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Value of Information Sharing in Inventory Management of Maintenance Spare Parts

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Abstract

This study uses the system dynamics tool Vensim to conduct simulation on two different types of maintenance spare parts information sharing models (i.e. the inter-user joint maintenance spare parts management model and the supplier-involved joint maintenance spare parts management model) as well as the spare parts management model without the implementation of information sharing. By comparing the change of revenues of both the supply and the demand sides before and after the implementation of information sharing, as well as under different information sharing models, we propose the optimal way of information sharing, and also contribute managerial implications for the implementation of information sharing in maintenance spare parts inventory management.

Keywords: *maintenance spare parts; inter-user joint maintenance spare parts management; supplier-involved joint maintenance spare parts management; information sharing; system dynamics*

1. Introduction

Spare parts are important essentials for enterprises to maintain operations and improve services. Effective spare parts management can improve operation efficiency, reduce operating costs (including spare parts inventory costs, management costs, the costs of waiting caused by production halts *etc.*), and improve the competitiveness of enterprises. With the rapid development of science and technology, and the ever-increasing competitiveness between businesses nowadays, enterprises compete more for customers other than products. In order to create and maintain more customers, the enterprise must provide continuous and efficient products and services to customers. Therefore, in this context, the effective management of spare parts is particularly important.

However, different from the traditional product management, the spare parts management has its own particularities, such as the unpredictability of demand, the complex variety, high use of funds, spare parts' longer life cycle of than that of the product, and final order problems *etc*. These features caused many problems in spare parts management process, for example, the low accuracy of spare parts demand forecast, the variety and quantity mismatching between the inventory and the demand, the backlog of spare parts inventory, and even many spare parts have not been used before scrapped, which will lead to high capital occupancy rates. These problems become more prominent for those high-value but less-used spare parts, such as for power enterprises, airlines, ship manufacturers. For instance, the management fees of spare parts inventory costs the Shanghai Automotive Industry Corporation (SAIC) hundreds of millions (Cao and Li,

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2014).

Many scholars study on inventory management of spare parts to seek an effective way to reduce spare parts inventory level. On one hand, some scholars suggest that by improving the accuracy of prediction to achieve lower inventory purposes. Ghaobbar and Friend (2003) applied 13 types of prediction methods to improve the prediction accuracy in predicting the spare parts demand for aircrafts. With the development of prediction technology, more advanced methods are also introduced to the spare parts demand forecast. Such as the two important forecasting methods proposed by Chen and his colleagues - the moving back-propagation neural network and the moving fuzzy neuron network (Chen *et al.*, 2010). Cao and Li (2014) proposed a two-stage prediction method based on the fuzzy neural network and the particle swarm optimization and using the real business data verified the validity.

With the development of information technology in recent years, the studies on information sharing of spare parts management is also increasing. In previous supply chain management research, information flow is considered as the main driving force of supply chain network operations. And information sharing as an important part of the information flow management, has been recognized as reducing transaction costs between nodes, improving the response speed of supply chain network, as well as an effective mean to enhance the whole supply chain competitive advantage. In spare parts management practice, enterprises are trying to conduct information sharing or spare parts pooling to reduce inventory levels and improve the efficiency of spare parts management. Chemweno *et al.*, (2015) confirmed the effectivenss of spare parts polling strategy, that is, the spare parts can be transtered and shared between partners, since it can help "to realize economices of scales" (Cohen *et al.*, 2006) However, in the existing research, the main focus was information sharing or spare parts pooling between users.

Currently, enterprises mainly adopt two spare parts management models, these two models correspond to two different models of information sharing: the inter-user joint maintenance spare parts management (IUJMSM) and the supplier-involved joint maintenance spare parts management (SIJMSM). In the existing literatures, there are few studies focusing on the benefits that the two information sharing models brought to the participants and the supply chain, as well as the studies on how to effectively establish and promote information sharing.

For this purpose, this study built simulation models on the two types of information sharing models, by comparing the results with the performance under the non-information sharing mode, we analyzed the effect of information sharing in spare parts management, and managerial implications has been proposed as well.

2. Problem Description and Assumptions

The spare parts supply chain system studied in this paper is a two-stage supply chain that includes spare parts suppliers and the demand side. The demand side will order spare parts from the suppliers according to their own needs or agreements signed with suppliers; Spare parts suppliers will based on the order to organize product production and deliver the products to the clients. The performance indicators adopted by the spare parts information sharing value research are the average rate of inventory levels, and the change rate of inventory. By comparing the change of these two indicators before and after sharing information, we analyze the value that information sharing brought to each participant (the supply and demand side), and propose managerial implications.

This study will focus on the key repairable maintenance spare parts. On the one hand, for the key spare parts, when the production equipment fails and can not be timely repair or replacement, this might lead to production halts which will affect the normal production and operation and result in great loss. Thus in order to ensure the timely maintenance during the breakdown, the spare parts for maintenance must be collected from the stock to replace the defective parts to ensure continued production. On the other hand, because the spare part is it repairable, that is, under various spare parts management models, the maintenance department can repair the defective part and store it in the inventory for future use.

The study used the following assumptions:

(1) The defective part can achieve the same performance as new spare parts after being repaired, therefore, we does not consider the loss of spare parts;

(2)The number of failure per unit time is depended on the number of machines, and subject to the Poisson distribution, and the mean number is “the number of machines / 2”;

(3) Spare parts suppliers apply make-to-stock production methods;

(4) Spare parts demanders adopt periodic replenishment, the demander should determine the amount of spare parts ordered at the beginning of each period.

The meaning of variables appeared in the model are as follows:

(1) Number of machines: The number of production equipment that the spare parts demander has, which is considered as exogenous variables;

(2) Number of failure: The number of equipment failure of each production equipment within each period that occurred in the demand side;

(3) User/supplier inventory strategy: The safety inventory cycle number that users or suppliers applied;

(4) Unreplaced defective part: The number of machines with failure but did not have enough spare parts to replace;

(5) Spare parts to be repaired: The number of defective part to be repaired;

(6) Spare parts inventory: The number of usable spare parts that owned by the user;

(7) Order quantity: The procurement number of spare parts for each cycle from the demand side;

(8) Unfulfilled order: The sum of the number of sales that the spare parts supplier does not meet the requirement that the demander ordered;

(9) Inventory: The number of salable spare parts that the supplier has;

(10) Sales: The number of spare parts that the supplier delivered to the demander in each cycle;

(11)Delivery: The number of spare parts shipped from the stock for maintenance.

