-9* when ordering the quantity in Cell B9 in worksheet *Example 11-10*. Column F (in worksheet *Example 11-10*) shows the retailer's total cost for various order quantities under the discounting scheme.

Quantity Discounts for Products for Which the Firm has Market Power

Associated spreadsheet: Worksheet *2-stage* in the workbook *Chapter11-quantity discounts* supports the discussion on page 294 of the book. Changing the manufacturer wholesale price in Cell B5 provides the corresponding optimal retail price in Cell D5. Demand and profit for the manufacturer are shown in Cells B6:B7 and those for the retailer in Cells D6:D7. The total supply chain profit is shown in Cell B9.

First find the wholesale price in Cell B5 that maximizes the manufacturer profit in Cell B7. Now find the wholesale price in Cell B5 that maximizes the total profit in Cell B9. What is the difference between the two prices?

Quantity Discounts for Products for Which the Firm has Market Power

Associated spreadsheet: Worksheet *2-part-tariff* in the workbook *Chapter11-quantity discounts* supports the discussion on page 295 of the book. Change the franchise fee in Cell B6 to see how the manufacturer and retailer profits change as a result.

Volume Based Quantity Discounts

Associated spreadsheet: Worksheet *Volume Discount* in the workbook *Chapter11-quantity discounts* supports the discussion on page 295/296 of the book. Change the discount price in Cell E6 to any value between 3.00 and 3.50 to see how profits in Cells B7, C7 and B9 are affected.

Example 11-11 Impact of Trade Promotions on Lot Sizes

Associated spreadsheet: Worksheet *Example 11-11* in the workbook *Chapter11-examples 11-12.*

The input data is provided in Cells A4:D8.

Cell B9 contains the EOQ (using Equation 11.5) at the regular price. Cell D10 contains the desired order quantity at the discount price (using Equation 11.15). Change the discount in Cell D7 to see how the desired order quantity in Cell D10 is affected.

Example 11-12 How Much of a Discount Should a Retailer Pass Through?

Associated spreadsheet: Worksheet *Example 11-12* in the workbook *Chapter11-examples 11-12.*

The input data is provided in Cells B4:D4.

The optimal retail price (with discount is shown in Cell D5 and the quantity sold at this price is shown in Cell D6.

Change the discount price in Cell D4 to see how the optimal retail price and demand are affected.

Chapter 12

Example 12-1 Evaluating Safety Inventory Given an Inventory Policy

Associated spreadsheet: Worksheet *Example 12-1* in the workbook *Chapter12-examples1 thru 13*

The input data is provided in Cells C3:C6.

Column A (from rows 11 on) contains different values of the reorder point ROP. Column B contains the corresponding safety inventory ($ss = ROP - D \times L$). Column C contains the average inventory ($= Q/2 + ss$) and Column D the average flow time (= average inventory / demand).

Example 12-2 Evaluating Cycle Service Level Given a Replenishment Policy

Associated spreadsheet: Worksheet *Example 12-2* in the workbook *Chapter12-examples1 thru 13*

The input data is provided in Cells C3:C6.

Mean demand during lead time (D_L) is evaluated in Cell D9 ($=D \times L$) and standard deviation during lead time (σ_L) is evaluated in Cell D10 ($\sqrt{L}\sigma_D$).

Column A (from rows 15 on) contains different values of the reorder point ROP. Column B contains the corresponding safety inventory ($ss = ROP - D \times L$). Column C contains the resulting cycle service level *CSL* using Equation 12.4 (*CSL =NORMDIST(ROP,* D_L *,* σ_L*, 1))*.

Example 12-3 Evaluating Safety Inventory Given a Desired Cycle Service Level

Associated spreadsheet: Worksheet *Example 12-3* in the workbook *Chapter12-examples1 thru 13*

The input data is provided in Cells C3:C6.

Mean demand during lead time (D_L) is evaluated in Cell D10 ($=D \times L$) and standard deviation during lead time (σ_L) is evaluated in Cell D11 ($\sqrt{L}\sigma_D$).

The required safety inventory is calculated in Cell D14 using Equation 12.5 (*ss = NORMSINV(CSL)* × σ_L).

Change the desired *CSL* in Cell D6 to see how the required safety inventory in Cell D14 changes.

Example 12-4 Evaluating Fill Rate Given Safety Inventory

Associated spreadsheet: Worksheet *Example 12-4* in the workbook *Chapter12-examples1 thru 13*

The input data is provided in Cells A3:E6.

Mean demand during lead time (D_L) is evaluated in Cell A6 (=$D \times L$) and standard deviation during lead time (σ_L) is evaluated in Cell B6 ($\sqrt{L}\sigma_D$).

The cycle service level *CSL* is then calculated in Cell A9 using Equation 12.4. The expected shortage per cycle *ESC* is calculated in Cell B9 using Equation 12.9. Finally, the fill rate *fr* is calculated in Cell C9 using Equation 12.6.

Change the batch size in Cell A3 and the safety inventory in Cell E3 and see how each change affects the *CSL* in Cell A9 and the fill rate *fr* in Cell C9.

Example 12-5 Evaluating Safety Inventory Given Fill Rate

Associated spreadsheet: Worksheet *Example 12-5* in the workbook *Chapter12-examples1 thru 13*

The input data is provided in Cells A3:C3.

Given the fill rate (*fr*) in Cell A3, the first step is to evaluate the desired expected shortage per cycle (*ESC*) in Cell D3 using the formula (Equation 12.6) $ESC = (1\text{-}fr) \times Q = (1\text{-}A3)*C3$.

In the Cell E3 we enter any value for the safety stock *ss*. In Cell A6 we then calculate the resulting *ESC* if the *ss* in Cell E3 is used. *ESC* is calculated using Equation 12.8 as follows:

ESC = -*ss*[1 – *NORMDIST(ss*/707,0,1,1)] + 707*NORMDIST*(*ss*/707,0,1,0)

= -E3*(1-NORMDIST(E3/B3,0,1,1))+B3*NORMDIST(E3/B3,0,1,0)

One way to solve the problem is to change the *ss* in Cell E3 until the *ESC* in Cell A6 equals the desired *ESC* in Cell D3.

Another way to solve the problem is using GOALSEEK. To use *GoalSeek*, proceed as follows:

1. Invoke *GoalSeek* using Data | What-If-Analysis | GoalSeek

2. **Set Cell** to be $A$6 (Expected Shortage per Cycle); set **To value** to be 250 (we want ESC to be 250 as in Cell D3), and **By changing cell** to be $D$3 (we are changing safety stock)

Repeat the process for different values of fill rate *fr* in Cell A3 to build Table 12-1.

Example 12-6 Benefits of Reducing Lead Time and Demand Uncertainty

Associated spreadsheet: Worksheet *Example 12-6* in the workbook *Chapter12-examples1 thru 13*

The input data is provided in Cells A3:D6.

Mean demand during lead time (D_L) is evaluated in Cell D10 (=$D \times L$) and standard deviation during lead time (σ_L) is evaluated in Cell D11 ($\sqrt{L}\sigma_D$).

