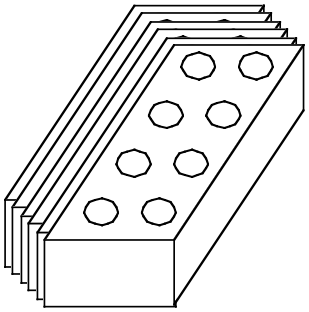
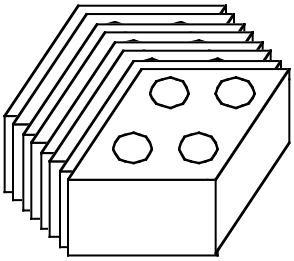
# Sensitivity Analysis

## Weekly supply of raw materials:



6 Large Bricks



8 Small Bricks

## Products:

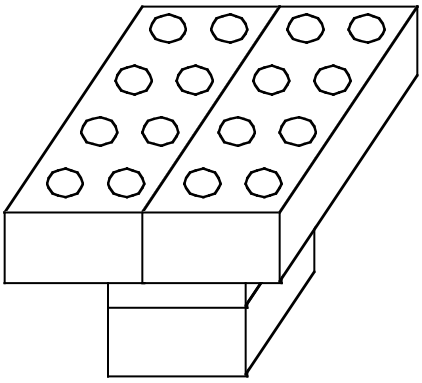
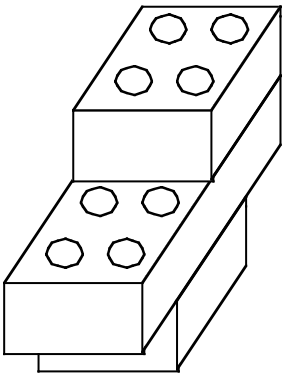