From the cost perspective, the spare parts demander hopes to achieve the lowest inventory cost while the spare parts demand can be fulfilled as well, which means that the "spare parts inventory" reaches the minimal when the "unreplaced defective part" at its minimum. Similarly, in order to reduce costs, the spare parts supplier hopes to minimize "inventory" when the " unfulfilled order " at its minimum.

3. Simulation Models

3.1. Non-information Sharing Spare Parts Management Model

In the traditional management of maintenance spare parts, the demand side and the supply side only communicate through the order, they do not share any information, completely independent of each other.

The operation of the supplier is as follows:

(1) Predict the future order quantity based on the past orders;

(2) Obtain the inventory difference by comparing the actual inventory level and the expected inventory level based on its own inventory strategy;

(3) Make production plans and organize production according to the inventory difference and the number of unfulfilled order in last cycle;

(4) When the production is completed, spare parts will be stored in the supplier's inventory, and wait for shipping based on orders.

Meanwhile, the operation of the demander is as follows:

(1) Predict the future demand of spare parts based on the machine failure history;

(2) Determine the order amount based on the prediction result of (1), and place the order to suppliers;

(3) Store the spare parts into its own inventory after receipt of order shipment;

(4) Extract the spare parts directly from the inventory and replace the defective ones during the equipment failure;

(5) Store the replaced parts into inventory after repair, waiting for future use.

The causal diagram below (Figure 1) demonstrates the spare parts management system. We will introduce the causality of this system step by step starting from the upper right corner of Figure 1.

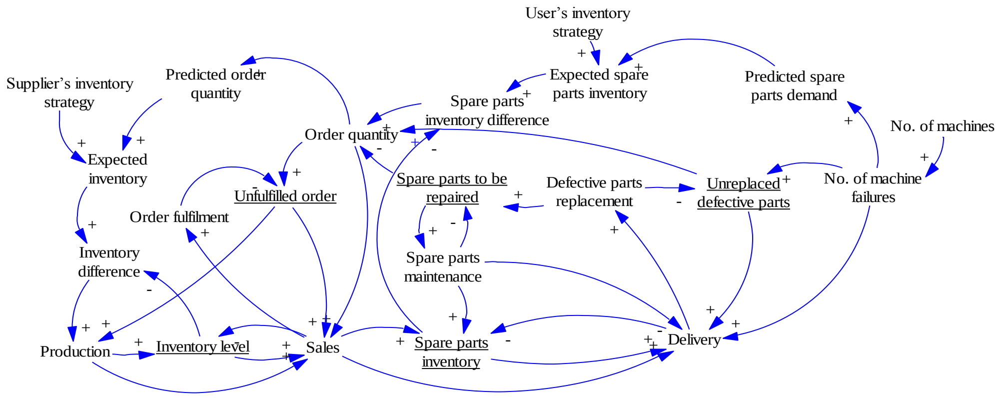


Figure 1. The Causal Diagram of Non-Information Sharing Spare Parts Management Model

The number of machine as an exogenous variable, is the actual number of production equipment owned by the demander. In each production cycle, machines may occur failures at random, the more machines, the more failures; and vice versa.

The spare parts demander predicts the spare parts demand based on the machine failure history by using exponential smoothing method, thus the demand has positive correlation with the number of machine failures. Then the demander will based on its inventory strategy to determine the expected spare parts inventory which equal to the product of inventory strategy and expected inventory. Then we obtain the inventory difference by comparing the actual inventory and the expected inventory. Since the object of our study is reparable parts, namely the spare parts that can be reused after repair; Here in the case of machine failure, we assume that the user will replace the fault parts by using the spare parts from its own inventory, and store the replacement pieces into repair spare parts inventory waiting to be repaired; and before the next cycle arrives the defective parts will be repaired and store into the inventory for later use. Therefore the order quantity should be based on the inventory difference and the number of spare parts to be repaired; the inventory difference will increase the order quantity, while the number of spare parts to be repaired will reduce the order quantity.

In the beginning of each cycle, the spare parts supplier predicts the spare parts demand based on the past order quantities by using exponential smoothing method, that is, the higher the past order quantity was, the higher the predicted quantity will be; and vise versa. Then the supplier will determine the expected spare parts inventory based on the product of to inventory strategy and expected inventory. The difference between the actual inventory and the expected inventory is the inventory difference, and the supplier will based on the sum of the inventory difference and the unfulfilled order quantity in last cycle to organize future production. The produced spare parts will be added into the inventory.

When the supplier received orders from clients, the supplier will extract the spare parts from inventory and sell, which will reduce the inventory as well as the amount of unfulfilled orders. But the maximum number of sales will equal] to the minimum number within the sum of inventory in last cycle and the production in the current cycle, and the unfulfilled order quantity in last cycle and the order quantity in the current cycle.

The spare parts will be stored into the demander’s inventory after receipt. As the machine failure occurs, the number of unreplaced defective parts will increase; while as the maintenance staff collects replacement parts from the inventory to replace the defective parts, thus the number of unreplaced defective parts will reduce. The inventory reduces as the spare parts have been extracted, however the maximum number of ready-to-collect spare parts in the warehouse equals to the sum number of inventory quantity in last cycle and the total sales in the current cycle.

The defective parts being replaced will be stored in the repairs spare parts inventory waiting to be repaired. The repaired parts will be re-placed in the inventory, thus the inventory level will increase.

In the causal diagram, variables that concerned by both demand and supply sides have been underlined as shown in Figure 1. The two variables concerned by the demand side are "unreplaced defective part" and "spare parts inventory"; and the two variables concerned by the supply side are "unfulfilled order " and "inventory level". From the figure we can clearly see the factors affecting these four variables, as well as the relationship between the variables.

According to the causal diagram described above, the system flow diagram is shown in Figure 2.

