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Optimization Design of the Multi-stage Inventory Management for Supply Chain

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Abstract

Aiming at the problem of multi echelon inventory management logistics network based on the concept, the automobile spare parts warehousing logistics as the breakthrough point, the supply chain inventory total profit as the objective function, the automobile spare parts supply chain inventory model is optimized, the multi echelon inventory management strategy, the strategy makes the enterprise inventory cost is reduced, the production efficiency is increased.

Keywords: *supply chain, inventory management, hierarchical design optimization, management strategy*

1. Introduction

The current globalization of economy and internationalization of market make the competitions among production enterprises turn to the supply chain [1]. Supply chain refers to the logistics network system from the purchase of raw materials to sales of the final product, contacting with suppliers, manufacturers, distributors, retailers and other related industries, containing the processes of processing, assembly, distribution of products, etc. In the whole link, process, processing, sales, each enterprise chain needs sufficient inventory to maintain the enterprise's production and operating activities within supply, and the inventory's operation and management will increase the production cost of enterprises [2, 3]. Therefore, to determine the optimal ordering strategy and reduce the supply chain inventory and achieve the purpose of maximizing profits is an important part of enterprise management decisions, helpful to the enterprise's market competitiveness.

At present, supply chain management has become the key research content at home and abroad [4-7]. Especially the progress and development of China's automobile industry provide the material guarantee for the research of supply chain. In 2014, total market demand will be more than 20 million cars in our country. Faced with such a huge automobile market, it will necessarily bring a huge auto spare parts market. According to statistics, auto market value after sale in China in 2011 is about 400 billion RMB, and will reach 700 billion RMB expected in 2015. Obviously the automobile spare parts inventory in the supply chain plays a very important role. Automobile after-sale spare parts supply chain, from suppliers, manufacturers, distributors to retailers, each link has inventory, thus a chain of inventory is formed, inventory chain of each node in the inventory not only affects the cost of a node enterprises, but also restricts between upstream and downstream enterprises, and even the comprehensive cost, the overall performance and competitive advantage of the entire supply chain. In each circulation, setting auto spare parts inventory can satisfy the uncertainty of customer demands [8]. The link in the supply chain inventory management involves multiple products and the rate

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of order [9], in addition, also involves the relationship between the upstream and downstream enterprises, namely the multistage stock management [10].

If the control of the spare parts inventory is not reasonable, which will result in a great increase in the automobile spare parts supply chain inventory and make the whole supply chain total inventory cost increase by 20% ~ 40%. This paper is for supply chain inventory problem then systematically to analyze and design, expecting to get the best inventory optimization, reduce the inventory cost, improve market competitiveness.

2. Auto Spare Parts Logistics Mode and the Analysis of Inventory Management

The automobile supply chain system is mainly composed of raw materials, spare parts supply chain, the whole car manufacturers, distributors, service station, the third party logistics enterprise and automobile users [11]. Spare parts logistics as the body of the after-sales service market, with the decline of profit in new car sales and gradually become an important source of corporate profits [12]. With the continuous development and improvement of auto spare parts market, the constitution of automobile spare parts supply chain presents the trend of network and complication [13]. For now, automobile spare parts supply chain can be divided into three components, auto spare parts manufacturing enterprise, automobile spare parts distribution enterprise, spare parts service station.

Our country's automobile spare parts logistics mode mainly includes the following:

First, the vehicle manufacturing enterprises provide the products to customers through the repair station and 4S shops [14].

Second, the vehicle manufacturing enterprises provide parts of the product to the customer, the other parts to small repairing and spare parts dealers through the automobile trade company.

Third, manufacturing enterprises provide the products to regional distributors, the latter distributes them to the downstream distributors and customers.

Fourth, spare parts manufacturing enterprises have their self-management model, some parts manufacturers are also directly involved in auto spare parts market, and set up their own logistics system to run.

Considering the reasons, auto spare parts logistics multistage stock inventory of our country can be classified according to the specific way of logistics in China.

2.1 Problems Existing in the Spare Parts Inventory

According to the survey: A Harbin automobile spare parts wholesaler owning more than 6000 different kinds of spare parts inventory is named as *A* company, who purchases directly from components manufacturing company in Hangzhou, and then distributed to various spare parts dealers. As a result of so many types of auto spare parts, such as the uncertainty of customer demand, customer demand for service quality, bringing much difficulty in automotive spare parts inventory management.

The existing problems by investigating are as follows:

The capital and safety stock of spare parts take an important role, *A* company usually make a purchase from the supplier in 15 days, and automobile spare parts procurement will be served in 8 days, but the safety stock can be stored for a month, which takes up a lot of inventory cost and a large number of depreciation cost virtually.

The occupancy rate for the warehouse is high, *A* company warehouse occupancy rate is as high as 80%, while maintaining high stock levels can reduce the loss caused by out of stock, also brings a bit of difficulty in the inventory check and count, which is not conducive to the management.

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Obviously the classification management of *A* company is not reasonable and scientific for its automobile spare parts. For example: *A* spare parts company, in the spare parts purchasing and storage is determined by the market experience with its all kinds of spare parts purchasing in bulk, although it is based on the practical experience as a very good reference value, but not a system of classified management methods to help improve the management benefit of the enterprise and reduce the inventory cost. What's more, *A* company supply chain has the lack of co-ordination in spare parts inventory. For example: *A* company simply pays attention to the benefit between company and its customers, therefore information with each other is not transparent in many aspects, which causes great influence in projection and judgment for *A* company, who can only rely on its experience to predict customer demand, thus increasing its inventory.

2.2 Auto Spare Parts Company ABC Inventory Classification Management

ABC classification, also called primary and secondary factors analysis, is according to the aspect in the main characteristics of the economic or technology to classify queue, distinguish the key and general, and make a difference in the management way of a analysis method [15].

