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Research Report: MISI-2015-9
The Optimal Inventory Policy for Perishable Products under Packaging Postponement
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THE OPTIMAL INVENTORY POLICY FOR PERISHABLE PRODUCTS UNDER PACKAGING POSTPONEMENT

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Summary:
Considering a multinational confectionary company's inventory problem where the company implements packaging postponement where the inventory is stored as bulk, this thesis enhances the decision making under uncertainty for calculating the optimal inventory level. Using the $[R, S]$ inventory policy and marginal analysis, a model is developed to calculate the optimal order up to level which ensures cost reduction and increase in profit.

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KEY INSIGHTS

1. The proposed model can be effectively used to determine the optimal inventory level of the bulk inventory, thereby reducing the cost of inventory and increasing profit.
2. The model is developed considering SKU's B&C; the model could be extended considering A SKU's.
3. Myopic policy is used to calculate the optimal inventory level. As the problem is dynamic, dynamic programming would be helpful in arriving at a more accurate value.

Introduction

Dealing with uncertainty has been an enduring problem for companies operating in various echelons of supply chain. Supply and demand uncertainty in the supply chain leads to difficulties in meeting supply with demand, which have two possibilities: excess (supply being more than demand) and shortage (supply being less than demand). Service-oriented supply chain contracts with penalties of shortage require companies to meet an agreed service level and keep safety stock to mitigate uncertainty. On the other hand, having excess inventory will incur high inventory cost and, in the case of perishable products, obsolescence cost. For perishable products with limited shelf life, meeting supply with demand should be done in the shortest possible lead time, thus keeping manufacturers from storing finished goods inventories for slow moving products. With high demand uncertainty, meeting service level requirements will require the company to keep high level of safety stock; which may lead to high obsolescence cost. In this thesis, we are exploring decision making under uncertainty using the company's inventory management problem as an example, with the goal of deciding the safety stock level to keep.

This project is motivated by a need to determine an optimal safety stock level for a newly built factory of a multinational confectionary company facing high demand uncertainty.

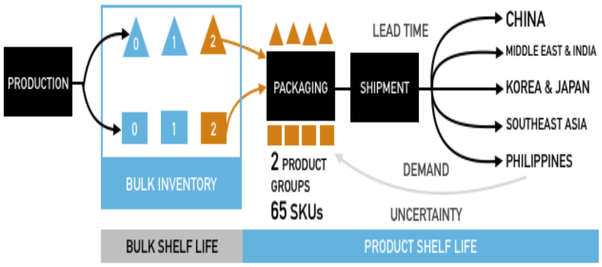

Figure 1: Business process illustration of Company X

Company X manufactures chocolates to be packed and shipped to distribution centers in a number of regions with differing cultures and languages. Such diversity raises the need for different labeling unique to each language region that in turn multiplies the number of SKUs the company produces. The market regions that the new plant will serve have highly stochastic demand, and forecast errors for these demands have been high. Distance to some of the distribution centers may require lengthy distribution lead time, while at the same time, the company's products are perishable goods subject to limited shelf life. Those constraints prompted the company to postpone product differentiation of slow-moving B and C-classified SKUs while storing perishable bulk inventory. An optimal safety stock level will minimize wastage while meeting service level, which will eventually minimize costs related to keeping perishable safety stock.

Literature Review

Product diversification is costly due to requirements of additional support activities and overhead resources. Increasing diversity and complexity lead to increase of demand for these overhead resources that will increase supply and costs if such resources are scalable. Some empirical studies show consistent evidence with this prediction, while other studies show otherwise. The trade-off between service level and safety stock can be depicted by an "exchange curve" between service and inventory turns [21]. With the same customer service level, increasing postponement is expected to reduce inventory and increase inventory turns [6].

The inventory problem of perishable product, known in the literature as newsvendor model, has a well-known trade-off between ordering too many or too few of the product. In food retail distribution, safety stock planning practices that involve demand seasonality and service level practices are strongly required for practical implementation. This issue is identified as one of the most important performance indicators in fresh food industries.