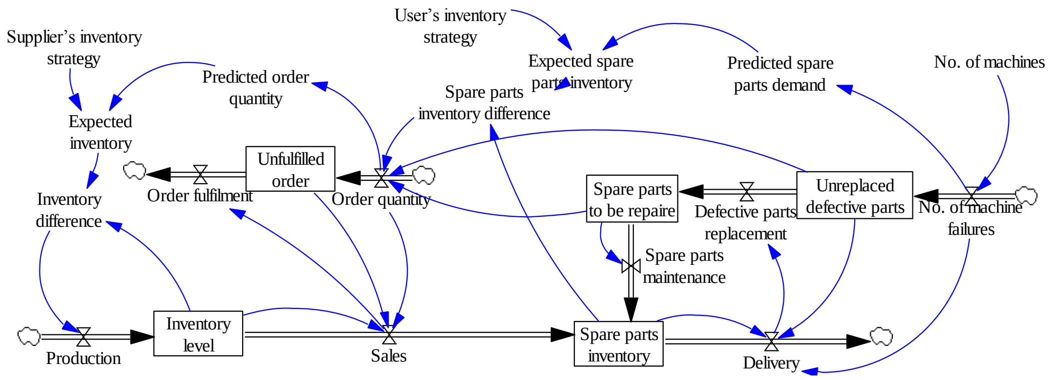


Figure 2. The Flow Diagram of Non-Information Sharing Spare Parts Management Model

At *t* time, the equations of the key variables in the flow diagram are as follows:

(1) unreplaced defective part(t)= unreplaced defective part(t-1)+ number of failure(t)- replaced defective part(t);

(2) defective part replacement(t)=delivery(t);

(3) delivery(t)=min{spare parts inventory(t-1)+sales(t)+spare parts maintenance(t), unreplaced defective part(t-1)+ number of failure(t)};

(4) order quantity(t)=max{spare parts inventory difference(t)-spare parts to be repaired(t-1), 0};

(5) unfulfilled order(t)= unfulfilled order(t-1)+ order quantity(t)- order fulfilment(t);

(6) inventory(t)= inventory(t-1)+ production(t)-sales(t);

(7) spare parts inventory(t)= spare parts inventory(t-1)+ sales(t)- delivery(t);

(8) predicted spare parts demand =Smooth(number of failure);

(9) production(t)= inventory difference(t)+unfulfilled order(t-1).

3.2. IUJMSM Information Sharing Model

The joint management between maintenance spare parts users refers to a plurality of spare parts demanders share information about inventory and machine failures, and conduct unified purchase and inventory management together. Here we assume there are two spare parts demanders (the case of multi demanders is similar), and the two sides have reached an agreement for joint management of spare parts.

The causal diagram of the information-sharing model is shown in Figure 3.

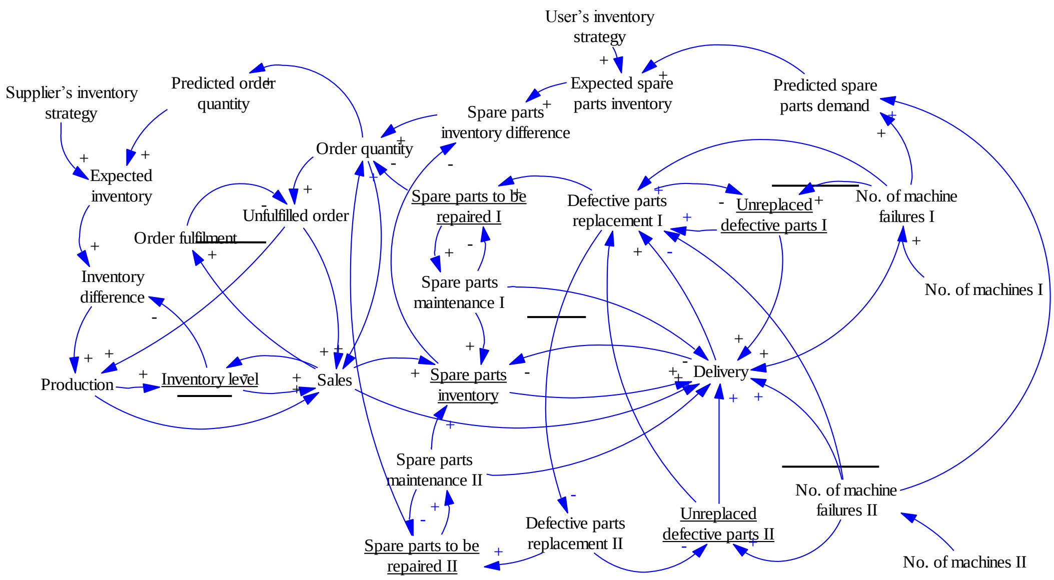


Figure 3. The Causal Diagram of IUJMSM Information Sharing Model

However, due to machine faults occurred in the two enterprises are random, so the available spare parts may not able to meet the needs of the two. In this case, we adopt the principle of proration, which means prorating spare parts according to the number of spare parts required the two enterprises. Thus, the number of one enterprise's replaced defective parts to be affected by the number of the other's demand.

Similarly, in Figure 3 we underlined the variables that concerned by both spare parts supply and demand sides. From the figure we can observe the factors that affect these variables, and their relationships with each other.

According to the above causal diagram, we plot the flow diagram of information-sharing model as shown in Figure 4.

