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| Reef Sandal Case Study |
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| Management Science (BA 625) – SUMMER 2010 |
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#### Executive Summary

 Reef is a manufacturer of fine sandals and apparel with headquarters in Carlsbad, CA. Demand for one of Reef’s products, the Fanning sandal, had quickly outpaced their supply chain’s production capacity and Reef was losing potential sales. The management team at Reef contracted our team at All Angles Consultancy to build a linear programming model that would optimize their supply chain and maximize their gross margin on the Fanning sandal.

 The supply chain for the Fanning sandal is complex, consisting of three different factories with differing lead times and production capacities. An additional option to use air freight from one of the factories to quickly turn additional units adds cost but can quickly satisfy demand. In order to ensure that a steady workforce is employed, each factory has a minimum monthly commitment of ten thousand units. And, to put icing on the cake, Reef has two sales channels with different demands and different wholesale prices. Taking all of these variables into consideration without computer assistance is difficult if not impossible and it is easy to understand why Reef production planners were having difficulty satisfying their demand.

 Reef is not the first company to have supply chain challenges and linear programming is an excellent tool to solve this type of problem. To build an LP model for Reef we first defined the decisions over which their managers had control. These decisions included the number of reorder units to satisfy for each sales channel each month, the number of units to produce at each factory monthly, and whether or not to use the quick turn option in a given month. Next we crafted the objective function which, in this case, was a matter of calculating their total gross margin for the Fanning sandal based on the decision variables that the model would control. Last we defined our model constraints which included factory capacities and minimums, demand for each month, and safety stock requirements.

 All Angles Consultancy was able to use this LP model to optimize Reef’s supply chain resulting in a total gross margin of $10.3M for the 18 month period. This is roughly 25% more than Reef’s estimates before optimization. Additionally, this model can be easily modified to account for changes in forecasted demand or constraints such as factory capacities and lead times. Future decisions based on new information can be made much more rapidly and accurately which should allow Reef to maximize their potential with the Fanning sandal line.

#### Introduction

Reef is a surf company that produces sandals and apparel in China and Indonesia, and then sells them worldwide. Throughout its history, the company has produced bestselling products that quickly sell out. One such product is a men’s sandal called the “Fanning.” It is named after a professional surfer, Mick Fanning, and it has pushed the boundary on combining athletic design with comfort in a stylish sandal. The only problem with this sandal is that Reef is unable to keep enough of it in stock to satisfy growing demand.

 The planning department has three factories that produce the sandal and each factory has different capabilities. For example, each factory has different production lead times, minimum production requirements and maximum capacity constraints. Due to these factors, the planning team would like to forecast the supply plan for 12-18 months in the future so that both Reef and each factory can plan their monthly operations. The reason each factory has a minimum production requirement is to maintain a steady workforce and continue to cover the fixed costs of the plant in times when demand is less. This is a partnership between Reef and the factory because it means Reef may have to order product earlier than needed but it keeps the skilled workers at the factory so that the product quality is high.

 As it stands right now, the planning department uses a basic Excel workbook to plan the monthly supply based on monthly demand. However, the team would like to implement a more sophisticated model that optimizes the many factors of the operation. As a result, All Angles Consultancy (AAC) has agreed to take the project. AAC will not only deliver a working optimization model that will show how to maximize profits in the current situation, but the model will also be versatile enough to be used for similar planning problems in the future. To the delight of Reef’s management team, the project was delivered on time and within budget.

#### Objective

The challenge from the Reef planning department is to show an optimal solution for factory allocation in units by month that satisfies monthly demand while making the highest gross margin for the company. The model does this all while taking the following variables into account:

* demand variances for prebookings by month and by the most profitable sales channels
* inventory costs of 1.25% per month
* 3 available factories ( named OT China, Co Oct China, and Co Oct Indo) that can make the product with different production lead times and different costs
* factory minimum order requirements
* factory maximum capacity constraints
* demand variances for at-once orders by month and by the most profitable sales channels
* cost and availability for a quick turn program at OT China

#### Method

In order to evaluate how to meet growing demand while at the same time aim to minimize costs, AAC created a model using Excel solver, a plug-in feature that is included in the MS Office 2007 and 2010 software package. This type of model allows for ease of use because MS Office is the most common and trusted software among business professionals. It allows for the customer to have instant familiarity with the product and that makes it easier to understand vs. a lesser-known software program that the customer most likely has never seen (i.e., JMP IN).