**Table**
Profit = $20/Table



**Chair**
Profit = $15/Chair

# Graphical Solution

Maximize $Z = (\$15)C + (\$20)T$

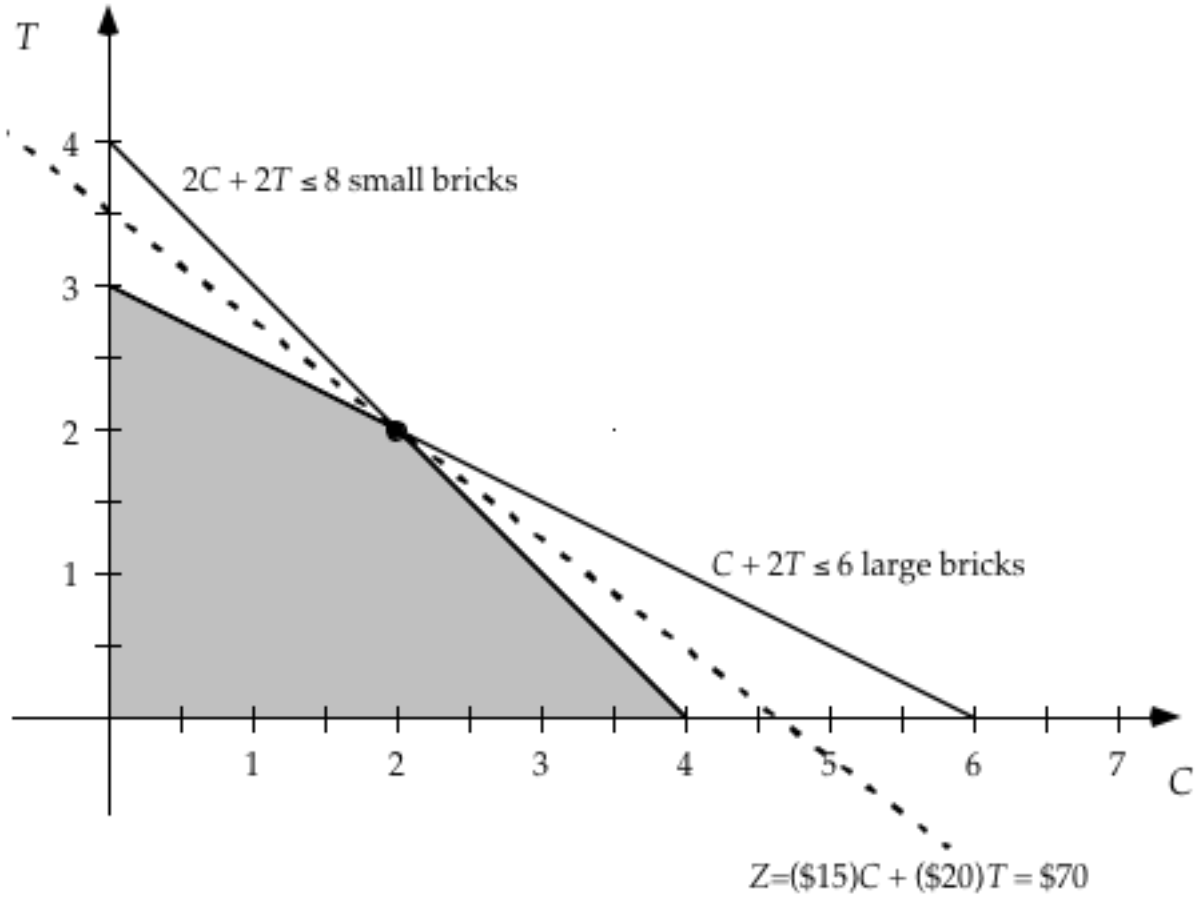
subject to

Large Bricks: $C + 2T \leq 6$

Small Bricks: $2C + 2T \leq 8$

and

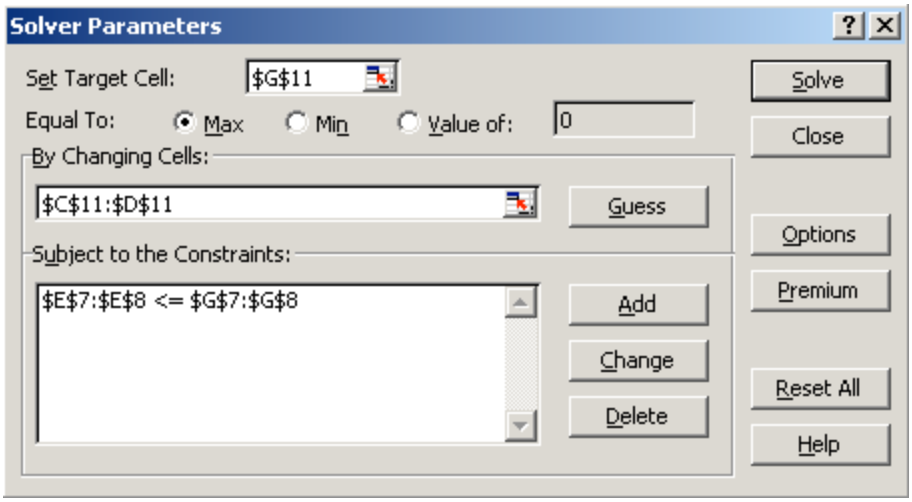
$C \geq 0, \ T \geq 0.$



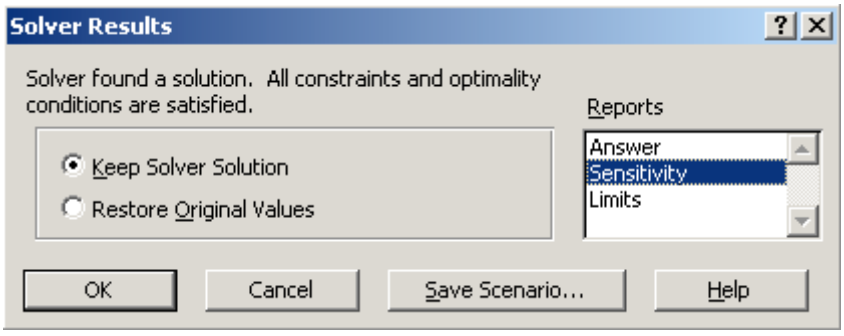
# Generating the Sensitivity Report

Solve the problem using the Solver:

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | **The Lego Production Problem** | | | | | | |
| 2 | | | | | | | |
| 3 | | | Tables | Chairs | | | |
| 4 | | Profit | $20.00 | $15.00 | | | |
| 5 | | | | | | | |
| 6 | | | Bill of Materials | | Total Used | | Available |
| 7 | | Large Bricks | 2 | 1 | 6 | <= | 6 |
| 8 | | Small Bricks | 2 | 2 | 8 | <= | 8 |
| 9 | | | | | | | |
| 10 | | | Tables | Chairs | | | Total Profit |
| 11 | | Production Quantity | 2 | 2 | | | $70.00 |




Then, choose "Sensitivity" under Reports.



# The Sensitivity Report

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | **The Lego Production Problem** | | | | | | |
| 2 | | | | | | | |
| 3 | | | Tables | Chairs | | | |
| 4 | | Profit | $20.00 | $15.00 | | | |
| 5 | | | | | | | |
| 6 | | | Bill of Materials | | Total Used | | Available |
| 7 | | Large Bricks | 2 | 1 | 6 | <= | 6 |
| 8 | | Small Bricks | 2 | 2 | 8 | <= | 8 |
| 9 | | | | | | | |
| 10 | | | Tables | Chairs | | | Total Profit |
| 11 | | Production Quantity | 2 | 2 | | | $70.00 |

Adjustable Cells

| Cell | Name | Final Value | Reduced Cost | Objective Coefficient | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $C$11 | Production Quantity: Tables | 2 | 0 | 20 | 10 | 5 |
| $D$11 | Production Quantity: Chairs | 2 | 0 | 15 | 5 | 5 |

Constraints

| Cell | Name | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $E$7 | Large Bricks Total Used | 6 | 5 | 6 | 2 | 2 |
| $E$8 | Small Bricks Total Used | 8 | 5 | 8 | 4 | 2 |

# Net Profit from Tables = $35

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | **The Lego Production Problem** | | | | | | |
| 2 | | | | | | | |
| 3 | | | Tables | Chairs | | | |
| 4 | | Profit | $35.00 | $15.00 | | | |
| 5 | | | | | | | |
| 6 | | | Bill of Materials | | Total Used | | Available |
| 7 | | Large Bricks | 2 | 1 | 6 | <= | 6 |
| 8 | | Small Bricks | 2 | 2 | 6 | <= | 8 |
| 9 | | | | | | | |
| 10 | | | Tables | Chairs | | | Total Profit |
| 11 | | Production Quantity | 3 | 0 | | | $105.00 |

Adjustable Cells

| Cell | Name | Final Value | Reduced Cost | Objective Coefficient | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $C$11 | Production Quantity: Tables | 3 | 0 | 35 | 1E+30 | 5 |
| $D$11 | Production Quantity: Chairs | 0 | -2.5 | 15 | 2.5 | 1E+30 |

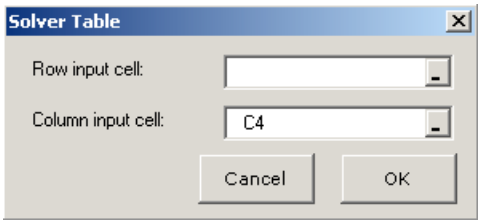
Constraints

| Cell | Name | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $E$7 | Large Bricks Total Used | 6 | 17.5 | 6 | 2 | 6 |
| $E$8 | Small Bricks Total Used | 6 | 0 | 8 | 1E+30 | 2 |