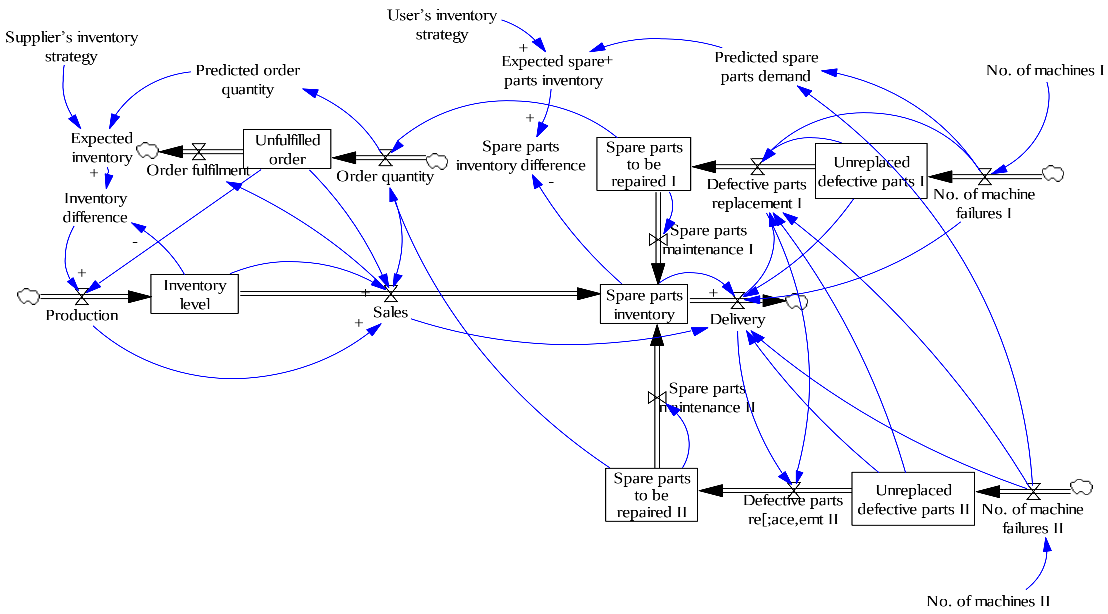


Figure 4. The Flow Diagram of IUJMSM Information Sharing Model

Compared with the non-information sharing flow diagram in the previous section, the equations of the key variables in this model are as follows:

(1) defective parts replacement I(t)
=delivery (t)×(unreplaced defective parts I(t-1)+ number of failures I(t))/
(unreplaced defective parts I(t-1)+ number of failures I(t)+ unreplaced defective parts II(t-1)
+ defective parts II(t));

(2) defective parts replacement II(t)= delivery (t)- replaced defective parts I(t);

(3) delivery (t)= min{inventory (t-1) + sales (t)+spare part maintenance I(t)+ spare part maintenance 2(t), unreplaced defective parts I(t-1)+ number of failures I(t) unreplaced defective parts II(t-1)+number of failures II(t)};

(4) order quantity (t)= max{inventory difference (t)-spare parts to be repaired I(t-1)-spare parts to be repaired II(t-1)，0};

(5) predicted spare parts demand (t)=Smooth(number of failures I+ number of failures II).

The other variables in this model remain same with the non-information sharing model.

3.3. SIJMSM Information Sharing Model

The flow of information in SIJMSM model is shown in Figure 5. The main steps are as follows:

(1) The demander need to pass the spare parts inventory information and maintenance information to suppliers;

(2) Upon receipt of the inventory and maintenance (i.e. delivery) data, the supplier will generate initial production orders based on the inventory management strategies made in the agreement;

(3) Send the initial production order to the demand side, thus the demander can adjust and modify the initial production order based on their own situation;

(4) The demander send the modified order to the supplier, then the supplier will generate the formal production order;

(5) The supplier designs warehousing, transportation and distribution arrangements based on the formal production order, as well as organizes spare parts production;

(6) After production the supplier will ship the spare parts to the demand side, and the demander will store the parts into inventory.

Note that in this mode, the inventory is managed by the supplier, thus there is no need to build warehouses in both the supply and demand side. The produced spare parts will be put into the warehouse directly, and the demander can extract the spare parts directly from the warehouse for the replacement of faulty parts.

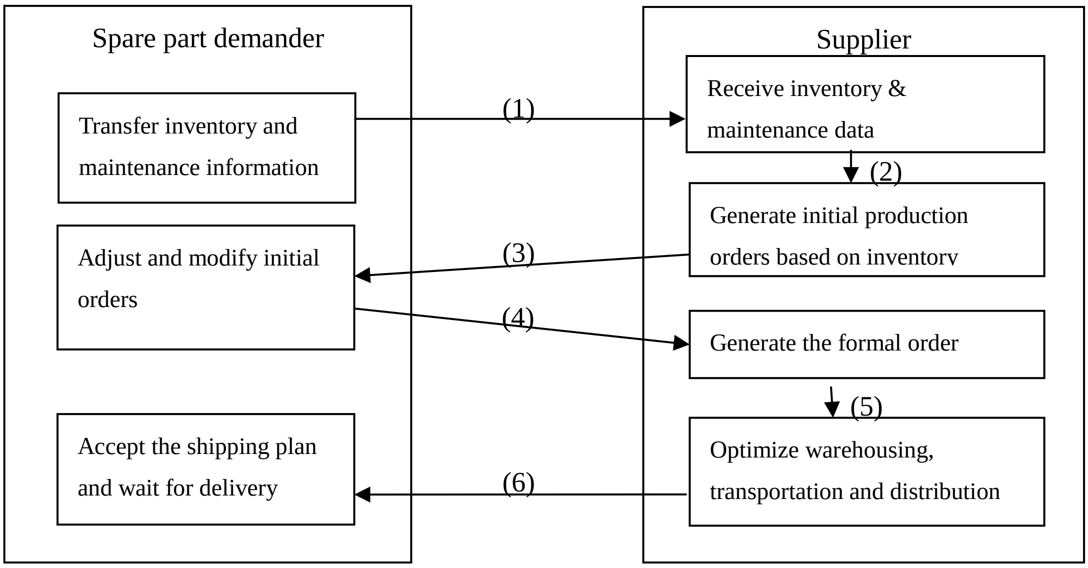


Figure 5. The Data Flow in SIJMSM Information Sharing Model

According to the data transfer process of SIJMSM information sharing model, we use system dynamics tools to build the causal flow diagram (Fig. 7).

Similarly, in this model the two demanders of spare parts will share a joint stock, however, this model is quite different with the IUJMSM information sharing model IUJMSM information sharing model.

(1) In this model, the supplier will directly predict the demand of spare parts based on the case of two demanders' machine failures, instead of the demander making the prediction;

(2) In this model, the demander does not need to make order decision, thus, the supplier does not need to predict the order demand of the demander either;

(3)The production order made by the supplier will be sent to the demander to adjust and modify, but in the IUJMSM information sharing model, the demander will not be required to make modifications to the order by the supplier;

(4)The spare parts supplier is able to have access to all the information related to maintenance and inventory, which the supplier can based on to make production orders; while in the IUJMSM information sharing model, the supplier can only make production decision based on the order demand forecast of the demand side;

(5) In this model, since the supply and demand sides shared stock, and the production prediction is made directly based on the demand, thus the supplier can make the unmet demand prediction directly based on the number of unreplaced defective part instead of

the unfulfilled order quantity.

