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| **A Diamond is Forever** |
| Two Approaches to Diamond Inventory |
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| Theodore DasherStephanie Kao |
| Chun Wa MokYi Xiang Chong |
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| **12/15/2010** |
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Background/Problem

Signet’s Jewelry is one of the largest diamond retailers in United States. They are looking to set up a new store in a small town, where diamonds have just become a demanded consumer product. Signet Jewelry will have this store serve as a monopoly in the town. Before the new store starts its business however, it must stock up diamonds in its warehouse. The new branch manager wants to analyze the nature of a store’s inventory flow. She wants to know how her store can best design its operation strategy so that they may have a smooth initial opening.

We gather relevant annual and seasonal financial statements from the branches of Signet’s Jewelry. The statements include details of sales, average prices, cost of sales, and inventory costs. To create an ordering strategy, we solve the inventory problem with two approaches based on consumer demand for diamonds: seasonal demand and demand based on diamond price. By solving the seasonal problem, we obtain the objective function to minimize inventory cost for the store. By solving the price inventory model, we maximize aggregate profit. As a result, we will be able to offer the store its optimal quantity of diamonds to order, the time period between each order, and the total cost of the order.

Seasonal Inventory Model

Background

This inventory model has a feature of lot-resize reorder. Orders for fixed quantities are placed when the diamond stock level in the warehouse falls to a preset figure. This requires a constant monitoring of stocks levels, every time a diamond is taken out from the stock. The major characteristic of this model is seasonal consumer demand. Consumers’ desire for diamonds is different during each season. For convenience and ease of interpretation, we divide the year into 4 seasons according to the seasonal statement from other branches of Signet’s Jewelry. The four time frames are: February 1 – May 1, May 2 – July 31, August 1 – October 30 and October 31 – January 31. Hypothetically, demand for diamonds will be the highest during Valentine’s Day and Christmas, therefore optimal diamond quantity to order should be the highest in the first and fourth time frame. This hypothesis will be proven by later results.

Model

The non-trivial part of the problem was to model a suitable demand constant. Based on the financial statements, we estimated the demand constant for each season from the sales of the respective season and the average price of diamonds. This gave us an idea of the consumption of diamonds on a daily basis. Fixed and inventory costs were taken directly from the financial statements.

Assumptions

Before going into analysis of our results, we state a set of assumptions this model is based on. First, stock level, labeled as S, is always kept at a positive level in case of unexpected demand for diamonds. We assume that data from seasonal statements taken from other branches will reflect the performance of the new store, at least for the first year of business. The diamond is also transported to the store right away once an order is placed. Lastly, we assume that a demand constant adjusted for each seasonal period adequately reflects our demand function.

Results

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Quarter Periods | Average Selling Price | Total Sales(millions) | Demand Constant | Cost of Sales | Fixed Cost Rate | Inventory Cost Rate |
| 1st | $6,440  | $0.32  | 0.5434644 | $513.70 | $225.25 | $12.33 |
| 2nd | $6,980  | $0.27  | 0.4218253 | $483.00 | $249.02 | $12.37 |
| 3rd | $8,260  | $0.23  | 0.3026714 | $448.20 | $299.52 | $14.26 |
| 4th | $6,140  | $0.43  | 0.7658696 | $768.90 | $218.32 | $12.89 |

The demand constant is the normalized average price divided by total sales. The fixed costs and inventory costs are taken from financial statements and normalized to a per period cost.

|  |  |  |  |
| --- | --- | --- | --- |
| **Quarter**  | **Order (Q)**  | **Time period, in Days, (T)**  | **Inventory Cost per period ($)**  |
| 1st  | 4.456064 | 8.1993667 | 254.94326762 |
| 2nd  | 4.121104 | 9.7696937 | 250.97805652 |
| 3rd  | 3.566149 | 11.782248 | 250.84258864 |
| 4th  | 5.093458 | 6.6505548 | 265.65467263 |

The results of the minimization problem are summarized in the table above. The store would order the number of diamonds Q every time period T in the respective season. They would accumulate an inventory cost $ per period. Notice that the diamond stores seem to order only a few diamonds in a short period of time. However, we think this makes sense, because the inventory cost for diamonds is exceptionally high due to securitization. There was a high inventory cost to fixed cost ratio in the financial statements. We learn that the high cost of inventory management has prompted jewelry store owners to hold less diamonds but order more often in order to reduce cost of securing diamonds in their warehouse.

Price Inventory Model

Background

The price inventory model is heavily based on the cost of diamonds from different producers. The goal was to maximize the store’s profits by reducing the cost of transportation and distribution. The strategy involves ordering “bundles” of diamonds from several producers. Each bundle contains a set of diamonds chosen from a list of the most commonly sold diamonds. The purpose of ordering diamonds in “bundles” is to reduce the cost to secure the diamonds during transportation. Rather than order all of the diamonds in one shipment and take the risk of losing the entire stock, we divide our shipments over several bundles so that one bundle lost does not jeopardize the entire stock. We use integer programming to optimally select our bundles and an inventory models to find a projection of the total costs.