Making an implementation of ABC taxonomy according to *A* company's inventory management problem, on the bases of reasonable classification, working out a corresponding inventory control strategy according to different automobile spare parts. There was a classification research drawn from *A* company's dozens of spare parts in its warehouse and got some spare parts sales within a month based on a field survey of *A* company, the specific data are shown in Table 1.

Table 1. Parts of the Spare Parts Sales of *A* Company

NO.	NAME	unit	Unit price(yuan)	Quantity	time
1	ignition coil	PCS	428	760	1month
2	S-M oil	barrel	285	660	1month
3	Air filter element-B12	PCS	59	2200	1month
4	Timing belt	PCS	243	442	1month
5	Gasoline filter element	PCS	72	1150	1month
6	Rivet	PCS	15	4678	1month
7	Former brake block	PCS	316	175	1month
8	Tire	PCS	520	58	1month
9	Starter	PCS	900	32	1month
10	generator	PCS	800	33	1month
11	tooth-shaped belt	PCS	145	167	1month
12	Astern mirror	PCS	140	150	1month
13	Gear oil	barrel	129	160	1month
14	High braking lamp	PCS	115	150	1month
15	Tail light	PCS	110	140	1month
16	antifreeze	barrel	85	212	1month
17	Brake pedal	PCS	76	220	1month
18	Brake disc	PCS	410	24	1month
19	Fuel tub	PCS	180	48	1month
20	Back oil seal of Crankshaft	PCS	89	98	1month
21	Rear shock Absorb	PCS	150	50	1month
22	Fore-balance ball head	PCS	65	80	1month
23	steering linkage	PCS	160	32	1month
24	Combination	PCS	135	30	1month

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25	switch thermostat	PCS	30	120	1month
26	Water temperature plug	PCS	35	90	1month
27	Front hub	PCS	100	30	1month
28	fuse	PCS	2	1408	1month
29	Mud skin	PCS	50	50	1month
30	Back braking pad-B12	PCS	70	35	1month
31	Front braking pad-B12	PCS	55	40	1month
32	Spark plug-B12	PCS	25	80	1month
33	Tyre nut-B12	PCS	8	220	1month
34	License plate	PCS	30	58	1month
35	Horn	PCS	40	30	1month
36	Input axis oil seal	PCS	22	50	1month
37	Front fog-light switch	PCS	36	25	1month
38	Front brake hose	PCS	16	50	1month
39	Dynamic steering belt	PCS	25	20	1month
40	Fuel cap	PCS	15	15	1month

To take the ABC classification extraction in 40 kinds spare parts from A company's spare parts list, these spare parts sell for 1256474 RMB in a month, to classify each spare parts month sales as a standard, spare parts sales accounted for 75% of the total amount is divided into class *A*, 20% of the total is divided into class *B*, 5% of the total is divided into class *C*. After ABC classification division, there are 6 kinds of class *A* spare parts, 12 kinds of class *B* spare parts, 22 kinds of class *C* spare parts in the 40 kinds of spare parts. The spare parts classification situations are shown in Table 2.

Table 2. ABC Classification in the Spare Parts of *A* Company

no.	name	Unit price	quantity	sales	Sales totally	Cumulative percentage of sales	The classification results
1	ignition coil	428	760	325280	325280	25.9%	A
2	S-M oil	285	660	188100	513380	40.9%	A
3	Air filter element-B12	59	2200	129800	643180	51.2%	A
4	Timing belt	243	442	107406	750586	59.7%	A
5	Gasoline filter element	72	1150	82800	833386	66.3%	A
6	Rivet	15	4678	70170	903556	71.9%	A
7	Former brake block	316	175	55300	958856	76.3%	B
8	Tire	520	58	30160	989016	78.7%	B
9	Starter	900	32	28800	1017816	81.0%	B
10	generator	800	33	26400	1044216	83.1%	B
11	tooth-shaped belt	145	167	24215	1068431	85.0%	B
12	Astern mirror	140	150	21000	1089431	86.7%	B
13	Gear oil	129	160	20640	1110071	88.3%	B
14	High braking lamp	115	150	17250	1127321	89.7%	B
15	Tail light	110	140	15400	1142721	90.9%	B
16	antifreeze	85	212	18020	1160741	92.4%	B
17	Brake pedal	76	220	16720	1177461	93.7%	B

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18	Brake disc	410	24	9840	1187301	94.5%	B
19	Fuel tub	180	48	8640	1195941	95.2%	C
20	Back oil seal of Crankshaft	89	98	8722	1204663	95.9%	C
21	Rear shock Absorb	150	50	7500	1212163	96.5%	C
22	Fore-balance ball head	65	80	5200	1217363	96.9%	C
23	steering linkage	160	32	5120	1222483	97.3%	C
24	Combination switch	135	30	4050	1226533	97.6%	C
25	thermostat	30	120	3600	1230133	97.9%	C
26	Water temperature plug	35	90	3150	1233283	98.2%	C
27	Front hub	100	30	3000	1236283	98.4%	C
28	fuse	2	1408	2816	1239099	98.6%	C
29	Mud skin	50	50	2500	1241599	98.8%	C
30	Back braking pad-B12	70	35	2450	1244049	99.0%	C
31	Front braking pad-B12	55	40	2200	1246249	99.2%	C
32	Spark plug-B12	25	80	2000	1248249	99.3%	C
33	Tyre nut-B12	8	220	1760	1250009	99.5%	C
34	License plate	30	58	1740	1251749	99.6%	C
35	Horn	40	30	1200	1252949	99.7%	C
36	Input axis oil seal	22	50	1100	1254049	99.8%	C
37	Front fog-light switch	36	25	900	1254949	99.9%	C
38	Front brake hose	16	50	800	1255749	99.9%	C
39	Dynamic steering belt	25	20	500	1256249	100.0%	C
40	Fuel cap	15	15	225	1256474	100.0%	C

After the classification of spare parts, *A* company can take different inventory control strategies, in order to save inventory costs, reduce inventory and improve the market competitiveness in the situation of meeting demand of the customers. According to different categories of spare parts, inventory control strategies taken are shown in Table 3.