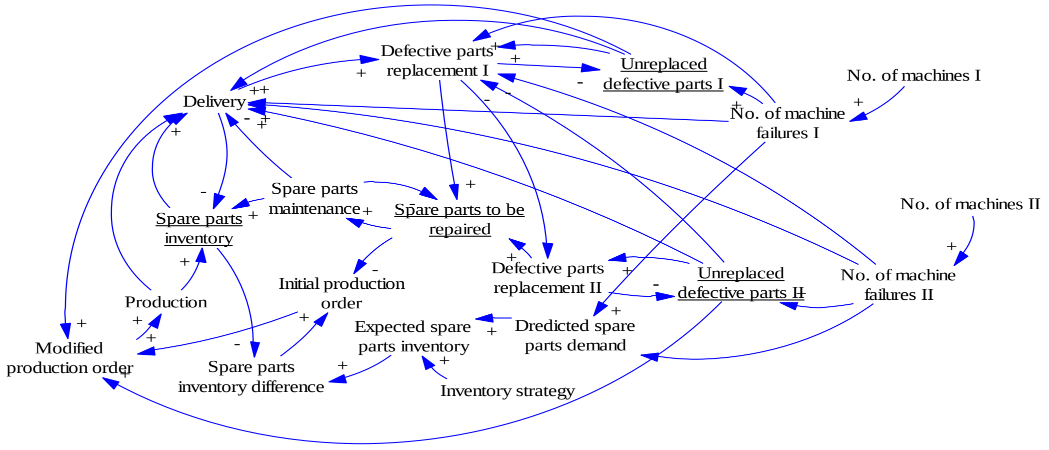


Figure 7. The Causal Diagram of SIJMSM Information Sharing Model

We build the flow diagram based on this causal diagram, as shown in Figure 8 below.

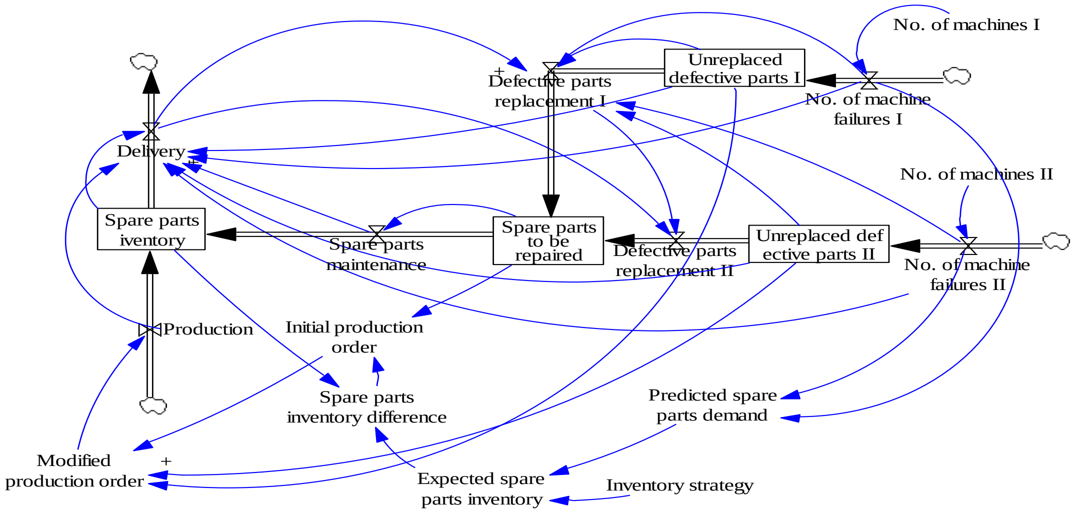


Figure 8. The Flow Diagram of SIJMSM Information Sharing Model

Compared with the IUJMSM information sharing model, the main variables changed in this flow diagram are as follows:

(1) Initial Production Order (t) = max {inventory difference (t) - spare parts to be repaired (t-1), 0};

(2) Modified Production Order (t) = Initial Production Order (t) + unreplaced defective parts I (t-1) + unreplaced defective parts II (t-1).

Other variables equations are similar to the IUJMSM information sharing model. If existing spare parts can not fully meet the needs of two clients, the supplier will adopt the same allocation strategy as in IUJMSM information sharing model.

4. Model Validation and Operation

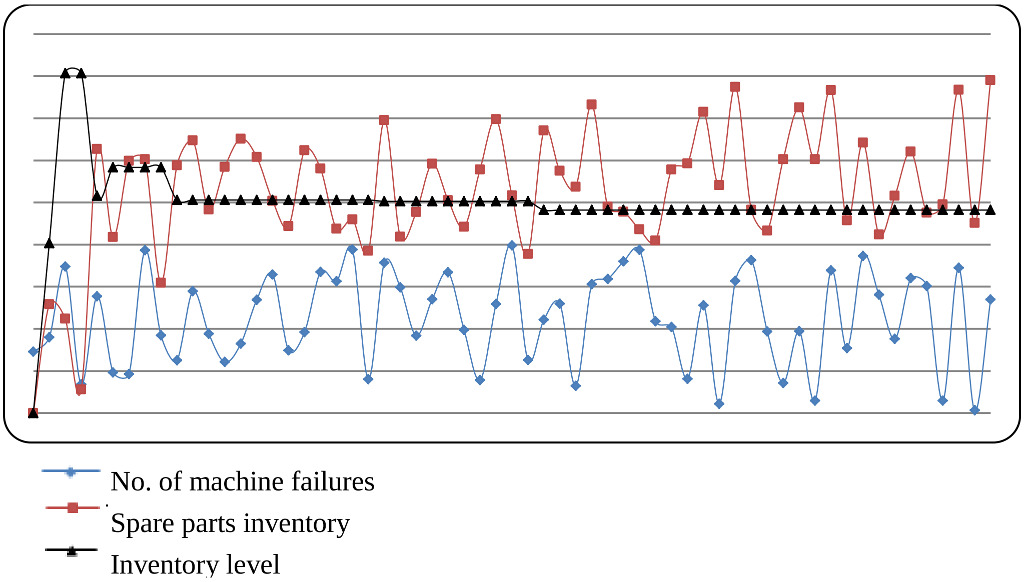
Before running the system dynamics model, we must first validate the model. Since it's quite difficult to adopt the direct verification structure, and given that the indirect structure verification can detect hidden defects as well (Barlas, 2000), thus here we mainly apply the indirect structure verification method – the extreme value analysis, to test the validity of the model.

After the validation, we use the system dynamics simulation tool Vensim to run the model.