The required safety inventory is evaluated in Cell D14 using Equation 12.5.

To see the impact of reducing lead time, change the lead time in Cell D5.

To see the impact of reducing demand uncertainty, change the standard deviation in Cell D4.

Example 12-7 Impact of Lead Time Uncertainty

Associated spreadsheet: Worksheet *Example 12-7* in the workbook *Chapter12-examples1 thru 13*

The input data is provided in Cells A3:D7.

Mean demand during lead time (D_L) is evaluated in Cell D10 (=$D \times L$) and standard deviation during lead time (σ_L) is evaluated in Cell D11 ($\sqrt{L\sigma_D^2 + D^2 s_L^2}$) using Equation 12.11.

The required safety inventory is then calculated in Cell D15 using Equation 12.5 as

$$ss = NORMSINV(CSL) \times \sigma_L = NORMSINV(D7)*E12$$

Change the standard deviation of lead time in Cell D6 to see how it impacts the required safety inventory in Cell D15.

Example 12-8 Impact of Correlation on Value of Aggregation

Associated spreadsheet: Worksheet *Example 12-8* in the workbook *Chapter12-examples1 thru 13*

The input data is provided in Cells A2:D9.

<u>For the disaggregate option</u>:

For each disaggregate location, the mean demand during lead time is evaluated in Cell D14 (=D2*D4) and the standard deviation during lead time is evaluated in Cell D15. The required safety inventory at each location is evaluated in Cell D18 and the total safety inventory across all locations is calculated in Cell D22.

<u>For the aggregate option</u>:

The mean weekly demand on aggregation is evaluated in Cell E12 (=D7*D2) and the standard deviation on aggregation is calculated in Cell E13 [=SQRT($D$7*$D$3^2+$D$6*$D$7*($D$7-1)*$D$3^2)] using Equation 12.14. The mean demand during lead time is evaluated in Cell E14 and the standard deviation during lead time is evaluated in Cell E15. The required safety inventory is evaluated in Cell E22.

The savings in safety inventory upon aggregation is evaluated in Cell E26, the savings in inventory value upon aggregation is evaluated in Cell E27, and the savings in annual holding cost is evaluated in Cell E28.

Changing the various inputs in Cells D3:D9 changes the annual savings in Cell E28. In particular, changing the correlation coefficient in Cell D6 allows one to build the results in Table 12-3.

Example 12-9 Tradeoffs of Physical Aggregation

Associated spreadsheet: Worksheet *Example 12-9* in the workbook *Chapter12-examples1 thru 13*

The input data is provided in Cells A2:D9.

For the disaggregate option:

For each disaggregate location, the mean demand during lead time is evaluated in Cell D14 (=D2*D4) and the standard deviation during lead time is evaluated in Cell D15. The required safety inventory at each location is evaluated in Cell D18 and the total safety inventory across all locations is calculated in Cell D22.

For the aggregate option:

The mean weekly demand on aggregation is evaluated in Cell E12 (=D7*D2) and the standard deviation on aggregation is calculated in Cell E13 [=SQRT($D$7*$D$3^2+$D$6*$D$7*($D$7-1)*$D$3^2)] using Equation 12.14. The mean demand during lead time is evaluated in Cell E14 and the standard deviation during lead time is evaluated in Cell E15. The required safety inventory is evaluated in Cell E22.

The savings in safety inventory upon aggregation is evaluated in Cell E26, the savings in inventory value upon aggregation is evaluated in Cell E27, and the savings in annual holding cost is evaluated in Cell E28.

The change in operating and transportation cost is evaluated in Cells A31:E35. Cell E31 contains the decrease in operating cost upon aggregation (given as input). The transport cost/unit for the disaggregate option is given in Cell D32. The total transportation cost for the disaggregate option is evaluated in Cell D33 (=D32*D2*52*D7). The transport cost/unit for the aggregate option is given in Cell E32. The total transportation cost for the aggregate option is evaluated in Cell E33 (=E32*D2*52*D7). The increase in transportation cost upon aggregation is evaluated in Cell E34 (=E33-D33). The net operating and transportation cost increase upon aggregation is calculated in Cell E35 (= transportation cost increase – operating cost decrease).

Compare the inventory savings in Cell E28 with the transportation and operating cost increase in Cell E35 to decide whether aggregation makes sense (if Cell E28 > Cell E35) or not (if Cell E28 < Cell E35).

Change any of the inputs in Cells D3:D9 to see how the change affects your decision.

Example 12-10 Impact of Coefficient of Variation on Value of Aggregation

Associated spreadsheet: Worksheet *Example 12-10* in the workbook *Chapter12-examples1 thru 13*

The input data is provided in Cells A4:C5.

For the disaggregate option (inventory is stocked in each store):

For each store, the required safety inventory is evaluated in Cells B7 (for motors) and C7 (for cleaner). and the total safety inventory across all locations is calculated in Cell D22. The total safety inventory across 1,600 stores is evaluated in Cells B8 (Motors) and C8 (Cleaner). The value of the safety inventory is evaluated in Cells B9 (motors) and C9 (cleaner).

For the aggregate option:

The mean weekly demand on aggregation is evaluated in Cells B11 (motors) and C11 (cleaner). The standard deviation on aggregation is evaluated in Cell B12 (motors) and Cell C12 (cleaner) using Equation 12.15 assuming demand to be independent across all 1,600 stores. The aggregate safety inventory is evaluated in Cells B14 (motors) and C14 (cleaner). The value of the safety inventory is evaluated in Cells B15 (motors) and C15 (cleaner).

The inventory and holding cost savings on aggregation are evaluated in Cells A17:C20.

Cells A26:C44 show all the calculations with safety inventory numbers rounded to the closest integer as in the book (Table 12-4).

Example 12-11 Value of Component Commonality

Associated spreadsheet: Worksheet *Example 12-11* in the workbook *Chapter12-examples1 thru 13*

The input data is provided in Cells A2:B7.

We first evaluate the required safety inventory (Cell B10) when each component type for each server is distinct. The required inventory per component type is given by NORMSINV($B$5)*SQRT($B$4)*$B$3. Thus the total required inventory across all component types (B6*B7) is given by B6*B7*NORMSINV($B$5)*SQRT($B$4)*$B$3.

As the number of finished products per component changes (Cells A11:A18), the required safety inventory changes in Cells B11:B18. The basic assumption is that if each component is in two finished products, the total required safety inventory will be $\sqrt{2}$ times less than the required safety inventory when all components are distinct for each finished product.

Example 12-12 Value of Postponement

Associated spreadsheet: Worksheet *Example 12-12* in the workbook *Chapter12-examples1 thru 13*

The input data is provided in Cells A2:D6.

For the without postponement option:

For each color, the mean demand during lead time is evaluated in Cell D11 (=D2*D4) and the standard deviation during lead time is evaluated in Cell D12. The required safety inventory of each color is evaluated in Cell D15 and the total safety inventory across all colors is calculated in Cell D19.