Table 3. Three Types of Inventory Control Strategy and Method

Project/level	A class of inventory	B class of inventory	C class of inventory
The degree of control	Strict	General	Simple
Inventory calculation	Calculation in detail based on the inventory model	General	Simple
The record of In- out	Record in detail	Record generally	Record simply
Inventory check frequency	Intensive	General	Lower
Safety stock	General	Bigger	Bigger

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3. Automobile Spare Parts Multilevel Inventory System Model Analysis

Obviously, involving *A* company spare parts inventory chain system including components manufacturing enterprises, automobile spare parts wholesale, auto spare parts dealers three levels, automobile spare parts wholesaler and auto spare parts dealers order lead time and customer demand is auto spare parts dealers are random variables. Through the system constraints determine (order quantity of inventory system at all levels, the maximum inventory, order quantity, *etc*.), Building mathematical model of multi-level inventory systems and multistage inventory system for system simulation, obtain the optimal solution of multi-stage inventory system model through optimization algorithm.

In determining the auto spare parts dealers, auto spare parts wholesaler inventory node ordering strategy, including at all levels the inventory cycle inventory node, reorder point and order quantity and other constraints, to solve the multi-stage inventory system optimization goal. The multi-stage supply chain inventory optimization can be divided into cost optimization and time optimization, *etc.*, base on the total supply chain profit maximum as auto spare parts multistage inventory optimization goal.

(1)Inventory maintenance cost of automobile spare parts wholesaler

As long as the car spare parts wholesaler *j* has products, namely $U_j(t) \geqslant 0$, inventory maintenance cost will be produced. The inventory maintenance cost of auto parts wholesaler *j* in the planning period is denoted as:

$$H_j = \mathrm{h}_j \cdot \int_0^T U_{j1}(t)dt = h_j \int_0^T Max(U_j(t),0)dt \quad (1)$$

(2) Shortage cost of automobile spare parts wholesaler

When the automobile spare parts wholesaler cannot meet the needs of downstream of auto spare parts dealers, namely $U_j(t) \geqslant 0$, generated shortage cost will be produced, so the shortage cost of the automotive spare parts wholesaler j in the planning period is denoted as:

$$B_j = b_j \cdot \int_0^T U_{j2}(t)dt = b_j \int_0^T Max(-U_j(t),0)dt \quad (2)$$

(3) The ordering cost of automobile spare parts wholesaler

Each time the automobile spare parts wholesaler *j* places an order with upstream manufacturers of auto parts, the corresponding ordering cost will be produced, ordering cost constituted by two elements, including fixed ordering cost G_{1j} and variable ordering cost G_{2j}, so the total ordering costs of the automotive spare parts wholesaler *j* in the planning period is denoted as:

$$D_\mathrm{j} = k_j \cdot (G_{1j} + G_{2j} \cdot R_j) \quad (3)$$

Inventory costs, holding cost, ordering cost and shortage cost of automobile spare parts dealers *i* and automobile spare parts wholesaler *j* have the same composition. $U_i(t)$ is the theoretical inventory of automobile spare parts dealer *i* for the moment *t*, decrease with the downstream customer orders. When The automobile spare parts dealer *i* places an order with its upstream automobile pares parts wholesaler, when the inventory level drops to the reorder point R_i . For $U_{i1}(t)$ is the actual inventory of auto spare parts dealers for time *t* , $U_{i1}(t)=Max(U_i(t),0)$; $U_{i2}(t)$ is the actual inventory of auto spare parts dealers for time *t* , $U_{i2}(t)=Max(-U_i(t),0)$; Automobile spare parts dealer *i* also take (T_i,R_i,Q_i) inventory control strategy, namely (T_i,R_i,Q_i) strategy. Similar with the automobile spare parts wholesaler, inventory cost of automobile spare parts dealer are as follows:

(1) Inventory maintenance cost of automobile spare parts dealers *i* as follows:

$$H_\mathrm{i} = \mathrm{h}_i \cdot \int_0^T U_{i1}(t)dt = h_i \int_0^T Max(U_i(t),0)dt \quad (4)$$

(2)The shortage cost of auto spare parts dealers *i* is:

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$$B_i = b_i \cdot \int_0^T U_{i2}(t)dt = b_i \int_0^T Max(-U_i(t),0)dt \quad (5)$$

(3)The total ordering cost of auto spare parts dealers *i* is:

$$D_i = k_i \cdot (G_{1i} + G_{2i} \cdot R_i) \quad (6)$$

3.1 Total Cost of Automobile Spare Parts Multilevel Inventory System

The total net margin within the planned period of automobile spare parts multilevel inventory system is total selling profit of supply chain deducting inventory costs of all levels of inventory node. Total selling profit of supply chain, total inventory maintenance cost, total shortage cost, total ordering cost, total net margin as follows:

(1)Total selling profit of supply chain

The total selling profit of automotive spare parts supply chain has related to unit profit of product and total sales of automotive spare parts dealers *i*, total selling profit is:

$$S = \sum_{i=1}^{N} S_i = \sum_{i=1}^{N} \int_0^T cX(i)dt \quad (7)$$

(2)Total inventory maintenance cost of automotive spare parts multilevel inventory system can be deduced from equation (1) and (5), the total inventory maintenance cost of automotive spare parts multilevel inventory system is:

$$\begin{aligned} H &= \sum_{i=1}^{N} H_i + \sum_{j=1}^{M} H_j = \sum_{i=1}^{N} h_i \cdot \int_0^T U_{i1}(t)dt + \sum_{j=1}^{M} h_j \cdot \int_0^T U_{j1}(t)dt \\ &= \sum_{i=1}^{N} h_i \cdot \int_0^T Max(U_i(t),0)dt + \sum_{j=i}^{M} h_j \cdot \int_0^T Max(U_j(t),0)dt \end{aligned} \quad (8)$$

