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Research on the Multi-Level Inventory Optimization of Automotive Parts Supply Chain Systems

Jie Yao and Wenwen Guo
School of Economy and Management, Northeast Dianli University, Jilin 132012, China

Abstract: Because of the fierce competition in the automobile market, the automobile companies not only need to reduce their own cost, but also need to reduce the cost in the supply chain. Through the analysis of the characteristics of automobile enterprises in the supply chain, this study established a mathematical model of multi-level inventory optimization to demonstrate that multi-level inventory optimization can minimize the inventory in the environment of supply chain.

Keywords: Inventory optimization, multi-level inventory, supply chain

INTRODUCTION

The supply chain management is a kind of integrated management thinking and method. It performs the logistics planning and controlling functions from raw material suppliers to the end-user. Among these, the supply chain management thinking has great effect on the inventory management. Compared with the inventory management in the supply chain environment, traditional inventory management is that each enterprise manages its own inventory independently in order to reduce the inventory stock and reduce the inventory cost for the purpose of maximizing the enterprise's self-interests. From the view of single-level inventory, this method has a certain kind of applicability, but from the view of entire supply chain, it also has some limitations. The inventory management in the environment of supply chain will not only consider about the enterprise's development, but also consider about the coordination and cooperation among each link in the supply chain. At the same time, it will also consider about the competition with the other supply chains. Now, more modern enterprises are still under the supply chain management. Therefore, the enterprises' inventory model should not be confined to the traditional inventory model, but should consider more about the multi-level inventory management in the supply chain, so as to reduce the inventory cost in the supply chain to realize the win-win between enterprises. Ma (2005) has a research of the supply chain management. Sun (2011) analyse the supply chain inventory optimization of weaponry industry. Zhang (2009) have a research of the management mechanism of multi-level inventory under the circumstance of automobile enterprises' supply chain.

Through the analysis of the auto parts' inventory operating condition in the supply chain by introducing multi-level inventory optimization model; this study has realized the cost optimization of multi-level inventory in the environment of supply chain.

THE SUPPLY CHAIN INVENTORY CONTROL

The highest goal of the inventory control in the environment of supply chain is to reduce the unnecessary inventory and realize the optimization of inventory control and management with no cost increasing and no affect on the production progress. The optimization and control of multi-level inventory is a kind of inventory management mode that optimizes the supply chain resources globally which has developed from single-stage inventory control. The old inventory mode adopts the single-level inventory policy. It determines the inventory at the current node only based on the inventory data at a single inventory point, but not considers about the inventory at the downstream nodes. This situation will cause the demand to be amplified which finally leads to the inventory of the whole supply chain to be expanded and cannot get the optimal result. If we want to control the supply chain globally and optimally, it is necessary to use multi-level inventory optimization and control.

There are two kinds of methods to make multi-level inventory optimization and control. One is non-centralized control tactic and the other is centralized control tactic.The non-centralized control tactic is that each inventory point takes their inventory tactic independently. Every node need to share their information. In practice, the majority of the results are suboptimal. The centralized control strategy is to put the control center on the core enterprises and the core

Corresponding Author Jie Yao, School of Economy and Management, Northeast Dianli University, Jilin 132012, China

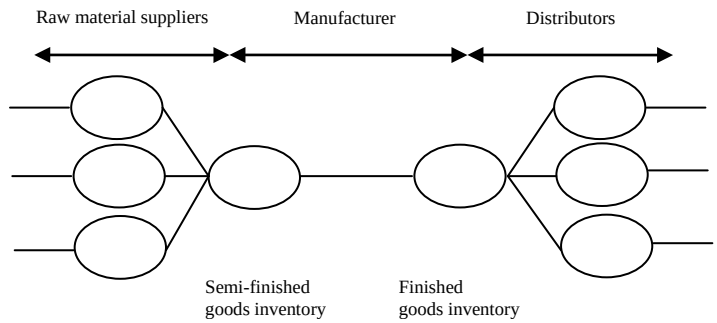

Fig. 1: Inventory mode of multi-level supply chain

enterprises will control the inventory of the supply chain and be responsible for the coordination of the inventory activities among the nodes. All of the control parameters of the inventory activities are all decided at the same time. The core enterprise will consider about the relationship and communications between different nodes and is responsible for the inventory optimization so as to get the minimum cost in the multi-level inventory system.

ESTABLISHMENT OF MULTI-LEVEL INVENTORY CONTROL SYSTEM IN THE SUPPLY CHAIN OF AUTOMOBILE PARTS

Analysis on the characteristics of the automobile parts supply chain mode: The automotive parts supply chain mode has the following key features.

First, the automobile manufacture enterprise is the core of the supply chain. As the core enterprise in the supply chain, the automobile manufacture enterprise is responsible for the integration and exchange of information. It will not only pull the supply of raw material from the upstream suppliers, but also push the products distribution of downstream distributors.

Second, the automotive supply chain system requires high level collaboration in the whole supply chain. Since there exists close relationship among different nodes in the supply chain, the close collaboration of them will shorten the cycle, decrease the cost and improve the promptness of the supply chain.

The multi-level inventory control system in the supply chain environment of automobile parts: In theory, the level of supply chain can be infinite. From product users to raw material suppliers, the whole supply chain is a kind of network chain mode with n levels in the supply chain. It can be divided into the first-level raw material suppliers, the second-level raw material suppliers, the third-level raw material suppliers and then the core enterprises. And the distributors can also be divided into the first-level distributors, the second-level distributors and so on and finally to the user. In reality, however, the levels in the supply chain are not the more the better, but the less the better. Therefore, the actual levels in the supply chain are not very long. The main application is the typical three levels mode that is supply-production-distribution. It is also the downstream part of supply chain. The inventory model of multi-level supply chain with manufacturers as the core enterpries is shown in Fig. 1.