In general, inventory control of perishable products is a challenging issue, as shown by a study that presents empirical results on the ordering behavior of retail store managers in supermarkets. The inventory modeling literature shows predominant pursuit of total profit maximization or total cost minimization approach.

Addressing full postponement (holding inventory only in bulk) is simpler and more intuitive than hybrid postponement. Aviv & Federgruen [1] provided a comprehensive design for postponement and its benefits under different demand distributions and demand correlation between items and time. The base case of their work explains the modeling for our case of full postponement and derives the bulk demand from demand of FGs.

The shelf life part must be extended to address the 2-period shelf life of our product scope. Chung & Erhun [2] shows how to model inventory replenishment model for perishable products with two periods of shelf life, including the expected profit. Their work focuses on designing supply contracts for multi-echelon supply chain and does not include postponement, however they included a single-echelon inventory replenishment model and profit model as part of their base case.

Methodology

The periodic review base-stock policy, also known as $[R, S]$ inventory replenishment policy, is used as a basis for the model developed to calculate safety stock. The $[R, S]$ policy translates to "every R period, produce items up to S units", and the model calculates a maximum inventory level (order-up-to level) S given a service level. This $[R, S]$ model is then expanded to include postponement and shelf life constraints of the company's problem, and given the demand forecast data, the model is used to calculate the company's safety stock for the products in scope. The calculation of optimal safety stock requires a balance between the costs of holding too much inventory (cost of overage) and holding too little inventory (cost of underage). The balance between these competing costs results in a critical ratio, or the ratio between cost of underage and the total competing costs, that translates to the optimal service level for the problem.

The single-product base stock policy can be given as: at the beginning of each review period, produce or order items up to S. The expected changes in stock levels over time, given this inventory replenishment policy, can be illustrated as follows.

In our problem, demand is not stationary. However, it is safe to assume an increase in demand from the forecast data given since the company does not plan to fully capture the market yet in the first year of operation. In this case, a myopic policy can be assumed with a sensible level of suboptimality. Determination of the optimum value of S can be done through a marginal analysis, i.e. analyzing the marginal tradeoff between stocking too much or too little inventory. Increasing S by one unit will affect two margins, *marginal loss* and *marginal gain*.

We developed a single-product postponement model with base stock inventory replenishment policy with 2 production stages bulk and finished goods (FG) and inventory held only in bulk. Since bulk and finished goods have a one-to-many relationship, we can use the same model for multiple bulks. The model calculates aggregated demand of bulk and its standard deviation given finished goods demand.

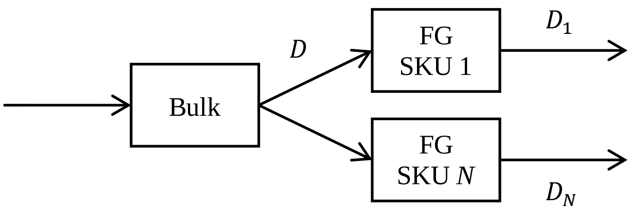

Figure 2: Single-product postponement model

The previous base-stock policy modeling assumes no perishability. In the case of no perishability, the expected loss and expected gain follows the base-stock policy model. In reality, though, the bulk inventory is perishable with 2-period shelf life (given $R = 1$ month). Therefore, the inventory can be categorized into two: new bulk inventory (aged 0-1 month) and old bulk inventory (aged 1-2 months). The carry-over inventory CO will expire at the end of the period, forcing the company to salvage the expired goods for less value. **Figure 3** depicts the perishability problem as a diagram.

