Optimization:
Inventory Optimization

Short Examples Series
using
Risk Simulator

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Optimization – Inventory Optimization

File Name: *Optimization – Inventory Optimization*
Location: *Modeling Toolkit | Optimization | Inventory Optimization*
Brief Description: *This sample model illustrates how to run an optimization on manufacturing inventory to maximize profits and minimize costs subject to manufacturing capacity constraints*
Requirements: *Modeling Toolkit, Risk Simulator*

This model is used to find the optimal allocation of parts in a manufacturer's portfolio of inventory. In the model, 8 different parts are shown, with their respective prices per unit (Figure 1). The demand for these parts is divided into 4 phases or cycles. For example, in the automotive aftermarket, certain parts are required more or less at certain times in the car's lifecycle (e.g., fewer parts may be needed during the first three years of a car's life than perhaps in years four to six, or years seven to ten, versus over ten years) or parts of a machine, or the inventory in a retail shop during the four seasons in a year, and so forth. The demand levels in these cycles for each part is simulated (assumptions have already been preset in the model) and can be based on expert opinions, expectations, forecasts, or historical data (e.g., using distributional fitting methods in Risk Simulator).

In this model, if the manufacturer makes a higher quantity of a product than it can sell, there will be an added holding cost per unit (storage cost, opportunity cost, cost of money, and so forth). Thus, it is less profitable to make too many units, but too few units means lost sales. In other words, if the manufacturer makes too much, it loses money because it could have made some more of something else, but if it makes too little of a product, it should have made more to sell more of the product and make a profit. So an optimal inventory and manufacturing quantity is required. This model is used to find the best allocation of parts to manufacturer given the uncertainty in demand and, at the same time, to maximize profits while minimizing cost.

However, the manufacturer has constraints. It cannot manufacture too many units of a single part due to resource, budget, and manufacturing constraints (size of factory, cycle time, manufacturing time, cost considerations, and so forth). For example, say the firm cannot produce more than 100,000 units per part, and during each manufacturing or seasonal cycle, it cannot produce more than 250,000 units, and the total parts produced are set at no more than 800,000 units. In short, the problem can be summarized as:

Objective: Maximize total net revenues
Problem: Find the best allocation of parts to maximize net revenues
Surplus and shortages are expensive
Constraints: Each part cannot exceed 100,000 units
Each cycle cannot exceed 250,000 units
Each part during each cycle should be between 15,000 and 35,000 units
Total parts cannot exceed 800,000 units
Assumptions: Surplus units has a holding inventory cost of $1

One very simple allocation is to produce an equal amount (e.g., 25,000 units per part, per cycle, thereby hitting all the constraints) as illustrated in Figure 1. The total net revenue from such a simple allocation is found to be $105,082,000.

Inventory Optimization

Units in '000s

Part	*Part A512*	*Part V542*	*Part X221*	*Part AV12*	*Part CF88*	*Part X52*	*Part X72*	*Part FM2*	*TOTAL*
Price	*$154*	*$135*	*$188*	*$250*	*$54*	*$79*	*$155*	*$230*	
Cycle 1 Demand	32.1200	18.1869	24.9693	17.1145	20.9422	21.8852	22.8831	15.9424	
Cycle 2 Demand	33.6296	29.1802	17.0791	20.0976	25.0521	19.9820	22.1348	22.8378	
Cycle 3 Demand	25.0197	33.0849	17.0325	24.0091	23.9793	28.8729	15.0658	19.0125	
Cycle 4 Demand	21.0919	15.0099	17.0732	31.2030	20.1536	21.9011	30.9182	21.0207	
Manufactured C1	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	*200.00*
Manufactured C2	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	*200.00*
Manufactured C3	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	*200.00*
Manufactured C4	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	*200.00*
Total Units	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	***800.000***
Surplus/Shortage	-11.86	4.54	23.85	7.58	9.87	7.36	9.00	21.19	
Gross Revenues	$14,798	$11,232	$14,317	$21,555	$4,864	$7,013	$13,188	$18,127	
Added Expenses	$12	$0	$0	$0	$0	$0	$0	$0	
Net Revenues	$14,786	$11,232	$14,317	$21,555	$4,864	$7,013	$13,188	$18,127	***$105,082***

Assumed Holding Cost (Per Unit) $1

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Problem: Find the best allocation of parts to maximize net revenues
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Total parts cannot exceed 800,000 units