(3)Total shortage cost of automotive spare parts multilevel inventory system can be deduced from equation (2) and (6), the total shortage cost of automotive spare parts multilevel inventory system is:

$$\begin{aligned} B &= \sum_{i=1}^{N} B_i + \sum_{j=1}^{M} B_j = \sum_{i=1}^{N} b_i \cdot \int_0^T U_{i2}(t)dt + \sum_{j=1}^{M} b_j \cdot \int_0^T U_{j2}(t)dt \\ &= \sum_{i=1}^{N} b_i \cdot \int_0^T Max(-U_i(t),0)dt + \sum_{j=i}^{M} b_j \cdot \int_0^T Max(-U_j(t),0)dt \end{aligned} \quad (9)$$

(4) Total ordering cost of automotive spare parts multilevel inventory system can be deduced from equation (3) and (7), the total ordering cost of automotive spare parts multilevel inventory system is:

$$D = \sum_{i=1}^{N} D_i + \sum_{j=1}^{M} D_j = \sum_{i=1}^{N} k_i \cdot (G_{1i} + G_{2i} \cdot R_i) + \sum_{j=1}^{M} k_j \cdot (G_{1j} + G_{2j} \cdot R_j) \quad (10)$$

(5) Total net margin of automotive spare parts multilevel inventory system

The total net margin of automotive spare parts multilevel inventory system is total selling profit subtracting total inventory maintenance cost, total shortage cost and total ordering cost. Can be obtained by equation (7) - (10).Total net margin of automotive spare parts multilevel inventory system is:

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$$
\begin{aligned}
Z &= S - H - B - D \\
&= \sum_{i=1}^{N} S_i - (\sum_{i=1}^{N} H_i + \sum_{j=1}^{M} H_j) - (\sum_{i=1}^{N} B_i + \sum_{j=1}^{M} B_j) - (\sum_{i=1}^{N} D_i + \sum_{j=1}^{M} D_j) \\
&= \sum_{i=1}^{N} \int_0^T c \cdot X(i) d_t - \sum_{i=1}^{N} h_i \cdot \int_0^T Max(U_i(t),0) d_t - \sum_{j=1}^{M} h_j \cdot \int_0^T Max(U_j(t),0) d_t - \\
&\quad b_i \cdot \int_0^T Max(-U_i(t),0) d_t - \sum_{0}^{M} b_j \cdot \int_0^T Max(-U_j(t),0) d_t - \sum_{i=1}^{N} k_i \cdot (G_{1i} + G_{2i} \cdot R_i) \\
&\quad - \sum_{0}^{M} k_j \cdot (G_{1j} + G_{2j} \cdot R_j)
\end{aligned} \tag{11}
$$

There are global variables:

T: Planning cycle, namely time overall length of system simulation run, t is a certain time point within planning cycles, which $0 \leqslant t \leqslant T$;

M: The number of automobile spare parts wholesaler, j is node ID of automobile spare parts wholesaler, which $1 \leqslant j \leqslant M$;

N: The number of automobile spare parts dealers, i is node ID of automobile spare parts dealers, which $1 \leqslant i \leqslant N$;

Z: The total profits which multilevel inventory system produced within planning cycle T;

H: The total inventory maintenance cost of multilevel inventory system within planning cycle T;

B: The total shortage cost which multilevel inventory system produced within planning cycle T;

D: The ordering cost which multilevel inventory system produced within planning cycle T;

c: Market profit of one-piece product, said the difference value between sale price of automobile spare parts dealer and purchase price of automobile spare parts wholesaler.

Variables of automobile spare parts wholesaler:

$U_j(t)$: Theory inventory level of automobile spare parts wholesaler j;

$U_{j1}(t)$: Physical inventory level of automobile spare parts wholesaler j, $U_{j1}(t)=Max(U_j(t),0)$;

$U_{j2}(t)$: Shortage of inventory of automobile spare parts wholesaler j; $U_{j2}(t)=Max(-U_j(t),0)$;

h_j: Unit inventory maintenance cost of automobile spare parts wholesaler j;

H_j: Total inventory maintenance cost within the planning cycle of automobile parts wholesaler j;

b_j: Unit shortage cost of automobile parts wholesaler j;

B_j: Total shortage costs within the planning cycle of automobile parts wholesaler j,

k_j: The ordering time within the planning cycle of automobile spare parts wholesaler j to the automobile parts manufacturing enterprise

G_{1j}: Fixed ordering cost of automobile parts wholesaler j;

G_{2j}: Variable ordering cost of automobile parts wholesaler j;

D_j: Total cost of automobile spare parts wholesaler j within the planning cycle to order goods from automobile parts manufacturing enterprise;

R_j: Order batch of automobile parts wholesaler j each time;

Variables of automobile spare parts dealer:

$U_i(t)$: Theory inventory level of automobile spare parts dealer i;

$U_{i1}(t)$: Physical inventory level of automobile spare parts dealer i, $U_{i1}(t)=Max(U_i(t),0)$;

$U_{i2}(t)$: Shortage of inventory of automobile spare parts dealer i; $U_{i2}(t)=Max(-U_i(t),0)$,

h_i: Unit inventory maintenance cost of automobile spare parts dealer i;

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H_i: Total inventory maintenance cost within the planning cycle of automobile parts dealer *i*;

b_i: Unit shortage cost of automobile parts dealer *i*;

B_i: Total shortage costs within the planning cycle of automobile parts dealer *i*;

k_i: The ordering time within the planning cycle of automobile spare parts dealer *i* to the automobile parts manufacturing enterprise;

G_{1i}: Fixed ordering cost of automobile parts dealer *i*;

G_{2i}: Variable ordering cost of automobile parts dealer *i*;

D_i: Total cost of automobile spare parts dealer *i* within the planning cycle to order goods from automobile parts manufacturing enterprise;

R_i: Order batch of automobile parts dealer *i* each time;

$X_i(t)$: Random demand of customer of automobile spare parts dealer *i*;

S_i: Selling profit of auto parts dealer *i* within the planning cycle。

To analyze and study the objective function and constraint condition of overall profits of multilevel inventory system, laying the theoretical foundation for further analysis of ordering strategy of each stock node.