# Using Solver Table to Investigate the Effect of Profit/Table on the Solution

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | **The Lego Production Problem** | | | | | | |
| 2 | | | | | | | |
| 3 | | | Tables | Chairs | | | |
| 4 | | Profit | $35.00 | $15.00 | | | |
| 5 | | | | | | | |
| 6 | | | Bill of Materials | | Total Used | | Available |
| 7 | | Large Bricks | 2 | 1 | 6 | <= | 6 |
| 8 | | Small Bricks | 2 | 2 | 6 | <= | 8 |
| 9 | | | | | | | |
| 10 | | | Tables | Chairs | | | Total Profit |
| 11 | | Production Quantity | 3 | 0 | | | $105.00 |
| 12 | | | | | | | |
| 13 | | | | | | | |
| 14 | | | | | | | |
| 15 | | Profit per Table | Tables | Chairs | Total Profit | | |
| 16 | | | 3 | 0 | $105.00 | | |
| 17 | | $10 | 0 | 4 | $60.00 | | |
| 18 | | $15 | 0 | 4 | $60.00 | | |
| 19 | | $20 | 2 | 2 | $70.00 | | |
| 20 | | $25 | 2 | 2 | $80.00 | | |
| 21 | | $30 | 3 | 0 | $90.00 | | |
| 22 | | $35 | 3 | 0 | $105.00 | | |
| 23 | | $40 | 3 | 0 | $120.00 | | |

| | C | D | E |
|---|---|---|---|
| 15 | Tables | Chairs | Total Profit |
| 16 | =C11 | =D11 | =G11 |




## Using Solver Table

1. In the first column of the table, skip the first row and then enter the various trial values for the data cell that will be varied (the profit per table values ranging from $10 to $40 in B17:B23).
2. In the first row of the table, enter equations referring to each output cell of interest (e.g., =C11, =D11, and =G11 in C16:E16).
3. Select the entire table (B16:E23) and choose Solver Table from the Tools menu.
4. Specify the column input cell (the data cell that is being varied in the first column—the profit per table in cell C4 in this case), and click OK.

For each trial value of the data cell in the first column, Solver is called on to re-solve the problem, and the value of the output cells are filled into the table.

# Seven Large Bricks

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | **The Lego Production Problem** | | | | | | |
| 2 | | | | | | | |
| 3 | | | Tables | Chairs | | | |
| 4 | | Profit | $20.00 | $15.00 | | | |
| 5 | | | | | | | |
| 6 | | | Bill of Materials | | Total Used | | Available |
| 7 | | Large Bricks | 2 | 1 | 7 | <= | 7 |
| 8 | | Small Bricks | 2 | 2 | 8 | <= | 8 |
| 9 | | | | | | | |
| 10 | | | Tables | Chairs | | | Total Profit |
| 11 | | Production Quantity | 3 | 1 | | | $75.00 |

Adjustable Cells

| Cell | Name | Final Value | Reduced Cost | Objective Coefficient | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $C$11 | Production Quantity: Tables | 3 | 0 | 20 | 10 | 5 |
| $D$11 | Production Quantity: Chairs | 1 | 0 | 15 | 5 | 5 |

Constraints

| Cell | Name | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $E$7 | Large Bricks Total Used | 7 | 5 | 7 | 1 | 3 |
| $E$8 | Small Bricks Total Used | 8 | 5 | 8 | 6 | 1 |

# Nine Large Bricks

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | **The Lego Production Problem** | | | | | | |
| 2 | | | | | | | |
| 3 | | | Tables | Chairs | | | |
| 4 | | Profit | $20.00 | $15.00 | | | |
| 5 | | | | | | | |
| 6 | | | Bill of Materials | | Total Used | | Available |
| 7 | | Large Bricks | 2 | 1 | 8 | <= | 9 |
| 8 | | Small Bricks | 2 | 2 | 8 | <= | 8 |
| 9 | | | | | | | |
| 10 | | | Tables | Chairs | | | Total Profit |
| 11 | | Production Quantity | 4 | 0 | | | $80.00 |

Adjustable Cells

| Cell | Name | Final Value | Reduced Cost | Objective Coefficient | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $C$11 | Production Quantity: Tables | 4 | 0 | 20 | 1E+30 | 5 |
| $D$11 | Production Quantity: Chairs | 0 | -5 | 15 | 5 | 1E+30 |