<u>For the postponement option</u>:

The mean weekly demand on postponement (all colors are aggregated) is evaluated in Cell E9 (=D6*D2) and the standard deviation on aggregation is calculated in Cell E10 [=SQRT(D6)*D3] using Equation 12.15. The required safety inventory is evaluated in Cell E19.

The savings in safety inventory upon aggregation is evaluated in Cell E23.

Change the entries in Cells D3:D5 to see how the savings in safety inventory in Cell E23 changes.

Example 12-13 Evaluating Safety Inventory for Period review

Associated spreadsheet: Worksheet *Example 12-13* in the workbook *Chapter12-examples1 thru 13*

The input data is provided in Cells A3:D7.

Mean demand during time $T+L$ (D_{T+L}) is evaluated in Cell D10 ($=D\times(T+L)$) and standard deviation during $T+L$ (σ_{T+L}) is evaluated in Cell D11 ($\sqrt{T+L}\sigma_D$).

The required safety inventory is calculated in Cell D14 using Equation 12.5 ($ss = NORMSINV(CSL)\times \sigma_{T+L}$). The order up to level (OUL = $D_{T+L} + ss$) is evaluated in Cell D15.

Change the review interval T in Cell D6 to see how the required safety inventory in Cell D14 changes.

Chapter 13

Building Table 13-2

Associated spreadsheet: Worksheet *Table 13-1,2* in the workbook *Chapter13-examples*

The input data is provided in Cells A2:C5, E2:F3, and A8:B22.

Enter a desired order quantity in Cell C5 (from among 400, 500, …, 1600, 1700). Cell G23 gives the expected profit from ordering the quantity in Cell C5. Cell F28 gives the expected profit from ordering quantity = C5 + 100 units. Cell F29 contains the expected marginal contribution of the additional 100 units.

If the value in Cell F29 is positive, it makes sense to increase the quantity in Cell C5 by 100.

Example 13-1 Optimal Service Level for Seasonal Items

Associated spreadsheet: Worksheet *Example 13-1* in the workbook *Chapter13-examples*

The input data is provided in Cells A4:E8.

The first step is to evaluate the cost of overstocking, C_o = *cost per unit – salvage value*, in Cell E11 and the cost of understocking, C_u = *retail price – cost per unit*, in Cell E12. The desired cycle service level is then obtained in Cell E13 using Equation 13.1 as $CSL = C_u /(C_u + C_o)$. The desired order size is obtained in Cell E14 using Equation 13.2 and the resulting expected profit is obtained in Cell E15 using Equation 13.3.

Example 13-2 Evaluating Expected Overstock and Understock

Associated spreadsheet: Worksheet *Example 13-2* in the workbook *Chapter13-examples*

The input data is provided in Cells A4:E8.

Scenario 1 evaluations use a specified order size in Cell E14. They then calculate the expected profit, overstock, and understock in in Cells E15:E17. Scenario 2 evaluations, in contrast, calculate the optimal order size in Cell F14 and then calculate the expected profit, overstock, and understock in in Cells F15:F17.

As a result, you can compare the performance of any order quantity (Scenario 1) with the optimal order quantity (Scenario 2).

Example 13-3 Quantity Discounts

Associated spreadsheet: Worksheet *Example 13-3* in the workbook *Chapter13-examples*

The input data is provided in Cells A4:E8, F4:F5, and CellsH4:I6.

<u>No Discount</u>

Column E (No Discount) evaluates the scenario without discounts. The first step is to evaluate the cost of overstocking, C_o = *cost per unit – salvage value*, in Cell E11 and the cost of understocking, C_u = *retail price – cost per unit*, in Cell E12. The desired cycle service level is then obtained in Cell E16 using Equation 13.1 as $CSL = C_u /(C_u + C_o)$. The desired order size is obtained in Cell E15 using Equation 13.2 and the resulting expected profit is obtained in Cell E17 using Equation 13.3. Expected overstock is evaluated in Cell E18 and expected understock in Cell E19.

<u>With Discount</u>

Column F (Discount) evaluates the scenario with discounts. The first step is to enter the desired order quantity in Cell F15. We then evaluate the cost per unit in Cell F6. For order sizes below 200, the cost per unit is $50. For order sizes of 200 or more, the cost per unit is $45. Based on the order size in Cell F15, the expected profit is evaluated in Cell F7, the expected overstock in Cell F18, and the expected understock in Cell F19.

Example 13-4 Imputing Cost of Stockout

Associated spreadsheet: Worksheet *Example 13-4,5* in the workbook *Chapter13-examples*

The input data is provided in Cells A5:B10 and Cell B17.

The first step is to evaluate Mean demand during lead time (D_L) in Cell B13 ($=D\times L$) and standard deviation during lead time (σ_L) in Cell B14 ($\sqrt{L}\sigma_D$).

Given the reorder point in Cell B17, we next evaluate the cycle service level *CSL* in Cell B16 [=NORMDIST(B17,B13,B14,1)].

The implied cost of understocking is obtained in Cell B15 using Equation 13.6.

Example 13-5 Evaluating Optimal Service Level

Associated spreadsheet: Worksheet *Example 13-4,5* in the workbook *Chapter13-examples*

The input data is provided in Cells A5:B10, Cell C15.

Column C evaluates the required safety stock (Cell C18) if demand during stockout is backlogged while Column D evaluates the required safety stock (Cell E18) if demand during stockout is lost.

<u>Demand during stockout is lost</u>

The first step is to evaluate Mean demand during lead time (D_L) in Cell E13 (=$D \times L$) and standard deviation during lead time (σ_L) in Cell E14 ($\sqrt{L}\sigma_D$).

Given the cost of understocking in Cell E15, the next step is to evaluate the desired cycle service level in Cell E16 using Equation 13.7. The required safety stock is then evaluated in Cell E18 and the required reorder point in Cell E17.

<u>Demand during stockout is backlogged</u>

The first step is to evaluate Mean demand during lead time (D_L) in Cell C13 (=$D \times L$) and standard deviation during lead time (σ_L) in Cell C14 ($\sqrt{L}\sigma_D$).

Given the cost of understocking in Cell C15, the next step is to evaluate the desired cycle service level in Cell C16 using Equation 13.6. The required safety stock is then evaluated in Cell C18 and the required reorder point in Cell C17.

Example 13-6 Impact of Improved Forecasts

Associated spreadsheet: Worksheet *Example 13-6* in the workbook *Chapter13-examples*

The input data is provided in Cells A4:E8 and Cell F5.

Column E evaluates expected profits for current standard deviation. Column F evaluates outcomes as standard deviation is reduced.

<u>Current standard deviation</u>

Cost of overstocking is evaluated in Cell E11 and the cost of understocking in Cell E12. The optimal cycle service level is then evaluated in Cell E16 using Equation 13.1. The optimal order quantity is evaluated in Cell E15 (Equation 13.2), the expected profit in Cell E17 (Equation 13.3), the expected overstock in Cell E18 (Equation 13.4), and the expected understock in Cell E19 (Equation 13.5).