4. Multi-stage Inventory System Optimization and Simulation

Use the logistics simulation software **Extendsim** development by USA company **Imagine That**, optimize and simulate multilevel inventory supply chain of *A* company.

4.1 Extendsim Model Construction

Through the logistics simulation software **Extendsim** built overall structure of the automobile spare parts multilevel inventory simulation system, and establish the database, named the **Inventory** database in this paper, shown in Table 4:

Table 4. Data Table of Inventory Database

Table name	Data Types	Data Description
Input	Fixedly setting	To save fixed and variable ordering coefficient, unit inventory maintenance cost, unit shortage cost, unit product profit
All levels of inventory node	Fixedly setting, dynamic change	To save reorder point of each inventory node, order quantity, inventory level at present
Each node cost	Dynamic change	To save reorder point of each inventory node, inventory maintenance cost, shortage cost, selling profit
Demand of each node	Dynamic change	To save demand of each inventory node
The total costs associated	Dynamic change	To save total ordering cost, total inventory maintenance cost, total shortage cost, total selling profit

Overall structure of the Inventory database shown in Figure 1:

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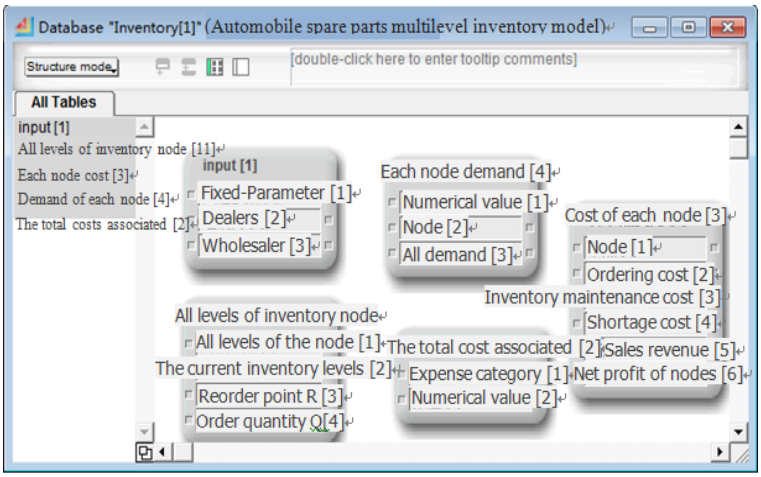

Figure 1. Inventory Database Structure

Then, save some fixed parameter values in the data table which associated with calculation of inventory cost, including fixed ordering cost, variable order cost, unit inventory maintenance cost, unit shortage cost, unit product profit and so on. For example: data table structure of each node cost shown in Figure 2.

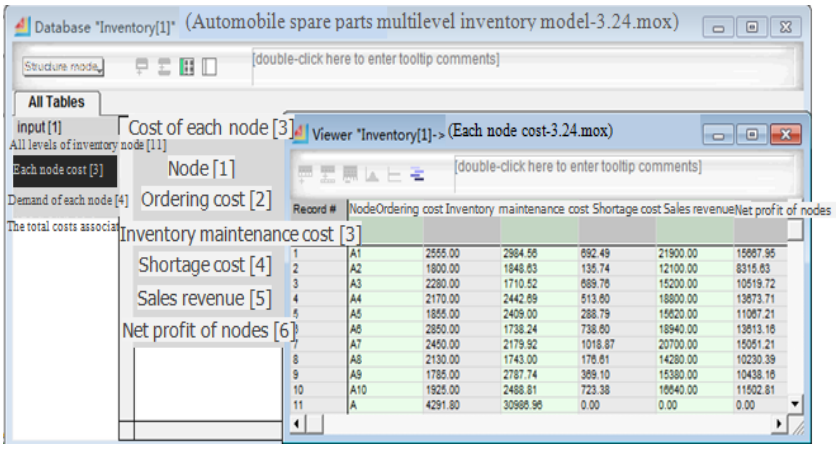

Figure 2. Data Table Structure of Each Node Cost

Automobile spare parts dealer inventory node inventory simulation model is composed by four parts, including demand processing section, check and order processing section, data processing section and data statistics section. Demand processing module generates the entity of customer demand in accordance with the time interval, then set the properties of demand on the entity, and then update inventory level in the inventory node at present according to demand. First, use the **Create** module generates entity of customer demand, then generates customer demand with **Random Number** module, and use the **Set** module to create **DemandSize** property of entity of customer demand and assigned demand to **DemandSize** property, then the demand made by **Get** modules. For example: customer demand processing module of automotive spare parts dealers shown in Figure 3.