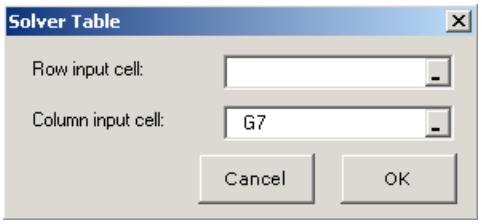
Constraints

| Cell | Name | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $E$7 | Large Bricks Total Used | 8 | 0 | 9 | 1E+30 | 1 |
| $E$8 | Small Bricks Total Used | 8 | 10 | 8 | 1 | 8 |

# Using Solver Table to Investigate the Impact of the Number of Large Bricks Available

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | **The Lego Production Problem** | | | | | | |
| 2 | | | | | | | |
| 3 | | | Tables | Chairs | | | |
| 4 | | Profit | $20.00 | $15.00 | | | |
| 5 | | | | | | | |
| 6 | | | Bill of Materials | | Total Used | | Available |
| 7 | | Large Bricks | 2 | 1 | 6 | <= | 6 |
| 8 | | Small Bricks | 2 | 2 | 8 | <= | 8 |
| 9 | | | | | | | |
| 10 | | | Tables | Chairs | | | Total Profit |
| 11 | | Production Quantity | 2 | 2 | | | $70.00 |
| 12 | | | | | | | |
| 13 | | | | | | | |
| 14 | | | | | | | |
| 15 | | Large Bricks | Tables | Chairs | Total Profit | | |
| 16 | | | 2 | 2 | $70.00 | | |
| 17 | | 2 | 0 | 2 | $30.00 | | |
| 18 | | 3 | 0 | 3 | $45.00 | | |
| 19 | | 4 | 0 | 4 | $60.00 | | |
| 20 | | 5 | 1 | 3 | $65.00 | | |
| 21 | | 6 | 2 | 2 | $70.00 | | |
| 22 | | 7 | 3 | 1 | $75.00 | | |
| 23 | | 8 | 4 | 0 | $80.00 | | |
| 24 | | 9 | 4 | 0 | $80.00 | | |
| 25 | | 10 | 4 | 0 | $80.00 | | |

| | C | D | E |
|---|---|---|---|
| 15 | Tables | Chairs | Total Profit |
| 16 | =C11 | =D11 | =G11 |




## Using Solver Table

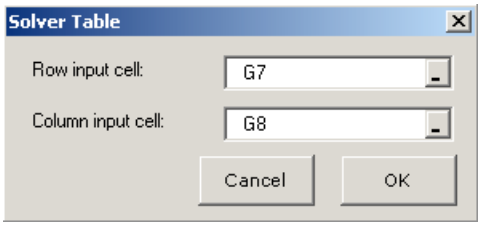
1. In the first column of the table, skip the first row and then enter the various trial values for the data cell that will be varied (the number of large bricks ranging from 2 to 10 in B17:B25).
2. In the first row of the table, enter equations referring to each output cell of interest (e.g., =C11, =D11, and =G11 in C16:E16).
3. Select the entire table (B16:E23) and choose Solver Table from the Tools menu.
4. Specify the column input cell (the data cell that is being varied in the first column—the number of large bricks in cell G7), and click OK.

For each trial value of the data cell in the first column, Solver is called on to re-solve the problem, and the value of the output cells are filled into the table.

# Two-Dimensional Solver Table

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | **The Lego Production Problem** | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | Tables | Chairs | | | | |
| 4 | | Profit | $20.00 | $15.00 | | | | |
| 5 | | | | | | | | |
| 6 | | | Bill of Materials | | Total Used | | Available | |
| 7 | | Large Bricks | 2 | 1 | 6 | <= | 6 | |
| 8 | | Small Bricks | 2 | 2 | 8 | <= | 8 | |
| 9 | | | | | | | | |
| 10 | | | Tables | Chairs | | | Total Profit | |
| 11 | | Production Quantity | 2 | 2 | | | $70.00 | |
| 12 | | | | | | | | |
| 13 | | | | | | | | |
| 14 | | | | | | Large Bricks | | |
| 15 | | | $70 | 4 | 5 | 6 | 7 | 8 |
| 16 | | | 6 | $50 | $55 | $60 | $60 | $60 |
| 17 | | | 7 | $55 | $60 | $65 | $70 | $70 |
| 18 | | Small Bricks | 8 | $60 | $65 | $70 | $75 | $80 |
| 19 | | | 9 | $60 | $70 | $75 | $80 | $85 |
| 20 | | | 10 | $60 | $75 | $80 | $85 | $90 |