In building the model, AAC knew that the project would be most beneficial to the customer if the model could show different outputs by allowing the input variables to be easily changed. AAC also knew from experience that factory costs and lead times were dynamic so it confirmed the need to make the model formula-driven based on the inputs. As a result, this model takes into account all of the inputs and links the all of the sourcing decisions and financial results to those inputs. If a selling price or product lead time changes, the user can simply input the new data in the top section of the Excel model and everything will take change accordingly. The final product is a robust tool for Reef to use and following section will describe the optimization model in detail.

#### Analysis: Optimization Model

###### Parameters Given:

 The following parameters in **Table 1** came from Reef’s operations department. They include factory costs, production and shipping lead times, production capacities, production minimums, inventory holding charge, air option quick-turn lead time and capacity, and air additional quick turn cost.

**Table 1: Parameters provided by Reef**

|  |  |  |  |
| --- | --- | --- | --- |
| **Factory** | **OT - China** | **Co-Oct China** | **Co-Oct Indo** |
| Standard Cost |  $9.89 |  $9.89 |  $9.89 |
| Production LT (days) | 60 | 90 | 120 |
| Transit LT (days) | 30 | 30 | 30 |
| Production Capacity (units) | 30,000 | 20,000 | 20,000 |
| Production Minimum (units) | 10,000 | 10,000 | 10,000 |
| Inventory Charge | 1.25% | 1.25% | 1.25% |
| \*Air option quick turn LT (days) | 30 |  N/A |   N/A |
| \*Air option quick turn capacity | 5,000 |   N/A |   N/A |
| \*Air additional quick turn cost | $3.00  |   N/A |   N/A |

\**Air option quick turn* refers to the expedited request to get more sandals made than the original order and has higher associated costs but a shorter lead time. This program is only available a few months of the year and OT China is the only factory that allows Reef to do this.

In addition to the sourcing parameters provided by Reef, AAC also incorporated the selling prices for the Fanning sandal. Currently, Reef sells the sandals to two main channels: chain and core. The chain designation refers to the big box retailers that often have stores located nationwide. Examples of chain stores include Macy’s, Nordstrom, Pac Sun, and Dick’s Sporting Goods. The average selling price for the Fanning sandal to the chain market is $21.00. The other channel is called the core and it refers to all stores who are not considered chain. These include all of the mom and pop surf shops, footwear only stores, and boutiques. The average selling price for the Fanning sandal to the core market is $22.00.

The account distribution between the chain and core shops is vast with only 1% of the number of accounts in the chain channel. However, this 1% of accounts makes up approximately 50% of revenue. Because of this large revenue coming from such a small amount of accounts, the chain customers demand a larger discount so that is why Reef sells the Fanning at a lower wholesale price. As a result, Reef does not make as much profit for each sandal sold to a chain customer when compared to selling the same sandal to a core customer. For this reason, the Reef operations department would like the model to demonstrate the most profitable action when the supply is not enough to satisfy all demand and which channel’s orders should be fulfilled first.

###### Supply Assumptions

For this study, there are a few assumptions that AAC and Reef agreed upon in order to simplify the model. First, every month is level set to be exactly 30 days. Reef actually uses a 4-4-5 fiscal calendar which means 4 weeks in the first month of quarter, 4 weeks in the second month, and 5 weeks in the last month of a quarter. For the purposes of this exercise; however, the model is built on 30-day months. Second, all sourcing decisions to produce product are placed with the factory on the first day of the month. This means the factory begins production immediately when it receives the order. Third, all supply receipts for a given month come in on the first day of that month. This means that all units received in the month may be used to satisfy demand within the same month.

Because this model begins in July, 2010, Reef had to provide AAC with the current on-hand inventory for July as well as pending receipts for the next 5 months. In this case, Reef explained the 30,000 units were on hand at the beginning of July and the operations team provided the data in **Table 2** to show pending receipts for July through November, 2010.

**Table 2**: **Pending Reef supply for July through November** **(Unit Receipts)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Month** | **OT - China** | **Co-Oct China** | **Co-Oct Indo** |
| Jul | 20,000 | 20,000 | 10,000 |
| Aug | 10,000 | 10,000 | 10,000 |
| Sep | 10,000 | 10,000 | 10,000 |
| Oct | N/A | 10,000 | 10,000 |
| Nov | N/A | N/A | 10,000 |