<u>Reduced standard deviation</u>

Enter the reduced standard deviation in Cell F5. Cost of overstocking is evaluated in Cell F11 and the cost of understocking in Cell F12. The optimal cycle service level is then evaluated in Cell F16 using Equation 13.1. The optimal order quantity is evaluated in Cell F15 (Equation 13.2), the expected profit in Cell F17 (Equation 13.3), the expected overstock in Cell F18 (Equation 13.4), and the expected understock in Cell F19 (Equation 13.5).

Compare the outcomes in columns E and F to obtain the value of improved forecasts. The worksheet *Simulation for Example 13-6* provides the outcome of 300 simulations in Cells E10:E13. Change the order quantity in Cell E9, press F9 and see how the outcomes in Cells E10:E13 change.

Postponement: Impact on Profits and Inventories

Associated spreadsheet: *Chapter13-postponement-Benetton*

<u>Value of Postponement</u>

The worksheet *Benetton* allows the evaluation of expected profits with and without postponement to evaluate the value of postponement.

The input data is provided in Cells A3:E10.

Cells A12:E22 provide the analysis for the case without postponement. The first step is to evaluate the cost of overstocking in Cell E12 and the cost of understocking in Cell E13. The next step is to evaluate the optimal cycle service level in Cell E14 using Equation 13.1. The next step is to evaluate the optimal order quantity per color in Cell E15 (Equation 13.2). We then evaluate the expected profit (Cell E16), the expected overstock (Cell E17) and the expected understock (Cell E18) per color.

Across the number of colors in Cell E10, we then evaluate the expected overstock cost (Cell E19), the expected understock cost (Cell E20), the total order quantity (Cell E21), and the expected profit (Cell E22).

Cells G12:K22 provide the analysis for the case with postponement. The first step is to evaluate the mean aggregate demand across all colors in Cell K12. The next step is to evaluate the standard deviation of aggregate demand in Cell K13. We next evaluate the cost of overstocking in Cell K14 and the cost of understocking in Cell K15. The next step is to evaluate the optimal cycle service level in Cell K16 using Equation 13.1. The next step is to evaluate the optimal aggregate order quantity in Cell K17 (Equation 13.2). This is the quantity that would be ordered if postponement is used. We then evaluate expected overstock (Cell K18) and the expected understock (Cell K19) with postponement.

For the case with postponement, we then evaluate the expected overstock cost (Cell K20), the expected understock cost (Cell K21), and the expected profit (Cell K22).

The value of postponement is evaluated in Cell K24 as the difference of the profit with and without postponement.

Change the entries in Cells E4 (standard deviation of demand), E6 (production cost with postponement), and E9 (correlation coefficient) to understand how each affects the value of postponement in cell K24.

<u>Postponement with a dominant product</u>

The worksheet *Postponement with dominant prod* allows the evaluation of expected profits with and without postponement to evaluate the value of postponement in the presence of a dominant product (a product that represents a large fraction of demand).

The input data is provided in Cells A3:F11.

Cells A13:F20 provide the analysis for the case without postponement. The first step is to evaluate the cost of overstocking in Cell E13 and the cost of understocking in Cell E14. For each of the four colors, the optimal cycle service level is then evaluated in cells B16:B19, the optimal order size is evaluated in

Cells C16:C19. We then evaluate the expected profit for each color in Cells D16:D19 and the total profit without postponement in Cell D20. The expected overstock for each color is evaluated in Cells E16:E19 and the total expected overstock is evaluated in Cell E20. The expected understock for each color is evaluated in Cells F16:F19 and the total expected understock is evaluated in Cell F20.

Cells H13:L21 provide the analysis for the case with complete postponement, i.e., all colors are postponed. The first step is to evaluate the mean aggregate demand across all colors in Cell L13. The next step is to evaluate the standard deviation of aggregate demand in Cell L14. We next evaluate the cost of overstocking in Cell L15 and the cost of understocking in Cell L16. The next step is to evaluate the optimal cycle service level in Cell L17 using Equation 13.1. The next step is to evaluate the optimal aggregate order quantity in Cell L18 (Equation 13.2). This is the quantity that would be ordered if complete postponement is used. We then evaluate expected overstock (Cell L19) and the expected understock (Cell L20) with postponement. The expected profit with complete postponement is evaluated in Cell L21.

The value of complete postponement is then evaluated in Cell L23 as the difference in expected profit with (Cell L21) and without postponement (Cell D20).

Try different values of the mean and standard deviation of demand in Cells E3:F4 to see how it affects the value of postponement. What happens if the demand for the dominant product looks more like the other colors?

Tailored Postponement: Impact on Profits and Inventories

Associated spreadsheet: Worksheet *Tailored postponement* in spreadsheet *Chapter13-postponement-Benetton*

The input data is provided in Cells A3:F11.

The analysis for the case without postponement (Cells A13:F20) and the case with complete postponement (Cells H13:L21) is exactly as discussed above in the "Postponement with a dominant product."

The analysis for tailored postponement is in Cells N13:R21. The first step is to evaluate the mean aggregate demand across all non-dominant colors in Cell R13. The next step is to evaluate the standard deviation of aggregate demand across non-dominant colors in Cell R14. We next evaluate the cost of overstocking in Cell R15 and the cost of understocking in Cell R16. The next step is to evaluate the optimal cycle service level in Cell L17 using Equation 13.1. The next step is to evaluate the optimal aggregate order quantity across non-dominant colors in Cell R18 (Equation 13.2). This is the quantity to be used for non-dominant products if only non-dominant products are postponed. We then evaluate the expected profit with tailored postponement in Cell R21 as the sum of the expected profit for the dominant color (Cell D16) and the profit after postponing all non-dominant colors.

The value of tailored postponement is evaluated in Cell R23 as the difference in expected profit with tailored postponement (Cell R21) and the expected profit without postponement (Cell D20).

Section 13.4: Multiple Products Under Capacity Constraints

Associated spreadsheet: *Section 13.4*

This spreadsheet accompanies the discussion in Section 13.4 of the book related to ordering multiple products under capacity constraints.

We start by considering the desired order for two products “High End” and “Mid Range” without capacity constraints in the worksheet *no constraint*. The input is provided in Cells A3:C9. The cost of understocking C_u for each of the two products is evaluated in Cells B11:C11. The cost of overstocking C_o for each of the two products is evaluated in Cells B12:C12. The optimal cycle service level (critical fractile) CSL^* for each product is evaluated in Cells B13:C13 using Equation 13.1. The optimal order quantity for each product is obtained in Cells B14:C14 using Equation 13.2. The total desired order quantity across the two products is evaluated in Cell D14. Given that the total desired order quantity in Cell D14 is larger than the available capacity in Cell B9, we need to modify the order quantities accounting for the capacity constraint.