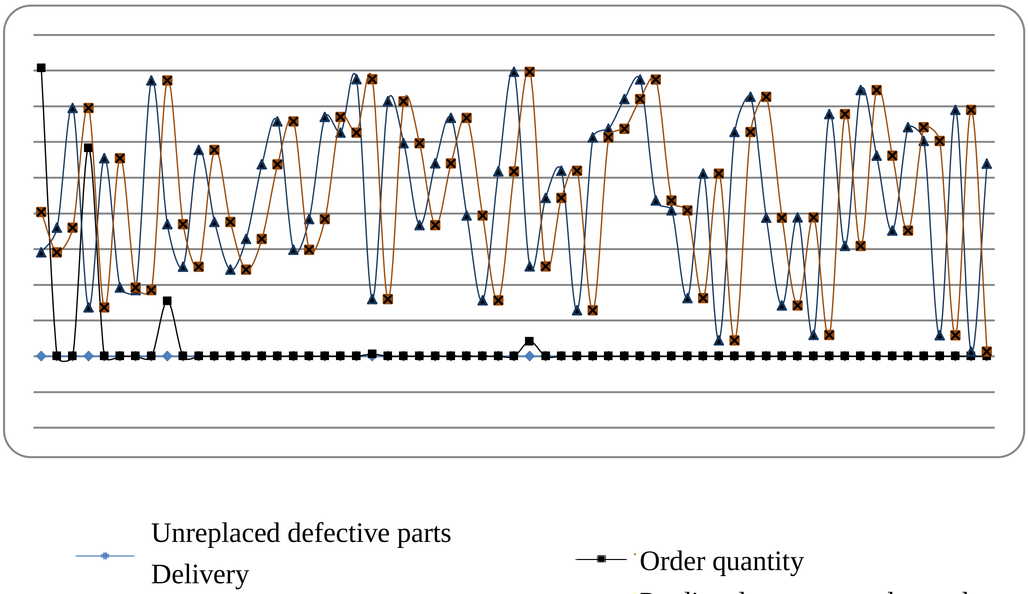
The initial value of the operating parameters: number of machines equals to 8; inventory strategy equals to 2; the initial value of each variable level all set as 0. The model operating cycle is 60 months. The reason we set this operating cycle is that the object of study is the equipment maintenance spare part in manufacturing enterprises, and these production facilities in general have longer lifetime, usually about 3 to 10 years.

4.1. Results of the Non-Information Sharing Spare Parts Management Model

The operation result is shown in Figure 9.



(a)



(b)

Figure 9. Result of the Non-Information Sharing Spare Parts Management Model

The Figure 9(a) has shown the changes of the number of machine failure, spare parts inventory and inventory level with the change of time; The Figure 9(b) has shown the changes of the unreplaced defective parts, order quantity, delivery quantity and predicted spare parts demand with the change of time.

4.2 Results of IUJMSM Information Sharing Model

The initial values of the operating parameters are the same as above. The results are shown in Figure 10.

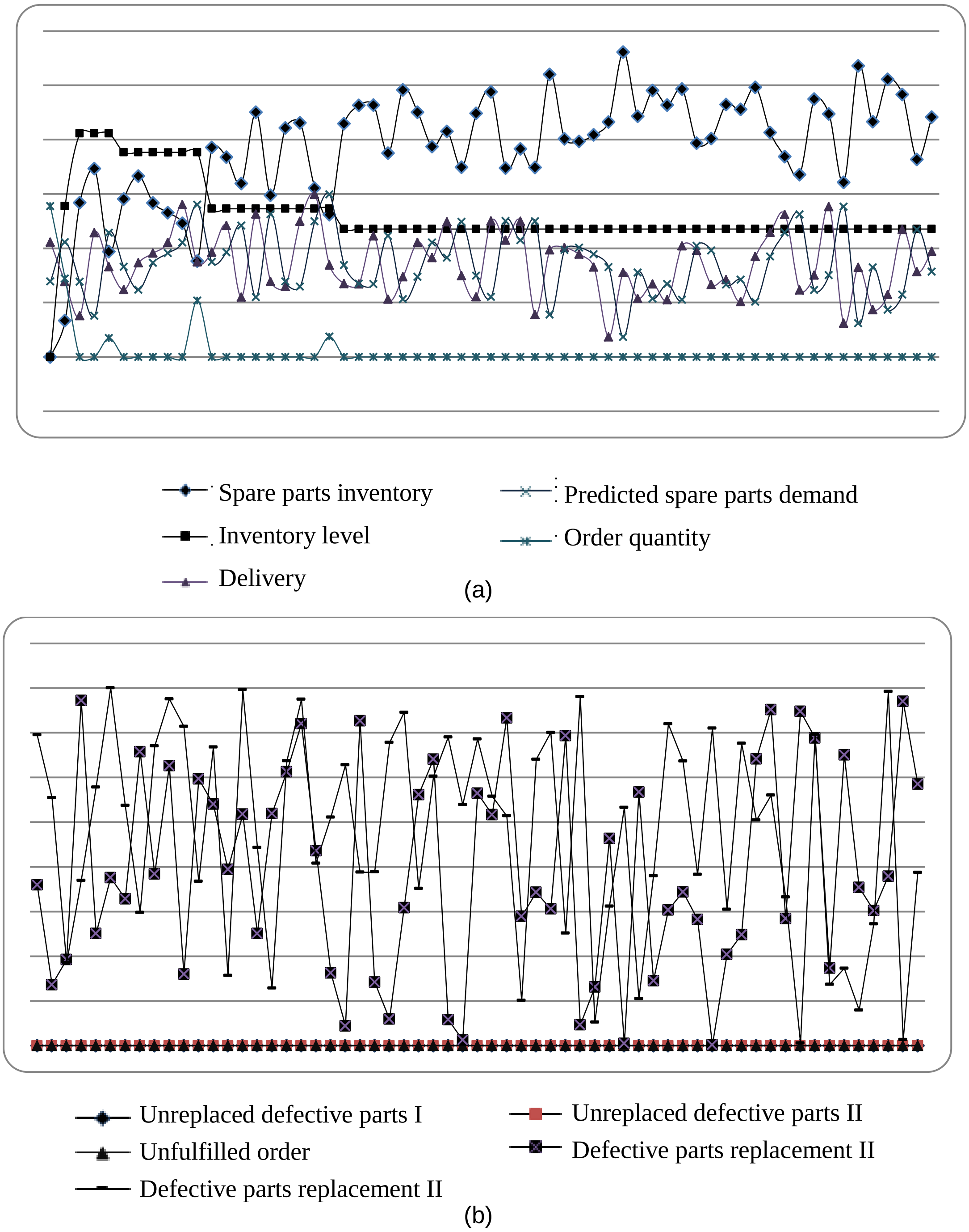
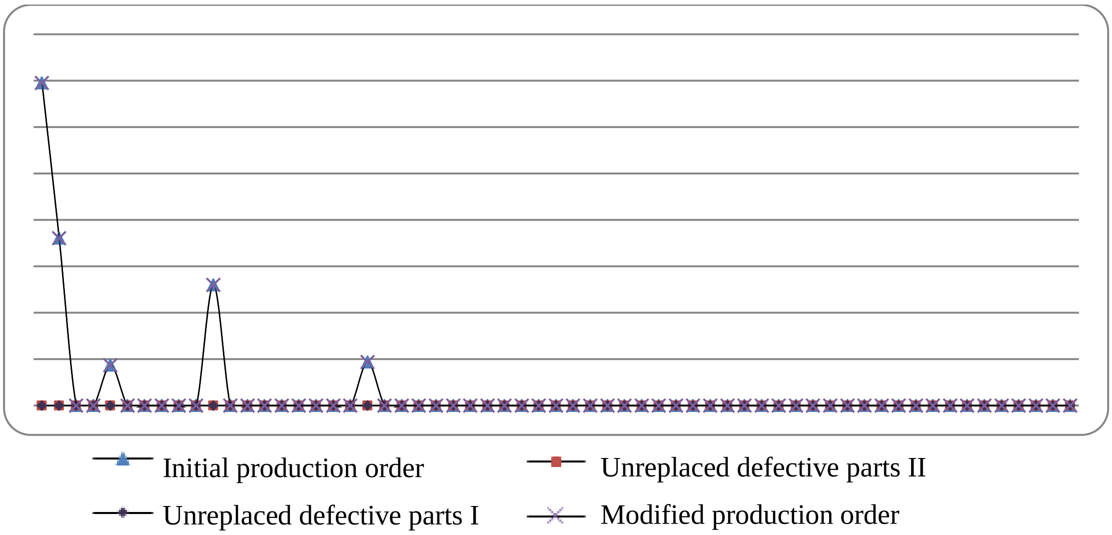