###### Demand assumptions

The Reef footwear forecaster provided AAC with a demand forecast for core prebooks and chain prebooks by month for July 2010 through December 2011. Prebooks refers to an order that the customer places with Reef 4 months prior to delivery. This order provides Reef with demand visibility so that the operations team can produce the desired amount of units. The prebooks are collected prior to the beginning of a selling season. Once a season begins, the forecaster produces a reorder forecast by month. The forecast is usually a rate based on historical ratios for the number of reorders to the number of prebooks for each month. The rate is then applied the next year to the new prebook amount. For example, if Reef sold 20,000 prebooks and 2,000 reorders in July 2009, the reorder rate would be 10% (20,000/2,000). Then, in 2010, the forecaster would see how many prebooks Reef collected for July. If the total prebooks was 30,000 units, then the reorder forecast for July 2010 would be 3,000 units (30,000 units \* 10%). Prebooks satisfied by the model are not a decision variable because Reef should fulfill all prebooks before reorders are considered. In addition to Reef providing the prebook demand by month, by customer type, the forecaster also provided a demand forecast by month and also by customer type.

Reef requested that AAC include a constraint called *Safety stock* in the model because the operations team wants to ensure that there are back up units available in case reorder demand is higher than expected. For this model, the Reef forecaster recommended that the safety stock be applicable for April through August in 2011. The amount of safety stock was equal to 20 % of the current demand for reorder units for both the chain and core channels combined. This constraint and many others are explained in the next section, along with the decision variables and objective function to maximize profitability.

###### Decision Variables

Demand:
$$Let V\_{i}=Reorder Units of Core to Satisfy in month i$$

$$for i= July 2010… December 2011$$

$$Let W\_{i}=Reorder Units of Chain to Satisfy in month i$$

$for i=July 2010…December 2011$

Supply:

$$Let X\_{i}=The number of units to Produce at the OT – China factory in month i$$

$$for i=July 2010…December 2011 $$

$$Let Y\_{i}=The number of units to Produce at the Co-Oct – China factory in month i$$

$$for i=July 2010…December 2011 $$

$$Let Z\_{i}=The number of units to Produce at the Co-Oct – Indo factory in month i$$

$$for i=July 2010…December 2011 $$

$$Let Q\_{i}=The number of units to Quick Turn at the Co-Oct – China factory in month i$$

$for i=July 2010…December 2011$

###### Objective Function

Maximize Gross Margin for the remainder of 2010 (July through December) and all of 2011.

$$Max gross margin=\sum\_{i=Jul10}^{i}\left(\$22-\$9.89\right)\left(Core Prebooks\_{i}+V\_{i}\right)+\left(\$21-\$9.89\right)\left(Chain Prebooks\_{i}+W\_{i}\right)-\left(\$3.00\right)(Q\_{i})- (1.25\%)(\$9.89)(Ending Inventory\_{i}) $$

###### *s.t.*

Demand Constraints:

$$Reorder Units Core Satisfied\_{i}\leq Reorder Units Core Demand\_{i}$$

$$Reorder Units Chain Satisfied\_{i}\leq Reorder Units Chain Demand\_{i}$$

$$Ending On Hand Inventory\_{Jul10}\geq 0$$

$$Ending On Hand Inventory\_{Aug10}\geq 0$$

$$Ending On Hand Inventory\_{Sep10}\geq 0$$

$$Ending On Hand Inventory\_{Oct10}\geq 0$$

$$Ending On Hand Inventory\_{Nov10}\geq 0$$

$$Ending On Hand Inventory\_{Dec10}\geq 0$$

$$Ending On Hand Inventory\_{Jan11}\geq 0$$

$$Ending On Hand Inventory\_{Feb11}\geq 0$$

$$Ending On Hand Inventory\_{Mar11}\geq 0$$

$Ending On Hand Inventory\_{Apr11}\geq \left(20\%\right)(Reorder Units Core Demand\_{Apr11}+Reorder Units Chain Demand\_{Apr11})$

$Ending On Hand Inventory\_{May11}\geq \left(20\%\right)(Reorder Units Core Demand\_{May11}+Reorder Units Chain Demand\_{May11})$

$Ending On Hand Inventory\_{Jun11}\geq \left(20\%\right)(Reorder Units Core Demand\_{Jun11}+Reorder Units Chain Demand\_{Jun11})$

$Ending On Hand Inventory\_{Jul11}\geq \left(20\%\right)(Reorder Units Core Demand\_{Jul11}+Reorder Units Chain Demand\_{Jul11})$