| | C |
|---|---|
| 15 | =G11 |




## Using a Two-Dimensional Solver Table

1. In the first row of the table, enter the various trial values for the first data cell that will be varied (number of large bricks in D15:H15).
2. In the first column of the table, enter the various trial values for the second data cell that will be varied (the number of small bricks in C16:C20).
3. Enter an equations referring to the output cell of interest in the upper-left-hand corner of the table (e.g., =G11 in cell C15).
4. Select the entire table (C15:H20) and choose Solver Table from the Tools menu.
5. Specify the row input cell (the data cell that is being varied in the first row) and the column input cell (the data cell that is being varied in the first column), and click OK.

# 100% Rule for Simultaneous Changes in the Objective Coefficients

*For simultaneous changes in the objective coefficients, if the sum of the percentage changes does not exceed 100%, the original solution will still be optimal.*

Adjustable Cells

| Cell | Name | Final Value | Reduced Cost | Objective Coefficient | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $C$11 | Production Quantity: Tables | 2 | 0 | 20 | 10 | 5 |
| $D$11 | Production Quantity: Chairs | 2 | 0 | 15 | 5 | 5 |

Constraints

| Cell | Name | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $E$7 | Large Bricks Total Used | 6 | 5 | 6 | 2 | 2 |
| $E$8 | Small Bricks Total Used | 8 | 5 | 8 | 4 | 2 |

**Examples:**

- (Profit/Table = $24) (Profit/Chair = $13)

- (Profit/Table = $25) (Profit/Chair = $12)

- (Profit/Table = $28) (Profit/Chair = $18)

# 100% Rule for Simultaneous Changes in the Right-Hand-Sides

*For simultaneous changes in the right-hand-sides, if the sum of the percentage changes does not exceed 100%, the shadow prices will still be valid.*

Adjustable Cells

| Cell | Name | Final Value | Reduced Cost | Objective Coefficient | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $C$11 | Production Quantity: Tables | 2 | 0 | 20 | 10 | 5 |
| $D$11 | Production Quantity: Chairs | 2 | 0 | 15 | 5 | 5 |

Constraints

| Cell | Name | Final Value | Shadow Price | Constraint R.H. Side | Allowable Increase | Allowable Decrease |
|---|---|---|---|---|---|---|
| $E$7 | Large Bricks Total Used | 6 | 5 | 6 | 2 | 2 |
| $E$8 | Small Bricks Total Used | 8 | 5 | 8 | 4 | 2 |

**Examples:**

- (+1 Large Brick) (+2 Small Bricks)

- (+1 Large Brick) (–1 Small Brick)

# Summary of Output from Computer Solution

Changing Cells:

| | |
|---|---|
| Final Value | The value of the variable in the optimal solution |
| Reduced Cost | Increase in the objective function value per unit increase in the value of a zero-valued variable (for small increases)—may be interpreted as the shadow price for the nonnegativity constraint. |
| Allowable Increase/ Decrease | Defines the range of the cost coefficients in the objective function for which the current solution (value of the variables in the optimal solution) will not change. |

Constraints:

| | |
|---|---|
| Final Value | The usage of the resource in the optimal solution. |
| Shadow price | The change in the value of the objective function per unit increase in the right hand side of the constraint: $\Delta Z = (\text{Shadow Price})(\Delta \text{RHS})$ (Note: only valid if change is within the allowable range for RHS values—see below.) |
| Constraint R.H. Side | The current value of the right hand side of the constraint (the amount of the resource available). |
| Allowable Increase/ Decrease | Defines the range of values of the RHS for which the shadow price is valid and hence for which the new objective function value can be calculated. (**NOT** the range for which the current solution will not change.) |