System Dynamics Modeling for Supply Chain Information Sharing

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Abstract

In this paper, we try to use the method of system dynamics to model supply chain information sharing. Firstly, we determine the model boundaries, establish system dynamics model of supply chain before information sharing, analyze the model’s simulation results under different changed parameters and suggest improvement proposal. Then, we establish system dynamics model of supply chain information sharing and make comparison and analysis on the two model’s simulation results, to show the importance of information sharing in supply chain management. We wish that all these simulations would provide scientific supports for enterprise decision-making.

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Keywords: supply chain; information sharing; system dynamics; modeling

1. Introduction

With economic globalization, networking and the knowledge economy, enterprise's internationalization tendency is more and more obvious, the market competition has a clear trend of globalization and integration, each firm in the world has been more closely linked by economic ties. UK leading supply chain management expert Christopher pointed out, ‘competition in the 21st century is no longer the competition between the enterprises, but the competition between the supply chains’ [1]. In supply chain management, a supply chain to be involved from the end customer to the original multi-supplier, an enterprise often involves multiple supply chain. Different enterprises in supply chain are different geographic locations. Ever since a long time ago, in the circulation link of supply chain, each department manages their own inventory, each supply chain link has its own supply chain inventory control strategies, and these control strategies are often not the same, otherwise inevitably the demand enlargement phenomenon would be generated, and which is unable to cause suppliers to respond to the needs of users.
quickly. Therefore, supply chain management should be supposed take members enterprise in the chain effective information sharing as the core and the foundation, otherwise it is difficult to ensure that management objectives realization. Global economic integration has brought the globalization of supply chain management, simultaneously, which also makes supply chain management face wide range impact of procurement and logistics with different cultural environment and different customers. For low-cost, timely and accurate manner to meet customer's different demand, supply chain management must be based on powerful information systems to share information to promote information flow, capital flow and logistics of the harmony and unity [2]. Supply chain information sharing have been implemented to share inventory information, sales data sharing, sales forecasts information sharing, order status tracking information sharing, new product development information sharing, supply chain operating parameters (such as product lead time, station queuing delays and service) sharing and so on [3].

As supply chain system is an open complex system, many factors are relevant, supply chain systems often deviate from reality if you cut the relevance. Moreover, under the supply chain environments, systematic characteristics such as systematic non-linear, high level of order, a couple of circuits and lasting change with time are getting obvious extremely. It is very difficult to set up inventory management model by routine operational research method. In the meantime, because of involving the business inside each member enterprise on the supply chain, a lot of data are difficult to collect. These have brought many difficulties for the study of inventory control in supply chain. System dynamics offers a key approach for above-mentioned problems, because of system dynamics is a viewpoint that based on the causal relation and the structure decision behavior. It sets up model from the system interior microscopic structure, at the same time, it analyses and researches inner link between system structure function and dynamic behavior by dint of computer simulation technology, thus we can find out the problem-solving countermeasure [4]. This paper tries to establish system dynamics models of member companies in a supply chain before information sharing and information sharing, compare the two programs and analyze information sharing and other issues in supply chain management by system dynamic simulation.

2. Model Study

System dynamics is the method to cope with the complex systemic problems with the combination of quantitative and qualitative methods, based on feedback control theory, using computer simulation technology as its measure [5]. According to system dynamics’ viewpoint, system dynamics model judges object system’s changing trend by simulating object system dynamically in order to study and plan future action and corresponding decision-making of the object system. The model is characterized by regarding the study object as a dynamic system. The dynamic system has a certain internal structure and is affected by external conditions. Its fundamental principle is: Use system modeling, sending the model to computer and verify the validity, in order to provide a basis to work out strategy and decision-making.

2.1. Definite Boundary and Model Construction

The structure of supply chain has various forms. There is overall supply chain, including supplier, manufacturer, distributors and retailer; and there is local supply chain, which is divided into upstream and downstream supply chain. In traditional multi-level supply chain model, the vast majority of models are the downstream supply chain, namely three-level supply chain system about manufacturer——distributor——retailer. Therefore, the model of this paper only involves the three levels.