$Ending On Hand Inventory\_{Aug11}\geq \left(20\%\right)(Reorder Units Core Demand\_{Aug11}+Reorder Units Chain Demand\_{Aug11})$

$$Ending On Hand Inventory\_{Sep11}\geq 0$$

$$Ending On Hand Inventory\_{Oct11}\geq 0$$

$$Ending On Hand Inventory\_{Nov11}\geq 0$$

$$Ending On Hand Inventory\_{Dec11}\geq 0$$

Supply Constraints:

$$Production Capacity Units OT China \_{i}\geq X\_{i}\geq Minimum Required Units OT China\_{i}$$

$$Production Capacity Units Co-Oct China \_{i}\geq X\_{i}\geq Minimum Required Units Co-Oct China\_{i}$$

$$Production Capacity Units Co-Oct Indo \_{i}\geq X\_{i}\geq Minimum Required Units Co-Oct Indo\_{i}$$

$Production Cap. Units Quickturn OT China \_{i}\geq X\_{i}\geq Minimum Req. Units Quickturn OT China\_{i}$

#### Discussion

 The optimization model made several interesting decisions that are critical to correcting Reef’s supply chain problems. First, the model decides to immediately utilize the quick turn program in July 2010 with 5,000 units of production. The reason for this is because the current on hand units, supply receipts, and production capacities were not enough to satisfy all demand for August. Therefore, unless the quick turn program was initiated, reorder demand would have to go unfulfilled. By immediately initiating the quick turn process, Reef will be able to satisfy additional demand in August and these sales would otherwise be lost.

 Another decision that the model made is that despite the quick turn program being active in July 2010, a portion of reorder demand for chain will have to go unfulfilled. Since the selling prices are different for the two sales channels, and because the model is trying to maximize gross margin dollars, the model tells Reef not to satisfy the reorder demand in the chain channel. This is because the gross margin for chain customers ($21.00 - $9.89 = $11.11) is worse than for core customers ($22.00 - $9.89 = $12.11). In 2011, the quick turn months of March through June in 2011 cease to be utilized; however, this early detection allows Reef to react quickly to any potential rising demand.

 A third interesting decision from the model is not to utilize the full capacity of all factories in each month. For example, Reef should not produce full capacity for OT China in July, August, and September 2010 and May through September in 2011. This may seem surprising because those months in 2011 require safety stock to be on hand in case reorders increase. However, the model meets the safety stock constraint by building up inventory as early as January 2011, which is the first month that will receive full capacity shipments. The buildup from January through July allows Reef to just meet its 3000 minimum safety stock constraint in July 2011. Producing below capacity in July, August and September of 2010 would also allow Reef to increase production if reorders begin trending higher than expected.

 Reef can feel confident in the production and inventory plan produced by AAC’s linear programming model. The total gross margin currently points to $10.3M and this is 25% higher than the amount Reef thought it would make before hiring AAC to create an optimization model. Due to AAC’s expertise, Reef can efficiently use each factory, satisfy demand for the most profitable channels first, minimize the amount of inventory that carries from one month to the next, and only use the quick turn program as a last resort to satisfy demand that the normal production schedule cannot.

#### Recommendations

AAC recommends that Reef follow the optimization plan presented from this project. The current plan should be confirmed by the Reef forecaster going back over the forecast by month and by sales channel to ensure accuracy. This is important because the accuracy of the model is dependent on those key variables. Next, the Reef operations team should communicate this monthly production plan with the factories to help them plan their resources. This will allow the factories to ensure there is no interruption in service and all purchase orders are delivered according to the scheduled lead times.

Once the model is in place, the Reef operations team should keep a close watch on the monthly demand for reorders to see whether it is tracking to plan. If reorders are tracking lower than planned, the forecaster should re-forecast the outlying months and take down the demand. By taking down demand, the sourcing decisions for production will automatically change to ensure that excess quantities of inventory are not being produced. If reorders are tracking higher than planned, the forecaster should also re-forecast the outlying months and take up the demand. This will automatically change the production schedule and if there are any months where demand is not satisfied, the quick turn program will likely be initiated. Once the model is showing the need for the quick turn (because current supply is not enough to satisfy demand), the Reef operations department should contact the OT China factory and notify them that the quick turn program will be utilized. This notification to the factory will allow them to stockpile the necessary bulk materials and air freight scheduling to allow the quick turn program to deliver such a fast production lead time.

AAC recommends that the Reef operations department monitor this model and look for areas for improvement. AAC will make enhancements for a nominal fee, as outlined in the vendor contract. This model may also be used for other Reef styles. The operations department need only change the input parameters in the first 14 rows of the Excel workbook and the entire model will re-calculate. Together, Reef and AAC will continue working on models that create sound financial decisions to operational production questions such as this one regarding the Fanning sandal.