The modified order quantities accounting for the capacity constraint are evaluated in worksheet *capacity constraint*. The input is provided in Cells A3:C9 and the unconstrained order quantities are shown in Cells D10:C10 as evaluated in the worksheet *no constraint*. Enter the desired order quantity of “High End” in Cell B14. The resulting order quantity for “Mid Range” is calculated in Cell C14 as the difference between the available capacity (Cell B9) and the quantity of “High End” ordered (Cell B14). The expected profit for each product is shown in Cells B15:C15. The expected marginal profit from increasing the amount ordered of each product is shown in Cells B16:C16. If one of the two products has a higher expected marginal profit, the quantity ordered of that product should be increased. Change the quantity in Cell B14 until the expected marginal profit across the two products is equal. This allocation of capacity maximizes the profit in Cell B17.

The worksheet *Optimization* models the optimal allocation problem to be solved using *Solver*. The input is provided in Cells A3:C9. The desired order quantity for “High End” is in Cell B12 and the order quantity for “Mid Range” is evaluated in Cell C12. The total expected profit is evaluated in cell B14. Solver is set up as follows:

> Set Objective: $B$14
>
> By Changing Variable Cells: $B$12
>
> Subject to the Constraints: $C$12 > 0
>
> Unconstrained variables are non-negative

The result is obtained by Clicking Solve.

<u>Construction of Table 13-5</u>

The details behind the construction of Table 13-5 are shown in the worksheet *Capacity allocation*. The input is provided in Cells A3:C9. Cells A12 on in Column A contain the remaining capacity once capacity in Column E has been assigned to “High End” and the capacity in Column F has been assigned to “Mid Range”. Thus, remaining capacity in Cell A14 = $B$9-SUM(E14:F14).

The capacity allocation to each product is based on the expected marginal contribution of each product. Cell B13 contains the expected marginal contribution of increasing the quantity allocated to “High End” in Cell E13. Similarly, Cell C13 contains the expected marginal contribution of increasing the quantity allocated to “Mid Range” in Cell F13. The additional unit of capacity is then allocated to the product with the higher expected marginal contribution. For example, the 100 units of capacity in Cell E14 is allocated to “High End” because the expected marginal contribution in Cell B13 for “High End” is larger than the expected marginal contribution in Cell C13 for “Mid Range.” Continuing down the rows, the 100 units of capacity in Cell F23 is allocated to “Mid Range” because the expected marginal contribution in Cell C22 for “Mid Range” is larger than the expected marginal contribution in Cell B22 for “High End.” This successive allocation of capacity is continued until all the capacity has been allocated in row 73.

Chapter 14

Example 14-1 Selecting a Transportation Network

Associated spreadsheet: Worksheet *Example14-1* in the workbook *Chapter14-examples*

The input data is provided in Cells A1:B8.

The worksheet evaluates the cost of three different strategies – direct shipping from suppliers to stores using full trucks (Cells A11:B18), shipping from suppliers to stores using optimally loaded trucks (Cells D11:E18), and shipping from suppliers to stores using milk runs (Cells A21:B29).

<u>Shipping from suppliers to stores using full trucks</u>

The batch size *Q* is obtained in Cell B11 as the capacity of the truck (because we are using full trucks) in Cell B6. The number of shipments per year are calculated in Cell B13 = demand per store (Cell B4) / Batch size (Cell B11). The truck cost / retail store / supplier is evaluated in Cell B14 = number of shipments per year (Cell B13) × [Fixed cost per truck (Cell B5) + Cost / Stop (Cell B8)]. The total truck cost is evaluated in Cell B15 = truck cost / retail store / supplier (Cell B14)× Number of suppliers (Cell B2) × Number of retail stores (Cell B3). The holding cost / retail store / supplier is evaluated in Cell B16 = Average inventory / retail store / supplier (Cell B12) × holding cost per unit per year (Cell B7). The total holding cost is evaluated in Cell B17 = holding cost / retail store / supplier (Cell B16) × Number of suppliers (Cell B2) × Number of retail stores (Cell B3). The total holding and truck cost of this policy is evaluated in Cell B18 = Total truck cost (Cell B15) + Total holding cost (Cell B17).

<u>Shipping from suppliers to stores using optimally loaded trucks</u>

The main difference from the previous policy is that instead of fully loading a truck we aim to place the optimal quantity on the truck based on fixed costs and holding costs using the EOQ model.

The optimal batch size *Q* is obtained in Cell E11 as the minimum of the EOQ (using a fixed cost = Cell B5 + Cell B8) and the capacity of the truck (Cell B6). If the EOQ is larger than the capacity, the order size is the truck capacity. If the EOQ is smaller than the capacity, the order size is the EOQ. All other calculations in Cells E12:E18 are similar to those in Cells B12:B18. The number of shipments per year are calculated in Cell E13 = demand per store (Cell B4) / optimal batch size (Cell E11). The truck cost / retail store / supplier is evaluated in Cell E14 = number of shipments per year (Cell E13) × [Fixed cost per truck (Cell B5) + Cost / Stop (Cell B8)]. The total truck cost is evaluated in Cell E15 = truck cost / retail store / supplier (Cell E14)× Number of suppliers (Cell B2) × Number of retail stores (Cell B3). The holding cost / retail store / supplier is evaluated in Cell E16 = Average inventory / retail store / supplier (Cell E12) × holding cost per unit per year (Cell B7). The total holding cost is evaluated in Cell E17 = holding cost / retail store / supplier (Cell E16) × Number of suppliers (Cell B2) × Number of retail stores (Cell B3). The total holding and truck cost of this policy is evaluated in Cell E18 = Total truck cost (Cell E15) + Total holding cost (Cell E17).

Shipping from suppliers to stores using full trucks with Milk Runs

In this policy we send out full trucks from a supplier but the trucks deliver using milk runs to the number of stores specified in Cell B21. Thus, if the entry in Cell B21 = 2, the truck leaving the supplier has half a truckload for one store and half for the other store.

The batch size is obtained in Cell B2 = capacity of the truck (because we are using full trucks) in Cell B6 / Number of stores per truck (Cell B21). The number of shipments per year from a supplier to each store are calculated in Cell B24 = demand per store (Cell B4) / Batch size (Cell B22). The truck cost / retail store / supplier is evaluated in Cell B25 = number of shipments per year (Cell B13) × [Fixed cost per truck (Cell B5) / Number of stores per truck (Cell B21) + Cost / Stop (Cell B8)]. The total truck cost is evaluated in Cell B26 = truck cost / retail store / supplier (Cell B25)× Number of suppliers (Cell B2) × Number of retail stores (Cell B3). The holding cost / retail store / supplier is evaluated in Cell B27 = Average inventory / retail store / supplier (Cell B23) × holding cost per unit per year (Cell B7). The total holding cost is evaluated in Cell B28 = holding cost / retail store / supplier (Cell B16) × Number of suppliers (Cell B2) × Number of retail stores (Cell B3). The total holding and truck cost of this policy is evaluated in Cell B29 = Total truck cost (Cell B26) + Total holding cost (Cell B28).