Assumptions: Surplus units has a holding inventory cost of $1

Figure 1: Inventory model before optimization

Optimization Procedure (Predefined)

In contrast, an optimization can be set up to solve this problem. The optimization has already been set up in the model and is ready to run. To run it:

1. Go to the Optimization Model worksheet and click on **Risk Simulator | Change Profile** and select the *Inventory Optimization* profile.
2. Click on the **Run Optimization** icon or click on **Risk Simulator | Optimization** | **Run Optimization** and click **OK**.
3. Click **Replace** when optimization is completed. The results show the optimal allocation of manufactured parts that maximizes the total net profit, increasing it from $105.082 million to $110.116 million. Clearly optimization has created value.

Inventory Optimization

Units in '000s									
Part	*Part A512*	*Part V542*	*Part X221*	*Part AV12*	*Part CF88*	*Part X52*	*Part X72*	*Part FM2*	*TOTAL*
Price	*$154*	*$135*	*$188*	*$250*	*$54*	*$79*	*$155*	*$230*	
Cycle 1 Demand	32.1200	18.1869	24.9693	17.1145	20.9422	21.8852	22.8831	15.9424	
Cycle 2 Demand	33.6296	29.1802	17.0791	20.0976	25.0521	19.9820	22.1348	22.8378	
Cycle 3 Demand	25.0197	33.0849	17.0325	24.0091	23.9793	28.8729	15.0658	19.0125	
Cycle 4 Demand	21.0919	15.0099	17.0732	31.2030	20.1536	21.9011	30.9182	21.0207	
Manufactured C1	31.851	18.188	25.000	17.466	23.000	22.258	24.261	24.411	*186.43*
Manufactured C2	24.623	31.800	25.000	23.750	27.000	24.360	22.391	25.753	*204.68*
Manufactured C3	25.017	35.000	25.000	25.775	25.000	29.022	22.391	28.801	*216.00*
Manufactured C4	18.510	15.012	25.000	33.009	25.000	24.360	30.958	21.035	*192.88*
Total Units	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	***800.000***
Surplus/Shortage	-11.86	4.54	23.85	7.58	9.87	7.36	9.00	21.19	
Gross Revenues	$15,400	$12,887	$14,317	$23,106	$4,867	$7,319	$14,105	$18,127	
Added Expenses	$12	$0	$0	$0	$0	$0	$0	$0	
Net Revenues	$15,388	$12,887	$14,317	$23,106	$4,867	$7,319	$14,105	$18,127	***$110,116***

Assumed Holding Cost (Per Unit) $1

Objective: Maximize total net revenues

Problem: Find the best allocation of parts to maximize net revenues
Surplus and shortages are expensive

Constraints: Each part cannot exceed 100,000 units
Each cycle cannot exceed 250,000 units
Total parts cannot exceed 800,000 units

Assumptions: Surplus units has a holding inventory cost of $1

Figure 2: Optimized results

4. Using these optimal allocations, run a simulation (the assumptions and forecasts have been predefined in the model) by clicking on the **RUN** icon or select **Risk Simulator | Run Simulation**.

5. On the Net Revenues forecast chart, select **Two-Tail** and type in **90** in the *Certainty* box and hit **TAB** on the keyboard to obtain the 90% confidence interval (between $105 million and $110 million). View the *Statistics* tab to obtain the mean expected value of $108 million for the net revenues.
6. Select **Right-Tail** and type in **105082** in the *Value* box, to find the probability that this optimal allocation's portfolio of manufactured products (Figure 2) will exceed the simple equal allocation's net revenues seen in Figure 1. The results indicate that there is a 94.70% probability that by using this optimal portfolio, the manufacturer will make more net profits than going with a simple equal allocation (Figure 3).