Model

We created a flexible methodology for practical inventory selection, and a demand model the suits the needs of price taking retailers. We tested our practicality using real data with the aid of the optimization package *Excel solver*. The model and optimization methodology are described below.

As in the seasonal inventory model, estimating the demand constants is a task of great importance. We fit a log-normal distribution function to the distribution of diamond sales that we observed in our dataset. Doing so give us a smooth functional representation of the data from which we will draw likelihoods. We can also use this distribution to simulate the wholesalers’ catalogue from which our diamond store will make its selections.

The model’s most tenuous assumption lies in our interpretation of this pdf. We say that if in aggregate this distribution reflects per period sales, than the rate at which diamonds of a given price are diminished from stock is proportional to the likelihood of their occurrence in our pdf.

We presume that diamonds are unique. No two shops can sell the same diamond. A single shop is here to be viewed as a microcosm of the market. It follows that the rate at which a diamond diminishes from a shop’s stock in a period, where we assume shop level stock experiences complete turnover in every period, is equal to the proportion of the relative rate at which it will diminish from market stock to the relative rate at which the shop’s inventory will diminish from market stock.

The rate at which a diamond diminishes from a shop’s stock in a period, , is simply the ratio of a diamond’s log likelihood to the log likelihood of all the diamond’s in shop inventory. Notice how at one extreme, a shop selling only one diamond sell’s that diamond at a rate of one per period, regardless of the diamond type, and on the other, the diamonds sold in the shop selling every diamond on the market diminished from stock at a rate proportional its occurrence in our pdf, just as prescribed in the starting assumption.

All the rates are relative in the sense that we have not defined the length of a period. We could do so directly, but we choose instead let users set increments relevant to the particular markets in which the sell. We recommend that the diamond having the lowest turnover rate be used as a baseline. Divide the’s by this, so that if diamond\* is depleted from inventory at one per month, other diamonds will deplete at > one month. Let λri be the real depletion rate of diamond i.

It is on the foundation of the above demand model that we form our inventory selection methodology. However, the inventory selection could take derived in any number of ways. It is likely that shops have experiential knowledge regarding demand for their wares. This knowledge should supplant our demand model in practice if available.

The problem of the inventory selection model method is to choose what diamonds to order and how to order them. We allow shops to choose number of batch orders, the quantity, cost, and frequency of these batch orders, and the selection of diamonds and their allocation into the batch orders. The model requires the shops to specify a profit equation, an order cost per batch order, an equation for insurance cost per batch, and constraints relating to order frequency, size, and number of batch types.

The method’s framework is that of an inventory model, where we choose the parameters by integer programming. Its objective is to maximize per period total profit. Profit is given by profit on each diamond stocked and sold less variable costs for all bundles. Variable cost is a function of batch order and insurance costs incurred, which are in turn dependent upon assignments of diamonds to the various bungles. The method is

 s.t.

 For all j and i

Where we find optimum variable cost, order frequency, and order quantity for any batch type served up an iteration of the above algorithm by solving the inventory problem

We created a demonstration model in excel. The specifications we used took the following functional forms: profit is a function of diamond price and a constant markup multiplier, and insurance cost as an exponential function of batch value, constant batch order cost. We constraints were that no more than a constant number of batches could be ordered in a period. The economic and practical rational for setting these specifications in our demonstration model were, for the most part, theorized. Users implementing our method would have to tune them to match the business realities faced by their shops.

Results



The final solution directs the user what diamonds to pick from the catalogue and how to batch purchase them (the xi,j’s), as well as how often to buy the batches and how many batches to buy. The methodology and demand model can be extended further. Perhaps shops chase a subset of buyers. Shops could factor a vector of quality indicators into their profit function, so that the function predicts higher profit from diamonds conforming to the tastes of the shop’s clientele. The model would likely favor selection of these diamonds.

Conclusion

The two models take into account two factors we believe to be most significant in stocking diamonds: seasonal demand and price. In both models, we saw that because the cost of securing diamonds in both transportation and storage is extraordinarily high for any reasonable good, it tended to have interesting effects on our results.

Our models suggest that diamond stores should attempt to order fewer diamonds and ensure in every possible way to reduce the risk of large losses. These losses include but not limited to making entire orders in one bundle or storing mass orders in the warehouse. Each of these causes a spike in inventory costs and therefore put the store in the red zone. The seemingly reasonable strategy is to order enough diamonds to reach the demand for the period. However the periods vary throughout the year, thus the store owner must maintain their inventory and keep a close eye on the stock levels.

The price inventory model integrates inventory modeling and integer programming. This combination lends to the model’s flexibility. The price model is appropriate for batch ordering, whereas the seasonal model is more appropriate for bulk ordering. *We envision two separate implementations. Wholesalers might buy from producers using the seasonal inventory model. Retailers could select from the wholesalers’ catalogues using the price inventory model.*

References/Sources

Financial Statements taken from Signet Jewelers:

http://www.signetjewelers.com/sj/pages/financial/news-filings/secfilings?type=4&Submit=Search

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presented for a different class by Dr. Rebecca Nugent