Change the demand in Cell B4 and the number of stores/truck in Cell B21 to evaluate the cost of different transportation policies.

Example 14-2 Tradeoffs When Selecting Transportation Mode

Associated spreadsheet: Worksheet *Example14-2* in the workbook *Chapter14-examples*

The input data is provided in Cells A3:E16. Observe that the Golden Freightways shipping cost changes with the quantity shipped. The first 150 cwt (=1,500 motors) are shipped at a cost of $8/cwt. The next 100 cwt (=1,000 motors) is shipped at $6/cwt. The original proposal shipped all quantity above 250 cwt at $4/cwt. The new proposal lowers this cost to $3/cwt.

The cost calculations from using each mode and quantity combination are shown in Cells A18:K26. Cells C19:C26 evaluate the average transportation cost / cwt based on the mode and quantity. For example, Cell 24 obtains the average cost / cwt if Golden is used to ship 3,000 motors (=300 cwt) at a time with the old rate. In this case, the first 1,500 motors are shipped at a cost of $8 each, the next 1,000 at accost of $6 each, and the final 500 at a cost of $4 each (for an average cost of $6.67 / motor). The transportation cost is evaluated in Cells C19:C26 = Number of motors purchased per year (Cell D3) × Weight per motor (Cell D5) × Average transportation cost / cwt (Cells C19:C26). The cycle inventory is obtained in Cells E19:E26 as half the lot size (Cells B19:B26). The lead time is obtained in Cells F19:F26 to be 1 day more than the transit time corresponding to the mode used (Cells E11:E16). The required safety inventory is evaluated in Cells G19:G26 as the percentage of lead time demand specified in Cell D6. The In-transit inventory is evaluated in Cells H19:H26 as the demand over the transit time (= lead time – 1).The total inventory is evaluated in Cells I19:I26 = cycle inventory (Cells E19:E26) + safety inventory (Cells G19:G26) + In-transit inventory (Cells H19:H26). The holding cost is evaluated in Cells J19:J26 = total inventory (Cells I19:I26) × cost per motor (Cell D4) × holding cost (Cell D7). The total cost is evaluated in Cells K19:K26 = Transportation cost (Cells D19:D26) + Holding cost (Cells J19:J26).

Change the number of motors purchased per year in Cell D3 from 120,000 to 240,000 and 360,000 to see how it affects the lowest cost transportation mode selected.

Example 14-3 Tradeoffs When Aggregating Inventory

Associated spreadsheet: Worksheet *Example14-3* in the workbook *Chapter14-examples*

The input data is provided in Cells A3:B17. The results for the current scenario are shown in Cells B19:B36, those for Option A (keep current structure but replenish once a week instead of once every 4 weeks) are in Cells C19:C36, and those for Option B (aggregate inventory in Madison) are in Cells D19:D36.

Current Scenario

This scenario involves 24 stocking locations (Cell B20) and a reorder interval of 4 weeks (Cell B21). The batch size thus equals 4 weeks of demand. For HighVal, the cycle inventory across all locations is evaluated in Cell B22 = reorder interval (Cell B21) × mean weekly demand / territory (Cell B5) × number of stocking locations (Cell B20) / 2 because cycle inventory = batch size / 2. The HighVal safety inventory across all locations is evaluated in Cell B23 using Equation 12.19. The total inventory in Cell B24 is the sum of the cycle and safety inventory. Similar calculations are repeated for LowVal in Cells B25:B27. The total annual inventory cost in Cell B28 is the sum of the inventory cost of HighVal and LowVal. The shipment size of HighVal and LowVal (Cell B31 and Cell B32 respectively) is the mean demand over the reorder interval. The shipment weight is calculated knowing the weight of each unit of HighVal (Cell B3) and LowVal (Cell B8). The number of shipments / year are evaluated in Cell B34 = 52 / reorder interval. The annual transportation cost is evaluated in Cell B35 based on the weight of each shipment and the number of shipments / year.

Option A

This scenario involves 24 stocking locations (Cell C20) and a reorder interval of 1 week (Cell C21). The batch size thus equals 1 week of demand. For HighVal, the cycle inventory across all locations is evaluated in Cell C22 = reorder interval (Cell C21) × mean weekly demand / territory (Cell B5) × number of stocking locations (Cell C20) / 2 because cycle inventory = batch size / 2. The HighVal safety inventory across all locations is evaluated in Cell C23 using Equation 12.19. The total inventory in Cell C24 is the sum of the cycle and safety inventory. Similar calculations are repeated for LowVal in Cells C25:C27. The total annual inventory cost in Cell C28 is the sum of the inventory cost of HighVal and LowVal. The shipment size of HighVal and LowVal (Cell C31 and Cell C32 respectively) is the mean demand over the reorder interval. The shipment weight is calculated knowing the weight of each unit of HighVal (Cell B3) and LowVal (Cell B8). The number of shipments / year are evaluated in Cell C34 = 52 / reorder interval. The annual transportation cost is evaluated in Cell C35 based on the weight of each shipment and the number of shipments / year.

Option B

This scenario involves 1 stocking location (Cell D20) and a reorder interval of 1 week (Cell D21). The batch size thus equals 1 week of demand. For HighVal, the aggregate cycle inventory is evaluated in Cell

D22 = reorder interval (Cell D21) × mean weekly demand / territory (Cell B5) × number of stocking locations (Cell CD0) / 2 because cycle inventory = batch size / 2. The HighVal aggregate safety inventory is evaluated in Cell D23 using Equation 12.19 (assuming that demand across all 24 locations is independent). The total inventory in Cell D24 is the sum of the cycle and safety inventory. Similar calculations are repeated for LowVal in Cells D25:D27. The total annual inventory cost in Cell D28 is the sum of the inventory cost of HighVal and LowVal. The shipment size of HighVal and LowVal (Cell D31 and Cell D32 respectively) is the mean demand over the reorder interval. The shipment weight is calculated knowing the weight of each unit of HighVal (Cell B3) and LowVal (Cell B8). The number of shipments / year are evaluated in Cell D34 = 52 / reorder interval. The annual transportation cost is evaluated in Cell D35 based on the weight of each shipment and the number of shipments / year.

To see how different parameters affect the optimal structure, change the SD of HighVal demand (Cell B6), the transportation cost multiplier (Cell B15), the customer order size multiplier (Cell B16), and the holding cost multiplier (Cell B17) to be lower as well as higher than their current value.

Chapter 15

Example 15-1 Impact of Local Optimization

Associated spreadsheet: Worksheet *Example15-1* in the workbook *Chapter15-examples*

The input data is provided in Cells A3:B10.

Column B considers the case when the retailer and the manufacturer act independently. Column C considers that case when the manufacturer and the retailer are vertically integrated.