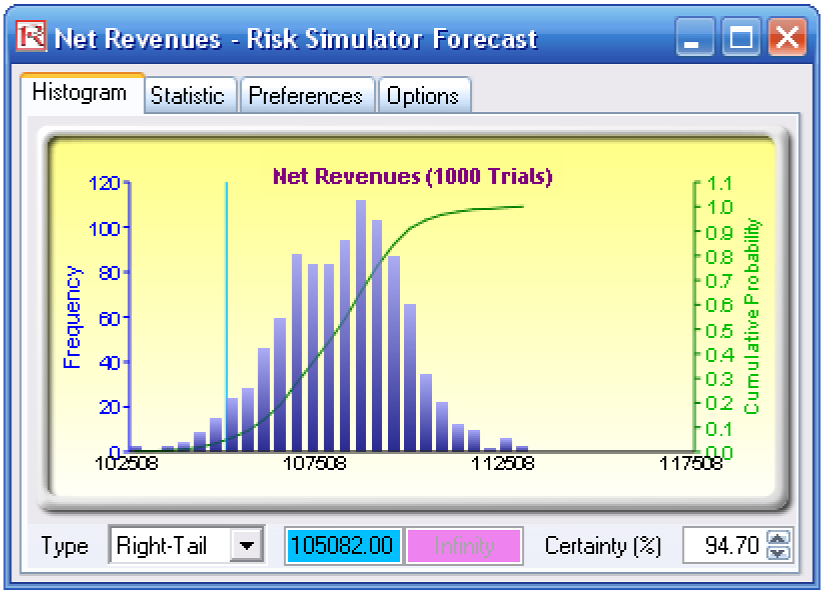

Figure 3: Optimized net revenues

Optimization Procedure (Manual)

To set up the model again from scratch, follow the instructions below:

1. Go to the *Optimization Model* worksheet and click on **Risk Simulator | New Profile** and give the profile a new name. You may have to reset the decision variables to some starting value (i.e., make the cells **C13:J16** all **25** as a starting point), so that you can immediately see when the optimization generates new values.
2. Click on cell **K23** and make it the objective to maximize (**Risk Simulator | Optimization** | **Set Objective**, and select **Maximize**).
3. Click on cell **C13** and make it a decision variable (**Risk Simulator | Optimization** | **Set Decision**, and select **Continuous** for getting a continuous variable (we need this because the model's values are in thousands of units and thousands of dollars) and set the bounds to be

between **15** and **35** (you can set your own bounds but these are typically constraints set by the manufacturer), to signify that the manufacturer can make only between 15,000 and 35,000 units of this part per cycle due to resource and budget or machine constraints.

4. Set the constraints by clicking on **Risk Simulator | Optimization** | **Set Constraint**, and select **ADD** for adding a new constraint. Add the three additional constraints in the model, namely, cells **K13 to K16 <= 250 for each cell**, **C18 to J18 <= 100 for each cell**, and **K18 <=800**. Do this one constraint at a time (Figure 4).
5. Click on the **Run Optimization** icon or click on **Risk Simulator | Optimization** | **Run Optimization**. Look through the tabs to make sure everything is set up correctly. Click on the *Method* tab and select **Static Optimization** and click **OK** to run the optimization.
6. Click **Replace** when optimization is completed. The results illustrate that the optimal allocation of manufactured parts that maximizes net profit, increases it from $105.082 million to $110.116 million. Clearly optimization has created value.
7. Using these optimal allocations, run a simulation (the assumptions and forecasts have been predefined in the model) by clicking on the **RUN** icon or select **Risk Simulator | Run Simulation**.
8. On the Net Revenues forecast chart, select **Two-Tail** and type in **90** in the *Certainty* box and hit **TAB** on the keyboard to obtain the 90% confidence interval (between $105 million and $110 million). View the *Statistics* tab to obtain the mean expected value of $108 million for the net revenues.
9. Select **Right-Tail** and type in **105082** in the *Value* box, to find the probability that this optimal allocation's portfolio of manufactured products will exceed the simple equal allocation's net revenues seen previously.

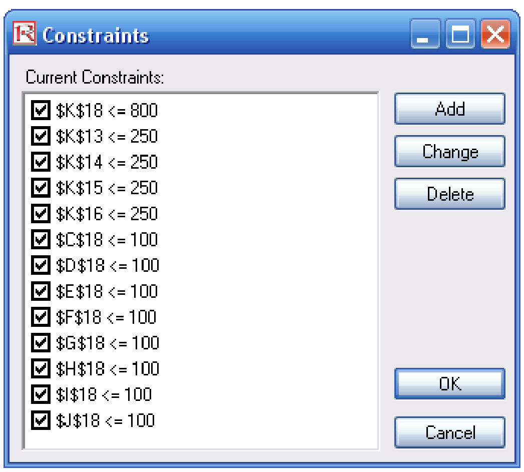

Figure 4: Setting constraints one at a time