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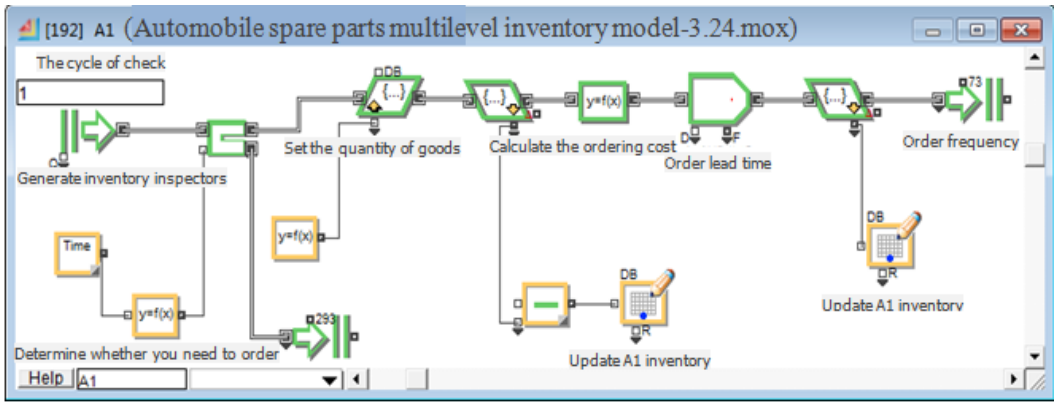

Figure 3. Customer Demand Processing Module of Automotive Spare Parts Dealers

Similarly, check library and order processing module of automobile spare parts dealer shown in Figure 4.

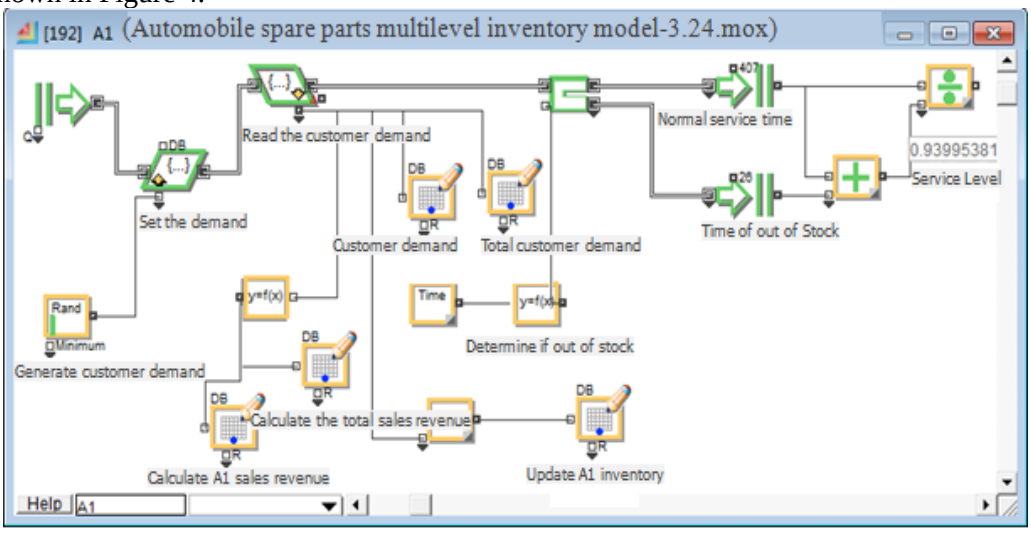

Figure 4. Check Library and Order Processing Module of Automobile Spare Parts Dealer

The data processing section shown in Figure 5, due to the selling profit and ordering cost of dealer inventory nodes are calculated in demand processing module and check and order processing module separately, then written into the corresponding data table, the data processing section used to solve the inventory maintenance cost and shortage cost of inventory node in the simulation run cycle.

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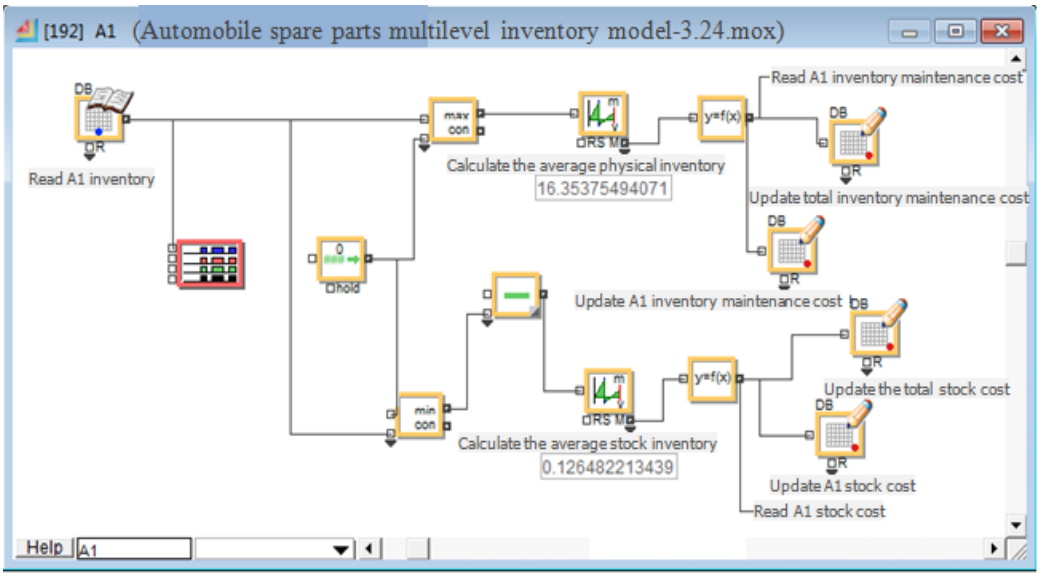

Figure 5. Data Processing Section of Automobile Spare Parts Dealer

Through modeling automobile spare parts multilevel inventory system, first describe the logical flow and overall structure and then build the overall database, built simulation module of automotive spare parts wholesaler and dealers respectively, including demand processing, check library and order processing, data processing and statistics section.