<u>Independent retailer</u>

The cost of understocking is evaluated in Cell B12 = p (Cell B7) – c (Cell B6). The cost of overstocking is evaluated in cell B13 = c (Cell B6) – s (Cell B8). The optimal order size placed by the retailer is evaluated in Cell B15 using Equations 13.1 and 13.2. The expected profit at the retailer is evaluated in Cell B18 using Equation 13.3. The expected profit at the manufacturer is evaluated in Cell B19 = order size (Cell B15) × [manufacturer's sale price (Cell B10) – manufacturer's cost (Cell B9)]. The total profit of the supply chain is evaluated in Cell B20 as the sum of the retailer and manufacturer profits.

<u>Vertically integrated supply chain</u>

In the vertically integrated supply chain, the sale price (Cell D10) equals the retailer's sale price (Cell B7), while the cost (Cell D9) equals the manufacturer's cost (Cell B9). The cost of understocking is evaluated in Cell D12 = D10 – D9. The cost of overstocking is evaluated in Cell D13 = D9 – D8. The optimal order size is evaluated in Cell D15 using Equations 13.1 and 13.2. The expected profit for the vertically integrated supply chain is evaluated in Cell D20 using Equation 13.3.

Change the manufacturer's sale price in Cell B10 to see how the profit in the case of the independent retailer (Cell B20) compares with the profit for the vertically integrated supply chain (Cell D20).

Example 15-2 Risk Sharing Through Buybacks

Associated spreadsheet: Worksheet *Example15-2* in the workbook *Chapter15-examples*

The input data is provided in Cells A3:B12. The manufacturer's buyback price is set in Cell B11. If the retailer incurs a return cost in Cell B8, the retailer's salvage value is obtained in Cell B7 = Max (0, buyback price b in Cell B11 – return cost in Cell B8).

The cost of understocking is evaluated in Cell B14 = p (Cell B6) – c (Cell B6). The cost of overstocking is evaluated in cell B16 = c (Cell B6) – s (Cell B7). The optimal order size placed by the retailer is evaluated in Cell B17 using Equations 13.1 and 13.2. The expected profit at the retailer is evaluated in Cell B20 using Equation 13.3. The expected overstock at the retailer is evaluated in Cell B18 using Equation 13.4. The expected overstock at the retailer equals the expected buyback for the manufacturer. Thus, the expected profit at the manufacturer is evaluated in Cell B21 = order size (Cell B17) × [manufacturer's sale price (Cell B10) – manufacturer's cost (Cell B9)] – expected overstock (Cell B18) ×

buyback price (Cell B11). The assumption here is that the manufacturer's salvage value is 0. The total profit of the supply chain is evaluated in Cell B20 as the sum of the retailer and manufacturer profits.

To build Table 15-3, enter the desired wholesale price in Cell B10 and the buyback price in Cell B11. The various results are shown in cells B17:B22.

Example 15-3 Risk Sharing Through Revenue Sharing

Associated spreadsheet: Worksheet *Example15-3* in the workbook *Chapter15-examples*

The input data is provided in Cells A4:B9.

Given the revenue share fraction of the manufacturer in Cell B7, the retailer's optimal cycle service level is evaluated in Cell B12 (assuming a salvage value of 0). The optimal order quantity is evaluated in Cell B13 using Equation 13.2. The expected overstock is evaluated in Cell B14 using Equation 13.4 and the expected understock is evaluated in Cell B15 using Equation 13.5. The expected manufacturer profit is evaluated in Cell B18 = $(c - v)O^* + fp(O^* - \text{expected overstock})$. The expected retailer profit is evaluated in Cell B19 =

$$\left(1 - f\right) p\left(O^* - \text{expected overstock at retailer}\right) + s_R \times \text{expected overstock at retailer} - cO^*$$

assuming a retailer salvage value of $s_R = 0$. The expected supply chain profit in Cell B20 is the sum of the retailer and manufacturer profits.

To build Table 15-4, enter the wholesale price in Cell B4 and the revenue share fraction of the manufacturer in Cell B7. The various results are shown in Cells B12:B15 and B18:B20.

Example 15-4 Risk Sharing Through Quantity Flexibility

Associated spreadsheet: Worksheet *Example15-4* in the workbook *Chapter15-examples*

The input data is provided in Cells A3:B9 and B12:B13.

Given the value of α in Cell B12, the maximum amount Q the manufacturer is required to supply is evaluated in Cell B14. Given the value of β in Cell B13, the minimum amount q the retailer is required to purchase is evaluated in Cell B15.

The retailer's expected purchase is evaluated in Cell B17. The retailer must purchase q even if demand is less than q, will purchase a quantity equal to demand if demand is between q and Q, and will purchase a quantity Q if demand is greater than Q. The retailer's expected sales are evaluated in cell B18. The retailer will sell a quantity equal to demand if demand is Q or less and a quantity equal to Q if demand is more than Q.

The expected profits for the manufacturer, retailer, and supply chain are evaluated in Cells B19:B21.

Given this setup, run Solver to obtain the retailer order quantity in Cell B10 that maximizes retailer expected profits in Cell B20.

To build Table 15-5, change the wholesale price in Cell B5, the values of α in Cell B12 and β in Cell B13. For each combination, rerun Solver to obtain the retailer order quantity in Cell B10 that maximizes retailer expected profits in Cell B20. The expected manufacturer profit is then obtained in Cell B19 and the expected supply chain profit in Cell B21.

Chapter 16

Example 16-1 Pricing to Multiple Segments

Associated spreadsheet: Worksheet *Example16-1* in the workbook *Chapter16-examples*

There are three cases we evaluate – (i) pricing to the two segments without a capacity constraint; (ii) selecting a constant price without a capacity constraint; (iii) pricing to the two segments with a capacity constraint.

<u>Pricing to the two segments without a capacity constraint</u>

Set the production capacity in Cell B3 = 5,000. For segment 1, the price is in Cell B5, the demand in Cell C5 (based on the demand curve 5,000 – 20 p_1), and the profit in Cell D5 (assuming a unit cost of 10). For segment 2, the price is in Cell B6, the demand in Cell C6 (based on the demand curve 5,000 – 40 p_2), and the profit in Cell D6 (assuming a unit cost of 10). The total profit across the two segments is evaluated in Cell D7. Setup Solver as follows:

Set Objective: $D$7

To: Max

By Changing Variable Cells: $B$5:$B$6

Subject to the Constraints: $C$7 <= $B$3 {This constraint is not active when Cell B3 = 5,000)

Run Solver to obtain the optimal prices for the two segments without capacity constraints.

<u>Selecting a constant price without a capacity constraint</u>

In this case we select a price in Cell G5 that applies to both segments. Demand across each segment is evaluated in Cells H5:H6 and the profit across each segment is evaluated in Cells I5:I6.