This supply chain is a kind of network chain structure which is from raw material supplier to the core enterprises (manufacturers) and then to the distributors. However, from the point of view of the whole supply chain, it is likely to form repeated inventory at each node in the supply chain. The suppliers of raw materials will prepare enough raw materials and inventory of finished goods in order to guarantee the supply of them in time. Manufacturers will prepare enough raw materials and inventory of finished goods in order to ensure the supply of finished product timely. And Distributors will also prepare enough inventories of finished goods in order to ensure the supply of finished products in time. However, it will lead to duplicated inventory. Because the unauthenticated of the demand information will develop along the supply chain, that will lead to the repetitive inventories at different nodes. Therefore, the demand is amplified so that it will cause the increase of the supply chain cost.

THE CONSTRUCTION OF MULTI-LEVEL INVENTORY OPTIMIZATION MODE UNDER THE SUPPLY CHAIN OF AUTOMOBILE PARTS

According to the characteristics of the auto parts industry, we choose the centralized inventory control tactic to establish the inventory management system model, as shown in Fig. 2.

The demand of each retailer is independent which is represented by D_{it}. According to the changes of the demand, the retailers can make their own order quantity which is represented by Q_{it}. The order of each retailer will be totalized and submitted to the distribution center to produce the total order which is then sent to the manufacturers. The manufactures will make the production plan according to the demand order and at the same time it will also lead to the demand of

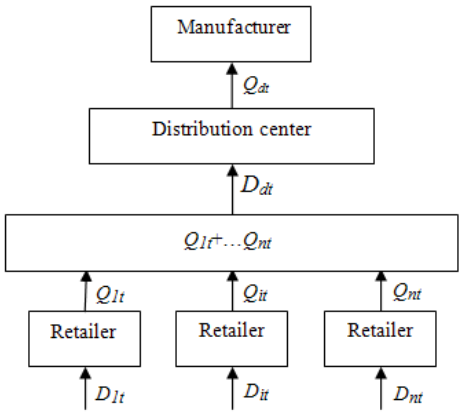

Fig. 2: Supply chain model under three-level inventory control

suppliers' raw material at the up-stream of supply chain. In the whole supply chain, there are three places to keep the inventory; they are the retailer, the distributor and the manufacture.

Model hypothesis and description of symbol: Here we assume that the demand of each retailer is independent and they sell the same product. We also assume the shortage costs can be measured when the product is out of stock. When the product is out of stock, the inventory quantity is 0.
The meanings of each symbol are as follows:

C_n : Storage costs (costs of per unit goods that occur in unit of time)
C_t : Transaction costs (total cost needed in one transaction activity, assume each transaction cost is the same in the supply chain)
C_s : Shortage costs (economic loss to the demand side when in short supply. Assume it is the same in the supply chain)
Y : Original inventory quantity
M : Each retailer's demand for products in unit time
N : The number of retailers
T : Order cycle
A : Average inventory (It is equal to half of the order)
B : Average shortage quantity
y^* : The optimal inventory
t^* : The optimal order cycle
Q^* : The optimal order quantity

Among them, the product demand in unit time is mn. After the time of y/(mn), the number of inventory is 0.

Establishment of the model and case analysis: This model is a three-level inventory control model. Set up a control model as follows.

Minimize C_{total} = min $\{C_1+C_2+C_3\}$ (C_1 is the storage cost of manufacturer, C_2 is the storage cost of distributor, C_3 is the storage cost of retailer).

The inventory control parameters are determined as follows:

Average inventory A: $\frac{1}{2}\frac{y^2}{n\cdot m}$

Average shortage quantity B: $\frac{1}{2}(n\cdot m\cdot t-y)(t-\frac{y}{n\cdot m})$

So we can get the average total cost function per unit time:

$$C(t,y)=\frac{1}{t}\left[\frac{1}{2}\frac{C_n\cdot y^2}{n\cdot m}+\frac{1}{2}\frac{C_s(n\cdot m\cdot t-y)^2}{n\cdot m}+C_t\right] \quad (1)$$

Differential the formula, we have the optimal order cycle time:

$$t^*=\sqrt{\frac{2C_t(C_s+C_n)}{n\cdot m\cdot C_s\cdot C_n}} \quad (2)$$

The optimal inventory:

$$y^*=\sqrt{\frac{2n\cdot m\cdot C_s\cdot C_t}{C_n\cdot(C_s+C_n)}} \quad (3)$$

The optimal order quantity:

$$Q^*=\sqrt{\frac{24C_t\cdot n\cdot m\cdot(C_n+C_s)}{C_n\cdot C_s}} \quad (4)$$

In this model, we have established the target function of inventory and determined the control parameters of inventory point. And this model can help us optimizing inventory on the basis of reducing the total inventory cost. It has avoided the repeated inventory of each node and accelerated the capital turnover rate.

CASE ANALYSIS

Automobile parts Company M produces part which is finally provided to Company S and Company T. The daily sales of these two companies are 50 units. The inventory storage cost of each product is 2 RMB yuan one day. The shortage cost of the product is 20 RMB yuan per unit. Each transaction will cost 2000 RMB yuan totally. Therefore, the order cycle time of Company M can be determined to be 4.7 days, the initial inventory can be determined to be 426 units and the shortage quantity per unit time can be determined to be 9.36 units.

CONCLUSION

Through the establishment of multi-level inventory optimization model under the circumstance of supply

chain, we can get the optimization result. It proves that this method can help us with solving the inventory problem which is caused by the amplification of demand information and achieving inventory optimization of the whole supply chain so that the capital turnover rate can be accelerated and the competitiveness of enterprises can be improved.

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