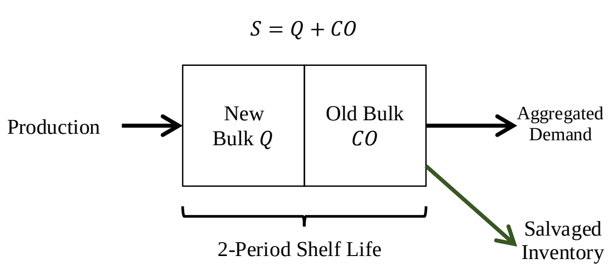

Figure 3: Inventory replenishment model with 2-period shelf life

Results

Using the heuristics, we can approximate close-to-optimal order-up-to level with 2-period perishability considered. However, we only consider expected values; the actual carry-over inventory might be higher or lower than the value. Therefore, we performed a sensitivity analysis with regard to carried-over inventory level to see the impact of old inventory level to order-up-to level. **Figure 4** shows the sensitivity analysis of carry-over inventory at the beginning of every period:

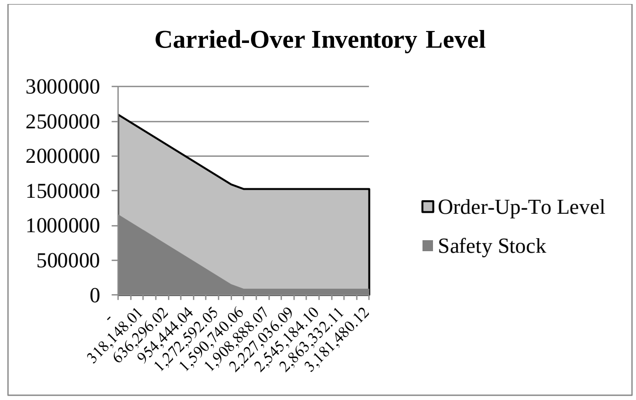

Figure 4: Carried-over inventory level versus optimal order-up-to level

The results of sensitivity analysis show positive or negative correlations between the safety stock level and different parameters of business factors, as shown by **Figure 5**:

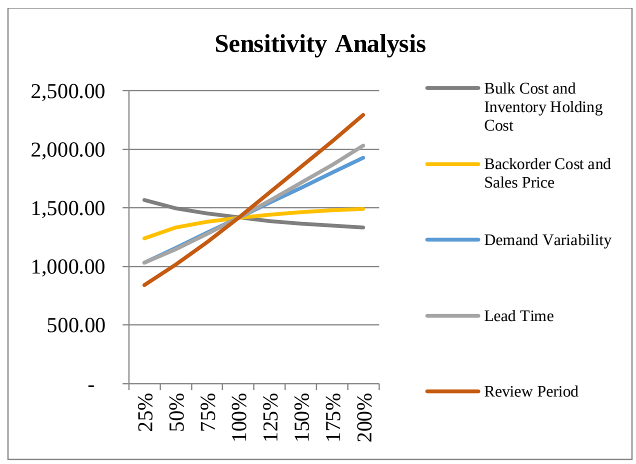

Figure 5: Sensitivity of the optimal inventory level to business parameters

Conclusions

This work provides an example of decision making under uncertainty in inventory management, using a case of a company that is setting up a new plant in its global supply chain network. It shows how principles of inventory management can be implemented to solve the company's problem in the case. Additionally, this work provides an extra wealth of knowledge on research in the implementation of traditional full postponement and inventory management of perishable goods. Especially for the inventory control for perishable products, we developed an efficient heuristic method to find a near-optimal order-up-to level considering the current inventory level of perishable items. This research may also lead to future research both to solve the company's problem more comprehensively and to contribute more to the literature on postponement for perishable products.

Based on the results of analyses in **Part 4.5**, there are two key managerial insights that can be derived from this thesis. First, changes in cost and price factors will affect the optimum service level, which in turn affects the optimum order-up-to level and safety stock. If a different service level has to be chosen, since the cost of underage is usually (much) larger than the cost of overage, it is usually better to use a higher value. The exception is when the cost of overage is larger than the cost of underage, where it is better to use a lower value.

Second, it is possible to reduce inventory and safety stock levels while maintaining a certain service level by reducing the business parameters that are not affecting the service level. These parameters are demand variability, lead time, and review period. Reduction in these parameters will lead to reduction of inventory levels. Reduction of demand variability can be achieved by either increasing forecast accuracy (reducing forecast errors) or implementing postponement, where production is postponed before the explosion of product variability. Reduction of lead time means speeding up the production process, while reduction of review period translates to increase of production frequency.

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