Inventory Optimization in a Retail Multi-Echelon Environment

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Summary: This project developed an inventory model to find the optimal inventory distribution in a retail three-echelon network that enables high target service level at the stores. Using a multi-echelon approach, the optimal network inventory cost can be achieved by low inventory and service level at the intermediate echelon. The study shows the interrelations between echelons that should be considered when developing each echelon’s inventory policy.

KEY INSIGHTS

1. A multi-echelon approach can offer optimal inventory distribution, in which the network inventory cost is lower than that of a single-echelon approach.

2. The optimal network inventory cost can be achieved by low inventory and service level at the intermediate echelon.

3. There exist interrelations between echelons in the network that should be considered when developing an echelon’s inventory policy to achieve optimal cost and protect against network service failure.

Introduction

Today’s retail market is highly competitive. Having out-of-stock at the retail stores can lead to lost sales or customers. Therefore, it is a retailer’s focus to maintain high product availability on the shelf. Thus high target service level is always set as a retailer’s performance objective. However, focusing only on the service level can confine the drive for operation efficiency, resulting in high inventory carrying cost. As such it is important to effectively allocate inventory in the network to obtain the optimal network inventory carrying cost, while still allowing high target service level to be achieved at the retail stores.

The focus of this study is to find the optimal inventory distribution in a retail multi-echelon network that offers the lowest network carrying cost while still enabling the retailer to achieve a high target service level. A multi-echelon approach is used due to its benefits over a single-echelon approach. In a single-echelon approach, each echelon sets its own inventory policies, regardless of those of the others. Once the lower echelons determine their policies, the result of their policies are combined and passed up to the upper echelon to be used as input demand to develop its own policy using its performance objective. In a multi-echelon approach, the echelons’ inventory policies are determined simultaneously with a single performance objective by considering the
interrelation between the echelons. Using a single-echelon approach in a multi-echelon situation can lead to three serious flaws. First, infinite supply, which is difficult to achieve in reality, from the upper echelons is assumed in a single echelon approach. Second, a single-echelon approach ignores the cost implications of one echelon’s policy on the other echelons. Third, the approach fails to reduce the bullwhip effect, leading to high inventory in the network. Using a multi-echelon approach, these flaws can be eliminated.

Industry Case

The study is based on a case study of RetailCo, a leading pharmacy and convenience store chain in the US, and SupplierCo, a big manufacturer of private-label products. Three echelons are included in the scope: SupplierCo’s warehouse, RetailCo’s distribution center (DC), and one hundreds RetailCo’s stores. The DC and stores are currently using a periodic, order-up-to-level (OUTL) inventory policy, in which review periods are agreed upon between the involved parties, while the OUTLs are determined by an echelon’s own inventory system based on its performance objectives and criteria. The supplier uses a daily review, OUTL inventory policy, in which a single OUTL is agreed upon by SupplierCo and RetailCo and is applied to all SKUs. Different target service levels are set for each echelon. In this study, store’s target service level is determined by the number of days without an out-of-stock, while the service level of the DC and the supplier are determined by ability to fulfill demand.

Inventory Model

The echelons’ inventory policies are replicated in the inventory model. Minimizing network inventory carrying cost is set as the objective function; store target service level and minimum OUTLs, determined by the shelf-facing quantities, are set as constraints; and the echelons’ OUTLs are set as decision variables. A heuristic approach combining a simulation and an optimization is used to find the optimal combination of the echelons’ OUTLs.

Results and Analysis

The result shows that we can achieve the optimal carrying cost by having low inventory and service level at the DC, while inventory and service levels at the supplier and the stores vary, depending on many factors such as production lead time and minimum OUTLs set at the stores (Refer to Figure 1 and Table 1 below). The comparison between the optimal and current inventory policies shows the benefit of a multi-echelon over a single-echelon approach currently used in the network by offering 53% lower inventory carrying cost. Highest savings of 67% shown at the supplier highlights the drawback of applying a single inventory policy to all SKUs with different demand characteristics (i.e. high and low demand).

![Optimal Inventory Distribution For SKUs With Different Sales Unit Volume](image)

**Figure 1 : The Network Optimal Inventory Distribution**

<table>
<thead>
<tr>
<th>SKU</th>
<th>Supplier</th>
<th>DC</th>
<th>Stores</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Sales Volume</td>
<td>100.0%</td>
<td>97.0%</td>
<td>98.8%</td>
</tr>
<tr>
<td>Medium Sales Volume</td>
<td>99.0%</td>
<td>86.8%</td>
<td>99.0%</td>
</tr>
<tr>
<td>Low Sales Volume</td>
<td>91.2%</td>
<td>75.6%</td>
<td>99.1%</td>
</tr>
</tbody>
</table>

**Table 1 : The Network Optimal Service Level**

The sensitivity analyses conducted in this study show the interrelations between echelons by estimating the impact of the echelon’s deviation from the optimal inventory policy, the echelon’s performance objective, and the echelon’s service disruption on the other echelons. Three main conclusions are obtained.

The first study was conducted to estimate the impact of DC’s deviation from the optimal OUTL on the other echelons. Results of the DC’s deviation from the optimal inventory policy are shown in Figure 2. Results reveal that reducing the DC’s OUTL, though saving inventory carrying cost, can compromise the network service level. Moving below optimal OUTL, service levels at the stores cannot meet target service level constraint. On the other hand, increasing OUTL does not always improve the lower echelon’s service level. At an OUTL above 110 units,
the increase in OUTL only increases DC’s service level, while store’s service level remains constant. In addition, the study also shows that deviation from the optimal OUTL has more impact on the lower echelons. Supplier’s deviations results in a similar trend.

Second, the target service level set as constraint at the stores influences inventory distribution and other echelons’ service level in the network, especially at the downstream echelon. With higher target service level, the stores and the DC need to maintain much higher inventory level and the DC needs to significantly increase its service level from 85% at store target service level of 95% to 92% at store target service level of 99.5%. High inventory at the downstream echelon allows the supplier to relax its service level. The supplier’s service level drops from 99% when store target service level is at 97.5% to 98% when store target service level is at 98.5%. The impact of the changes in store target service level on the echelons’ optimal inventory policies is shown in Figure 3.

Third, analysis shows that supplier’s service disruption resulted from quality failure at the production ending stage marginally reduces its service level but significantly reduces the service levels of the DC and the stores. From Figure 4, only 1% probability of service disruption can result in service levels at the stores dropping below target service level. Considering the substantial impact from the supplier’s service disruption, additional inventory on top of the suggested optimal inventory policies may be needed in the network to protect against the possibility of network service failure.
Conclusion

A heuristic multi-echelon approach is used to find the optimal inventory distribution in the network. The study shows the benefit of a multi-echelon over a single-echelon approach by offering lower network inventory carrying cost. To achieve multi-echelon optimal inventory carrying cost, we need collaboration between the echelons to set up inventory policies, integration of demand and inventory information to offer demand visibility, and sophisticated optimization tool to find the optimal inventory policies for the network. The study shows that in a multi-echelon approach, optimal carrying cost can be achieved by having low inventory and service level at the DC and there are interrelations between the echelons’ inventory policies and performances that should be considered when setting up an echelon’s inventory policy to achieve optimal network carrying cost.