4.2 Deterministic Input Parameters

This paper set up the operation cycle of simulation system as 365 days a year. This paper studies multilevel inventory of a single spare parts, have a research on *A* spare part which is sales of more selected in category of automobile spare parts wholesalers *A*, the purchase price of this spare parts from parts manufacturing enterprises is 120 RMB, the retail price of each automobile spare parts dealer is 140 RMB, therefore selling profit of one spare parts in the whole supply chain is 20 RMB.

Automobile spare parts dealers and wholesaler use the way to check the library periodically, check the inventory regularly, every time order quantity is a fixed value, namely use (T, R, Q) ordering policy. The ordering policy of automobile spare parts dealers and wholesaler is (1, 5, 10), namely check inventory every day, order 10 products from the automotive spare parts wholesaler when stocks below 5; the ordering policy of automobile spare parts wholesaler is (15, 550, 550), namely ever 15 days, automotive spare parts wholesaler checks the inventory one time, order 550 products from the automotive components manufacturers when stocks below 550.

The unit inventory maintenance cost of automobile spare parts dealers is 0.5 RMB per piece one day, the unit shortage cost is 9.5 RMB per piece one day; the unit inventory maintenance cost of automobile spare parts wholesaler is 0.2 RMB per piece one day, the unit shortage cost is 3.8 RMB per piece one day.

4.3 Random Input Parameters

Use the exponential distribution show customer demand time of each automobile spare parts dealer, uniform distribution every time demand. The order time, from automobile spare parts dealer orders from the automotive spare parts wholesalers to products arrive, and the order time, that automobile spare parts wholesaler orders from auto parts manufacturers, obey Poisson distribution.

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Table 5. The Random Input Parameters of Each Inventory Node

Inventory node	Mean of order lead time (days)	Mean of customer arrival time interval (days)	Customer demand
A1	0.4	0.9	1～4
A2	0.5	1.2	1～3
A3	0.6	1.2	1～4
A4	0.7	0.8	1～3
A5	0.7	0.9	1～3
A6	0.6	1	1～4
A7	0.7	0.9	1～4
A8	0.8	1	1～3
A9	0.8	1.2	1～4
A10	0.7	1	1～4
A	8	—	—

5. The Simulation Results

Set the corresponding parameter values of each module and Inventory database, then click the *Run Simulation* button to run the simulation. Because the influence of random input parameters, every result is not the same, So we need to do simulation experiment for many times to simulation model, so that count the output results, the simulation was ran 20 times. Theory inventory level changes of automobile spare parts wholesaler *A* and dealer *A1* in once simulation experiment of the simulation operation cycle are shown in Figure 6 and 7 separately:

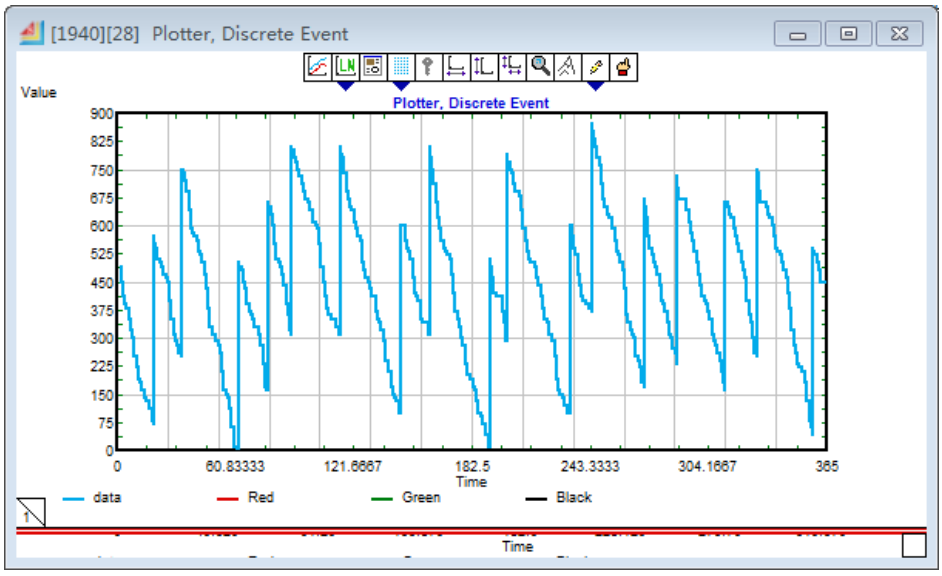

Figure 6. Theory Inventory Level of Automobile Spare Parts Wholesaler *A*

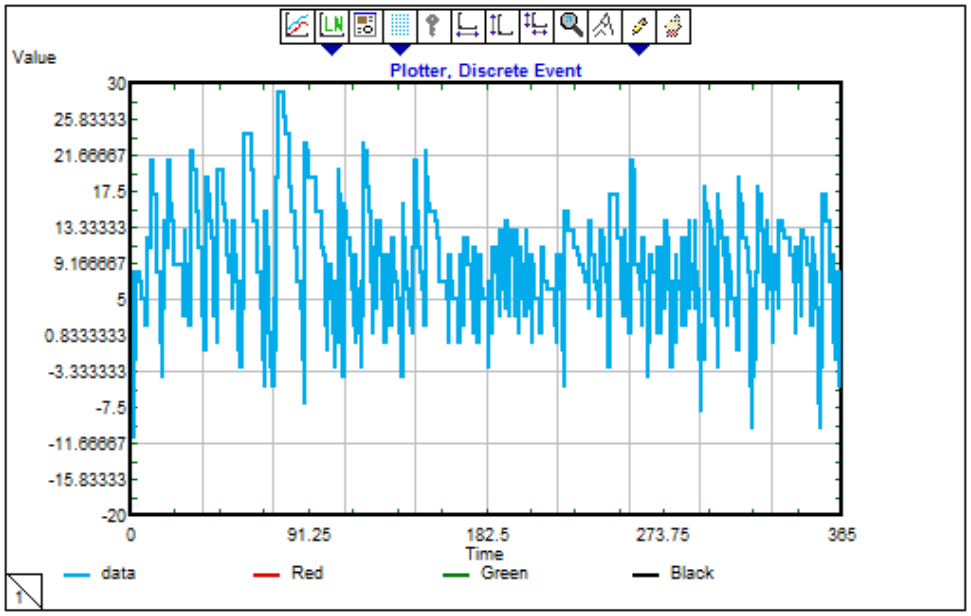

Figure 7. Theory Inventory Level of Automobile Spare Parts Dealers *A1*

Because there are a lot of random variables of automotive spare parts multistage inventory system which this article studies, including the inventory node customer demand, order lead time etc. The results of simulation optimization will be different. It is necessary to select several optimization results to compare and analyze. Obtained 10 simulation optimization results with the *Optimizer* module. Two of these simulation results shown in Figure 8 and Figure 9.

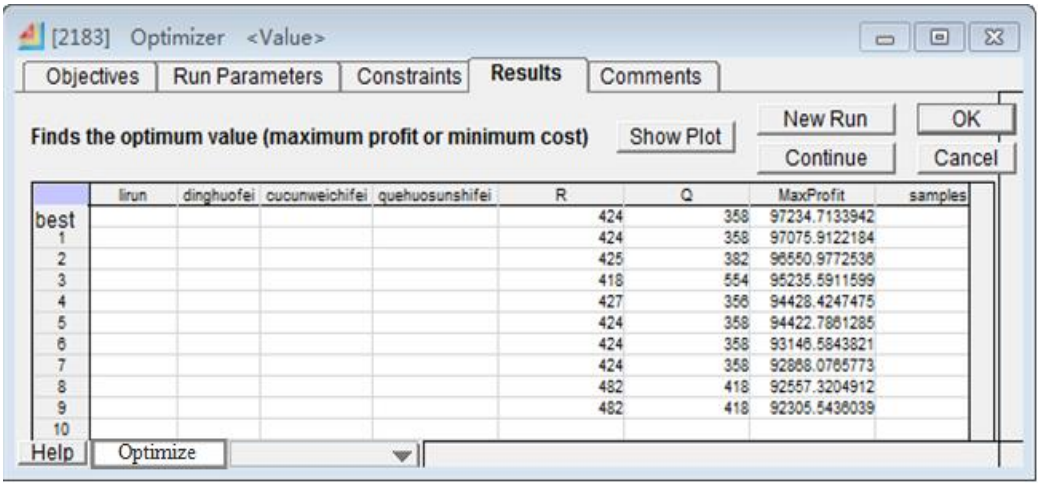

Figure 8.The Optimization Results 1

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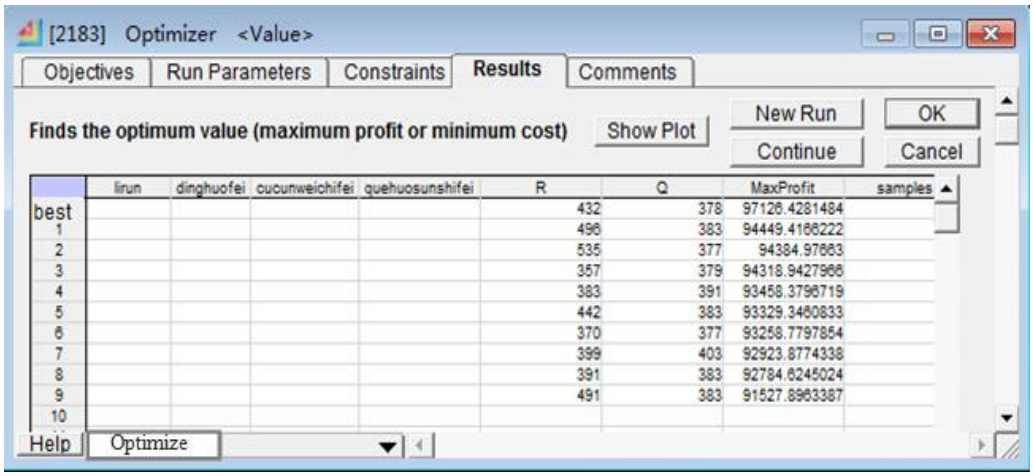

Figure 9.The Optimization Results 2

To extract the optimal result of each optimization results, as an input parameter to re-enter multistage inventory simulation model running 20 times, get mean of each output results are normalized, written in the Table, as shown in Table 6:

Table 6. The Statistic Optimization Results

(R，Q)	Total ordering cost (RMB)	Total inventory maintain cost (RMB)	Total shortage coat(RMB)	Net profit (RMB)
(513,386)	25949.2	51619.61	3396.495	88594
(486,382)	25940.4	46992.79	9787.164	86839
(404,384)	25944.8	40023.56	15467.12	88124
(395,393)	25964.6	39505.01	13212.5	90877
(379,531)	25049.6	45701.91	11830.6	86977
(476,401)	25792.1	45185.09	8978.817	89603
(480,395)	25969	44268.18	10634.33	88688
(432,416)	25823.6	43858.65	11579	88298
(424,358)	26259.2	40291.75	11869.45	91139
(432,378)	26119.4	42861.4	10222.62	90356

According to Table 6, the overall net profit of automotive spare parts multilevel inventory system under the original ordering policy is 81935.15 RMB, after simulation optimization we can get the inventory strategy, it increase overall net profit of automobile spare parts supply chain, and reduce the inventory cost.

6. Conclusion

This paper takes the automobile spare parts supply chain inventory to sales management as the starting point, systematically study the multilevel inventory management mode and its optimization method. Optimized inventory strategy make the total net profit of automobile spare parts of multilevel inventory system improved compared with the original ordering strategy multistage inventory system, the total net income has improved.

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