Switching Rules for Optimal Ordering

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Summary: This research focuses on optimizing the raw material ordering policy for one product segment in a CPG company. The product faces a high degree of volatility in demand, with suppliers offering quantity discounts. The model we developed provides the minimum order quantity (MOQ) to use while re-ordering raw materials in a way that reduces total costs while storing sufficient inventory. It incorporates a switching rule that switches the MOQ to a higher or lower value depending on the demand forecast.

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KEY INSIGHTS

1. Accuracy of the demand forecast is vital in adhering to the production plan for a CPG company. A high forecast error introduces a large degree of bias to the model.

2. Holding cost holds less weight in determining the total cost. Ordering cost becomes the driving factor in choosing the ordering policy

3. There is no one perfect switching rule that works for all products. It varies based on the dollar value of product, and the holding charge being considered.

Introduction

Inventory management is one of the most important responsibilities in an organization, as it involves capital and impacts the service level to customers. Inventory can be categorized into different levels: raw material, work in progress, and finished goods. While reducing inventory at all three levels to lower inventory costs is important, having sufficient inventory to prevent production delays and stock-outs is vital.

The project's objective is to review the raw material ordering process and production planning for a product in a CPG company and optimize the raw material ordering policy.

The product faces high volatility in demand, and raw material suppliers offer incremental quantity discounts. Currently, the company chooses an MOQ that covers 1 month of demand. Due to the high degree of demand volatility, components ordered have a lot of fluctuation in quantity, and the company is not able to take advantage of the discounts offered for purchasing larger quantities.

This forms the basis of our research problem: how to optimize the raw material ordering policy in a way that

reduces the total costs while storing sufficient raw materials to ensure continuity of the production plan.

We develop a mathematical model to optimize raw material ordering quantity for the product that hits the "sweet spot" between over-stocking and under-stocking. The optimal order quantity will maintain a balance between the ordering cost and the holding cost, as shown in Figure 1. The model will provide the optimal MOQ to use while re-ordering raw materials. It will also incorporate a switching rule that automatically switches the MOQ to a higher or lower value depending on the demand forecast and determines the order quantity (OQ) of the raw material.
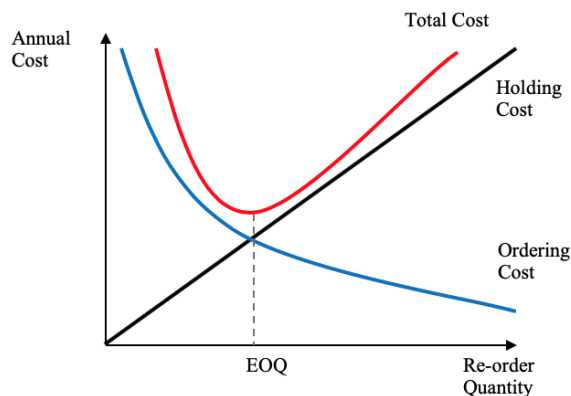

Figure 1. Plot of annual cost vs. re-order quantity

Methodology
The following input data sets are used in the model:

1. **Waterfall forecast for the upcoming 18 months:** Weekly rolling forecast for the material usage demand per week that is continuously revised.
2. **Historical inventory trend (HIT) data**: Data table of different inventory levels of the product, such as: available inventory, production usage, safety stock, and the dollar values for each of the stock keeping units (SKUs).
3. **MOQ price slab**: Unit price ($) offered by the suppliers for the incremental quantities.

Data Analysis
We did some preliminary analysis on the data to identify if the peaks in demand are seasonal, or if the demand is normally distributed.

By directly looking at the past 12 months' demand forecast and the upcoming 12 months' demand forecast, we could not see any inherent seasonality. In comparing the de-seasonalized monthly demand year-over-year to we noticed that the annual de-seasonalized monthly demands do not have the same pattern either.

In the demand distribution, if most of the observations are relatively close to the mean without much variation, then it is a good fit for a normal distribution. Otherwise, if standard deviation is large, there is a chance that the demand can become negative, but we know that that is not possible. We observed that the observations spread far across from the mean in each of the cases and that the demand distribution is not normally distributed but rather a random distribution.

DRP System
We adopted the DRP system to develop the model with the following input data: 1) weekly demand forecast for 10 months; 2) current inventory level for each week; 3) safety stock target; 4) historical inventory usage; 5) lead time for replenishment, which is a standard assumption of 4 weeks throughout the model; and 6) target service level of 99.3%.

The standard EOQ model is not applicable to our project because the real demand and product does not satisfy the assumptions: 1) demand is not constant, with a lot of volatility; 2) lead time is constant and known; 3) stock-outs can occur, but we want to avoid it; 4) items are ordered in lots; and 5) unit item cost is not constant and incremental discounts are offered. Instead, we order in incremental multiples of the MOQ. The best MOQ value will be determined as

a result of the simulation by doing a sensitivity analysis, which will give us the minimum total cost and no stock-outs. We simulated the demand for different values of safety stock to reach the optimal value.

We designed the production plan using the following equations:

$$OR_t = OP_{t-4}$$

$$IOH_t = IOH_{t-1} + OR_t - Usage_{t-1}$$

$$PL_t = OP_{t-1} + OP_{t-2} + OP_{t-3}$$

$$IP_t = IOH_t + PL_t$$

$$If\ IP_t - (F_t + F_{t+1} + F_{t+2} + F_{t+3}) < SS$$

$$Then, OP_t = Max\left(\left\lceil \frac{(F_t + F_{t+1} + F_{t+2} + F_{t+3}) - IP_t + SS}{MOQ} \right\rceil \times MOQ, 0\right)$$

where,

OR = Order received
OP = Order placed
IOH = Inventory on hand
PL = Pipeline order
IP = Inventory position
SS = Safety stock
F = Demand forecast

We calculated the total ordering cost and holding cost and made the following assumptions for all other costs involved in a DRP system:

1. Transportation cost is included in the per-unit ordering cost
2. Stock-out cost is out of scope

We do not consider the capacity to be a constraint at the production facility and assume unlimited shelf life of the materials.