Figure 10. Result of IUJMSM Information Sharing Model

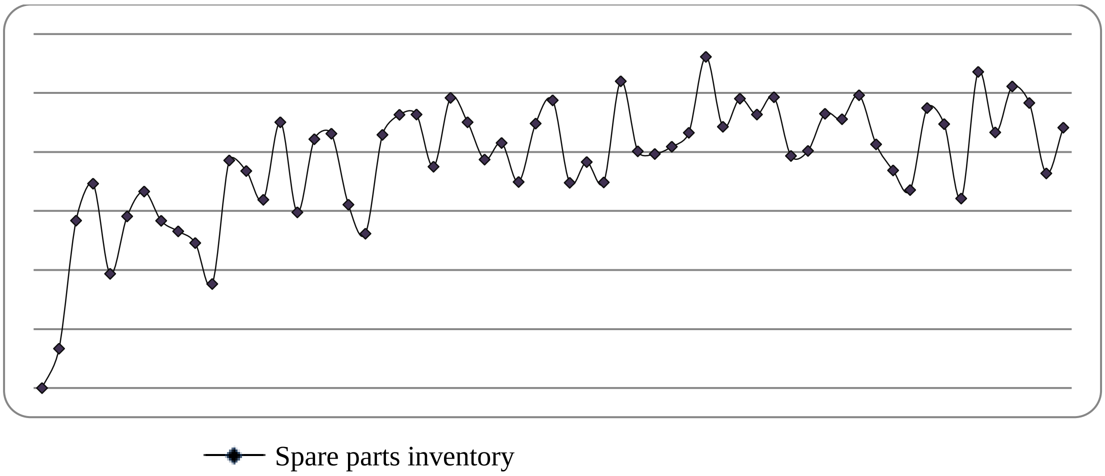
Figure 10(a) has shown under the IUJMSM information sharing model, the relations between spare parts inventory, inventory level, delivery quantity, predicted spare parts demand and order quantity with the change of time; We can see from the figure, in this mode, the unreplaced defective parts is zero. And the spare parts inventory and the predicted spare parts demand fluctuates up and down over times. The Figure 10 (b) shows the relations between unreplaced defective parts I, unreplaced defective parts II, unfulfilled order, replaced defective parts I and replaced defective parts II with the change of time.

4.3. Results of SIJMSM Information Sharing Model

We use the same method of verification as in the previous two sections, as well as use the same parameters to run the model. The results are shown in Figure 11. Figure 11(a) shows the changes of initial production order, unreplaced defective parts I, unreplaced defective parts II, and modified production order with the change of time. As can be seen from the figure, since the unreplaced defective parts I and parts II are all zero, thus the initial production order and the modified production order completely overlap. Figure 11(b) shows the change of spare parts inventory over time. We can see the spare parts inventory fluctuates over time with an upward trend.



(a)



(b)

Figure 11. Results of SIJMSM Information Sharing Model

4. Performance Analysis of Spare Parts Information Sharing

After conducting simulations on the three models, the results of the model were analyzed. Among the three models, the value of unreplaced spare parts and unfulfilled order quantity are all zero. The reason for this result is because we have adopted a conservative inventory strategy, namely the security stock is set as the demand for two cycles. In this case, we analyze the average spare parts inventory differences of both supply and demand sides under three different scenarios.

(1) The Average Spare Parts Inventory of the Demand Side

The changes of the demand side's average spare parts inventory level with the change of the number of machines under each model are shown in the following Table 1 to Table 3.