<u>Pricing to the two segments with a capacity constraint</u>

Set the production capacity in Cell B3 = 4,000. For segment 1, the price is in Cell B5, the demand in Cell C5 (based on the demand curve 5,000 – 20 p_1), and the profit in Cell D5 (assuming a unit cost of 10). For segment 2, the price is in Cell B6, the demand in Cell C6 (based on the demand curve 5,000 – 40 p_2), and the profit in Cell D6 (assuming a unit cost of 10). The total profit across the two segments is evaluated in Cell D7. Setup Solver as follows:

Set Objective: $D$7

To: Max

By Changing Variable Cells: $B$5:$B$6

Subject to the Constraints: $C$7 <= $B$3 {This constraint is active when Cell B3 = 4,000)

Run Solver to obtain the optimal prices for the two segments with capacity constraints.

Example 16-2 Allocating Capacity to Multiple Segments

Associated spreadsheet: Worksheet *Example16-2* in the workbook *Chapter16-examples*

The inputs are in Cells A3:C6.

Segment B is the lower priced segment while segment A is the higher price segment. The mean demand for segment A is in Cell C5 and the standard deviation is in Cell C6.

The desired capacity to be reserved for segment A is evaluated in Cell C8 using Equation 16.4.

Change the revenue that segment A is willing to pay in cell C3 and see how it affects the quantity reserved in Cell C8.

Example 16-3 Dynamic Pricing

Associated spreadsheet: Worksheets *Example16-3(dynamic price)* and *Example16-3(fixed price)* in the workbook *Chapter16-examples*

Dynamic pricing

Use worksheet *Example16-3(dynamic price).* We are given demand curves for each of the three periods in the season. The quantity available at the beginning of the season is in Cell B3. Given the prices for each period in Cells B5:B7, the demand in each period is evaluated in cells C5:C7 and the revenue in each period is evaluated in cells D5:D7. The total revenue across all three periods is evaluated in Cell D8.

Our goal is to find prices in each of the three seasons that maximize the revenue in cell D8 given the initial quantity in Cell B3. We set up a Solver model as follows:

Set Objective: $D$8

To: Max

By Changing Variable Cells: $B$5:$B$7

Subject to the Constraints: $C$8 <= $B$3
$C$5:$C$7 >= 0

Run Solver to obtain the optimal prices in Cells B5:B7.

Change the initial quantity in Cell B3 and rerun Solver to see how prices change in the three periods.

Fixed price

Use worksheet *Example16-3(fixed price).* We are given demand curves for each of the three periods in the season. The quantity available at the beginning of the season is in Cell B3. The price for each of the three periods (Cells B5:B7) is the same and equals the value in cell B5. Given the prices for each period in Cells B5:B7, the demand in each period is evaluated in cells C5:C7 and the revenue in each period is evaluated in cells D5:D7. The total revenue across all three periods is evaluated in Cell D8.

Our goal is to find a fixed price for all three seasons that maximizes the revenue in cell D8 given the initial quantity in Cell B3. We set up a Solver model as follows:

Set Objective: $D$8

To: Max

By Changing Variable Cells: $B$5

Subject to the Constraints: $C$8 <= $B$3
$B$5 >= 0

Run Solver to obtain the optimal price in Cells B5.

Change the initial quantity in Cell B3 and rerun Solver to see how prices change in the three periods.

Example 16-4 Evaluating Quantity with Dynamic Pricing

Associated spreadsheet: Worksheets *Example16-4* in the workbook *Chapter16-examples*

The goal here is to find an initial quantity for the season that maximizes season profits assuming dynamic pricing for the season.

The cost per unit is in Cell B2 and the initial order quantity in Cell B3. Given the prices for each period in Cells B5:B7, the demand in each period is evaluated in cells C5:C7 and the revenue in each period is evaluated in cells D5:D7. The total revenue across all three periods is evaluated in Cell D8. The profit is evaluated in Cell D9 = Revenue (Cell D8) – quantity at beginning of season (Cell B3) × cost per unit (Cell B2).

We set up a Solver model as follows:

Set Objective: $D$9

To: Max

By Changing Variable Cells: $B$3, $B$5: $B$7

Subject to the Constraints: $C$8 <= $B$3
$B$5:$B$7 >= 0
$B$3>= 0

Run Solver to obtain the optimal quantity in Cell B3 and the optimal prices in Cells B5:B7.

Change the cost / unit in Cell B2 and see how the optimal quantity and prices are affected.

The Challenge of Strategic Customers

Associated spreadsheet: Worksheets *Example16-4(strategic)* in the workbook *Chapter16-examples*

In the presence of strategic customers who decide to delay purchases anticipating price decrease, a firm may see a drop of profits unless tactics are changed. Our goal is to first understand the impact of strategic customers.

As in Example 16-4, we start the season with 245 units (Cell B3). When customers are not strategic, the optimal prices for the three periods are in Cells B5:B7, demand for the three periods is in Cells C5:C7, and the revenue in the three periods is in Cells D5:D7. Total revenue is in Cell D8 and total profit without strategic customers is in Cell D9.

We assume that the prices over the first two periods (Cells E5:E6) are the same even in the presence of strategic customers. Enter the anticipated demand in the first two periods with strategic customers in Cells F5:F6. The unsold quantity for the third period is evaluated in cell F7. The price in the third period (Cell E7) is calculated to ensure that all units remaining in the third period (Cell F7) are sold at this price. Total profit with strategic customers is evaluated in cell G9.

<u>Using a Fixed Price in Response to Strategic Customers</u>

Associated spreadsheet: Worksheets *Example16-4(fixed price)* in the workbook *Chapter16-examples*

One response to strategic customers is to have a fixed price (as Tiffany does) over the entire season. As a result there is no benefit for a customer from delaying their purchase.

We start the season with 245 units (Cell B3). Our goal is to find a fixed price (Cell B5) for all three periods that maximizes the profit in Cell D9. We set up a Solver model as follows:

Set Objective: $D$9

To: Max

By Changing Variable Cells: $B$3, $B$5

Subject to the Constraints: $C$8 <= $B$3
$B$5 >= 0

Example 16-5 Overbooking

Associated spreadsheet: Worksheets *Example16-5* in the workbook *Chapter16-examples*

The inputs are in Cells A2:B4.

The first step is to evaluate using Equation 16.6 the probability that cancellations will be less than or equal to the optimal booking level s^* (Cell B6).

Cancellation distribution is fixed

The mean of the cancelation distribution is in Cell B9 and the standard deviation is in Cell B10. The optimal overbooking level is obtained in Cell B11 using Equation 16.7. The optimal order level in Cell B12 is the sum of the capacity (Cell B2) and the optimal overbooking level (Cell B11).

Cancellation distribution is order size dependent

In this case the number of cancellations depends upon how many orders have been accepted. The average cancellation rate is in Cell B15. Rather than a fixed standard deviation we provide a coefficient of variation for cancellations in Cell B16.

Equation 16.8 must hold at the optimal overbooking level. Thus, using the optimal overbooking level in the right hand side of Equation 16.8 should result in the same overbooking level. We enter a desired overbooking level in Cell B18. The implied overbooking level from Equation 16.8 is returned in Cell B17. If the value in Cell B17 is not the same as the value in Cell B18, change the value in Cell B18. Continue iterating in this manner until the two values are the same. The resulting overbooking level is optimal.