While simulating, the first step was to find the optimal safety stock value. To find this, we began by using the safety stock calculated in Equation 3 and then lowered the value by 25% each time, to reach the optimal value that minimizes total cost while hitting the service level target. Once the safety stock was set, we again iterated the model with different MOQ values to reach the optimal value that minimizes cost and obtains the target service level of 99.3%.

Switching Rules

The objective of the switching rule is to switch to a lower or higher value of MOQ depending on the value of the demand, which is illustrated in Figure 2. Since the demand for the product is highly volatile, having
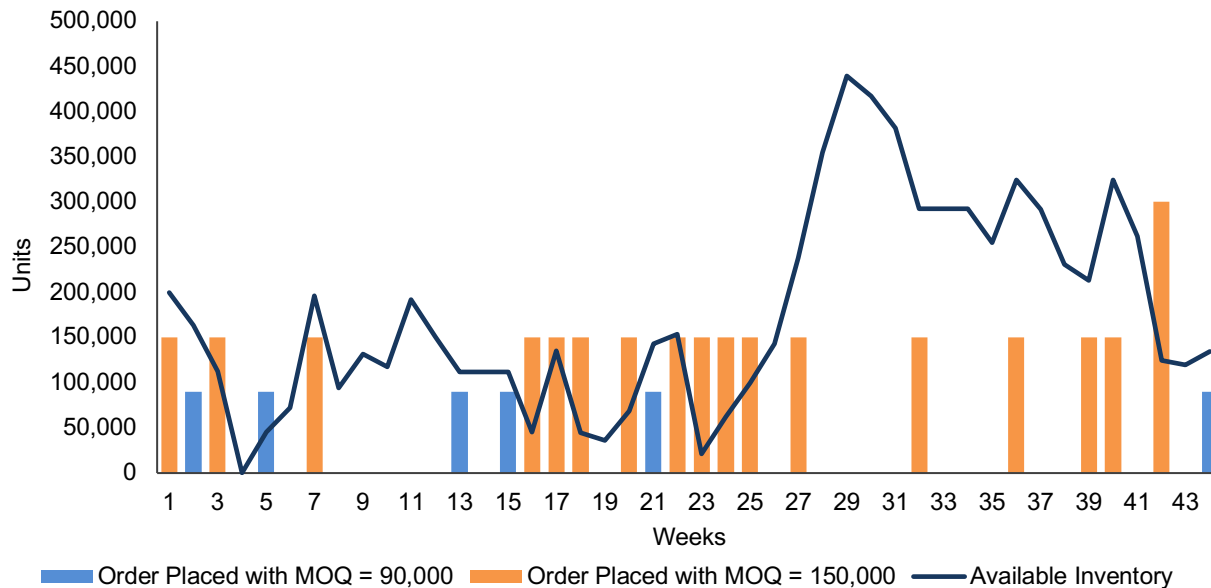

Figure 2. Switching rule for product

Table 1. Model simulation results

Switching Rule	Safety Stock	MOQ 1	MOQ 2	Stock-Out Events	Ordering Cost	Holding Cost	Total Cost
No Switching	52,540	100000	100000	0	$476,942	$4,051	$480,993
Switching Rule 1	52,540	80000	155000	0	$476,942	$4,223	$481,165
Switching Rule 2	52540	100000	190000	0	$476,942	$4,437	$481,379
Switching Rule 3	52540	50000	90000	0	$476,942	$3,862	$480,804
Switching Rule 4	52540	90000	150000	0	$476,942	$4,322	$481,264
Switching Rule 5	52540	53000	85000	0	$476,942	$3,876	$480,818

one large MOQ throughout can lead to overstocking and holding too much inventory at certain times of the year.

In the different experiments we conducted to obtain the best one, the switching rule determines when to switch to a lower or higher MOQ, and also the optimal values of the MOQs that achieve the target service level and are the lowest cost.

Switching Rule 1: Current demand forecast vs. average rolling forecast for the entire year

Switching Rule 2: Demand forecast for the upcoming 4th week vs. average rolling forecast for the entire year

Switching Rule 3: Current demand forecast vs. actual usage for the previous year

Switching Rule 4: Demand forecast for the upcoming 4th week vs. actual usage for the previous year

Switching Rule 5: Average demand forecast for the next 4 weeks vs. average rolling forecast for the entire year

Results

We iterated the model with differing values of MOQ and safety stock to obtain the values that give us the lowest cost and achieve the target service level of 99.3%. We obtained the ordering policies with one MOQ throughout the run, which became the basis for

the switching rule. In simulating the five switching rules, and comparing them against the base model without MOQ switching, we get the results as illustrated in Table 1.

Conclusion

This research project began with the goal of optimizing the raw material ordering policy for the company by incorporating switching rules to minimize the total costs and simultaneously avoid stock-outs. In analyzing the results obtained from the various model simulations and comparing the costs between the base model without MOQ switching and models with the different switching rule applied, we conclude that a switching rule is not always a lower cost option. This discrepancy could be due to the various biases introduced in the model from the forecasting error, or due to the high volatility of the demand. In addition, our sample size is very small, comprising only 3 SKUs of one product type, as against thousands of SKUs and products in the CPG company. The sponsoring company can nevertheless use this model to optimize their ordering policy, with or without switching, to obtain reduced cost. The model generated through this project can serve as a tool that defines the MOQ to be ordered automatically.