Table 1. The Non-Information Sharing Spare Parts Inventory Management Model

The relation between the demander's average inventory and the number of machines

No. of Machines	1	5	10	20	30	40	50
Avg. inventory	1	7	14	28	42	57	71

Table 2. IUJMSM Information Sharing Model

The relation between number of machines and the average spare parts inventory

Inventory		No. of machines of demander II						
		1	5	10	20	30	40	50
No. of machines of demander I	1	1	4	7	14	21	28	36
	5	4	6	10	16	23	30	37
	10	7	10	13	20	26	33	40
	20	14	17	20	26	33	40	46
	30	22	23	27	33	39	46	53
	40	29	31	34	40	46	52	59
	50	36	38	41	47	53	59	66

Table 3. SIJMSM Information Sharing Model

The relation between the number of machines and the average spare parts inventory

Inventory		No. of machines of demander II						
		1	5	10	20	30	40	50
No. of machines of demander I	1	1	4	7	14	22	29	36
	5	4	6	10	17	24	31	38
	10	7	10	13	20	27	34	41
	20	14	16	20	26	33	40	47
	30	21	23	26	33	39	46	53
	40	28	30	33	40	46	52	59
	50	36	37	40	46	53	59	66

Table 1 above shows that in non-information sharing spare parts inventory management model, the relation between the demander's average inventory and the number of machines; Table 2 shows in the joint management model, the relation between the number of machines and the average spare parts inventory of each demander; and Table 3 shows in SIJMSM information sharing model, the relation between the number of machines and the average spare parts inventory of each demander. In both IUJMSM and SIJMSM information sharing model, given that the joint-stock manufacturing enterprise (*i.e.*, the maintenance spare parts demand side) need to share the spare parts inventory holding costs by signing the agreement, thus in the two joint management models, the average spare parts inventory for each maintenance spares demand side equals to 'total stock of spare parts / 2'.

Through the analysis of three tables above, we obtain the following conclusions:

1) As the number of machines increases, the demand spare parts inventory will increase as well, and the ratio between the number of machines and the average spare parts inventory is shown in Table 4:

Table 4. Change Ratio between the Number of Machines and the Average Spare Parts Inventory

No. of Machines	1	5	10	20	30	40	50
No. of Machines /Avg inventory	1	1.40	1.40	1.40	1.40	1.425	1.42

As we can see from Table 4, with the increase of number of machines, the average spare parts inventory is almost increase with the same proportion.

2) Based on Table 2 and Table 3, we found that the value of the left diagonal completely equal in the two tables, that is, in IUJMSM and SIJMSM information sharing model, if the two demanders' number of machines involved in the joint stock remain equal, there is no difference in these two scenario to the demand side.

3) Comparing Table 1 with Table 2 and Table 3 respectively, we observed that IUJMSM and SIJMSM information sharing model can not always benefit the joint-stock participants. Whether the involved participants will be benefited depends mainly on the relation between the number of machines the other participant has and their own number of machines.

a. If the other participant's number of machines is not more than the enterprise's own number of machines, then the enterprise can be benefited from information sharing;

b. If the other participant's number of machines is greater than the enterprise's own number of machines, then the two joint management models can not benefit the enterprise.

According to social exchange theory, if the enterprise wants to reduce their spare parts inventory costs through either IUJMSM or SIJMSM information sharing model, they will certainly seek for a partner whose number of machines is similar or lower than their own, otherwise, the enterprise can not benefit from information sharing. But if the other participant with less machines can not benefit in these models, according to the social exchange theory, the participant will not be attracted by the information sharing. Therefore, if the enterprise wants to partner with an equipment manufacturer with less machines to jointly stock their inventory, the enterprise must offer incentives (such as giving certain concessions in the inventory cost allocation), to make sure the two parties will both obtain balanced and greater benefits than in the non-information sharing model, otherwise the information-sharing agreement will be difficult to achieve.

2. The Average Spare Parts Inventory of Spare Parts Supplier

In the non-information sharing model and IUJMSM information sharing model, the change relations between the supplier's average inventory level and the user's number of machines is shown in Table 5 and Table 6 respectively. In SIJMSM information sharing model, since supply side and demand side will share inventory, thus it is considered that supplier's stock is zero.

Table 5. The non-Information Sharing Model

The change of supplier's average inventory with user's number of machines (only one user)

Demander's No. of machines	1	5	10	20	30	40	50
Supplier's avg. inventory	1	6	12	24	36	48	60

Table 6. IUJMSM Information Sharing Model

The change of supplier's average inventory with user's number of machines (the two users with equal number of machines)

Demander's No. of machines	1	5	10	20	30	40	50
Supplier's avg. inventory	1	7	14	29	44	59	74

In IUJMSM information sharing model, one spare part supplier will have two users with equal manufacturing machines. By comparing Table 5 and Table 6, we found that although the number of user has doubled, the increase of the supplier's average stocks is less than 1 times. While in SIJMSM information sharing model, since the supplier's inventory remains zero, therefore we can conclude that information sharing can improve supplier's performance, it can significantly reduce their inventory levels.

5. Conclusion

This study mainly analyzes the two currently widely used information sharing models among enterprises - the IUJMSM information sharing model and SIJMSM information sharing model, and further compares enterprise's performance under these two information-sharing models with that in the non- information sharing model. Then through the analysis of simulation results, we conclude that for the spare parts demand side, the increase of machines will lead to the increase of spare parts inventory, but the ratio between the average number of machines and spare parts inventory is almost unchanged, approximately about 1.4. In addition, in the IUJMSM information sharing model and the SIJMSM information sharing model, if the participated demanders' number of machines are equal with each other, then the two models make no difference to the spare parts demand side; however, only when the other participant's machines is less than the participated enterprise its own, the information sharing can bring obvious benefits to the enterprise. For spare parts suppliers, whether in the IUJMSM information sharing model or in the SIJMSM information sharing model, the information sharing will bring significant performance improvement.

The innovations and contributions of this paper are:

(1)Although many scholars studied on the issue of spare parts management and the value of information sharing, and some also related to the information sharing issues in spare parts management, these studies did not systematically discuss the value of information sharing in spare parts management. This paper summarized the previous studies, and systematically studied the various information sharing models in spare parts management, as well as further analyze influence of the implementation of information-sharing strategies on enterprises' performance;

(2) Although the system dynamics simulation method has been widely used in supply chain management research, such as the bullwhip effect, supply chain design, there is less studies using this method to study the the value of information sharing in spare parts management.

There are still more issues to be studied in the further. For example, the enterprise's performance studied in this paper focused on inventory levels, sales etc., we did not include the cost factor, thus further studies can take into account the costs and profits factors, study the value of information sharing from more aspects.

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