We could find the factors relevant to the question between the systems after determining the boundary. We could identify system-related factors with this paper as follows: Manufacturer Output Rate, Manufacturer Shipping Rate, Distributor Delivery Rate, Market Sales Rate, Market Demand Rate, Manufacturer Demand Rate, Manufacturer Sales Forecasting, Manufacturer Expect Inventory, Expect
Inventory Sustainable Time, Inventory Adjustment Time, Distributor Ordering Rate, Distributor Sales Forecasting, Distributor Expect Inventory, Retailer Ordering Rate, Retailer Expect Stock, Moving Average and so on. First, we consider the relationship between factors before information sharing. From the concept of system dynamics, we could divide the elements into levels, rates, auxiliaries and constants. Then, we could use the diagram-editing tool in Vensim version 5.9 to build the flow diagram of supply chain management system (Fig. 1). As supply chain members independent of each other, each member only considers to maximize their own interests, the orders of every link of supply chain depend on sales forecasting of every link. The sales forecasting of every link of this model is expressed as exponential smoothing. The Smoothing Cycle takes fixed value; the Inventory Adjustment Time and Expect Inventory Adjust Time take fixed value.

Fig. 1 is the flow diagram of supply chain management system before information sharing. Levels are Manufacturer Ending Inventory, Distributor Ending Inventory and Retailer Ending Inventory. Rates are Manufacturer Output Rate, Manufacturer Shipping Rate, Distributor Shipping Rate and Market Sales Rate. Auxiliaries are Manufacture Demand Rate, Manufacture Expect Inventory, Manufacture Sales Forecasting, Distributor Order Rate, Distributor Expect Inventory, Distributor Sales Forecasting, Retailer Order Rate, Retailer Expect Inventory, Retailer Sales Forecasting, Manufacturer Beginning Inventory, Distributor Beginning Inventory and Retailer Beginning Inventory. Constants are Market Demand Rate, Inventory Adjustment Time, Expect Stocks Sustainable Time and Moving Average.

Investigating Fig. 1, we could find that many cause-effect influences are not unilateral but form some feedback loops through interaction among variables. There exist the following main feedback loops:

- Manufacturer Ending Inventory → Manufacturer Beginning Inventory → Manufacturer Shipping Rate → Manufacture Sales Forecasting → Manufacture Demand Rate → Manufacturer Output Rate → Manufacturer Ending Inventory
- Distributor Ending Inventory → Distributor Beginning Inventory → Distributor Shipping Rate → Distributor Sales Forecasting → Distributor Order Rate → Manufacturer Shipping Rate → Distributor Ending Inventory
- Retailer Ending Inventory → Retailer Beginning Inventory → Market Sales Rate → Retailer Sales Forecasting → Retailer Order Rate → Distributor Shipping Rate → Retailer Ending Inventory

![Fig. 1 Flow Diagram of Supply Chain Management System before Information Sharing](image-url)
2.2. Simulation and Analysis of the Model

Fig. 2 and Fig. 3 are the simulation results of supply chain management system model before information sharing.

Fig. 2 shows that the demand information is enlarged from customer to manufacturer, supply chain system exists obvious bullwhip effect. In early system running period, the demands of each enterprise in supply chain are gradually enlarged. The system becomes more stable after 70 weeks.

![Fig. 2 Simulation Result of Supply Chain Management System Model before Information Sharing](image1)

In Fig. 2,
- Curve 1: Market Demand Rate Units: package/week
- Curve 2: Retailer Order Rate Units: package/week
- Curve 3: Distributor Order Rate Units: package/week
- Curve 4: Manufacture Demand Rate Units: package/week

Then we contrast ending inventory of each enterprise in supply chain.

Fig. 3 shows that the inventory oscillation amplitude of the upstream members is greater than the downstream members. In early system running period, the demands of each enterprise in supply chain are gradually enlarged. The system becomes more stable after 70 weeks. The simulation is the same as each enterprise’s demands of supply chain system as Fig. 2.

In real life, the market demands for any product are not fixed. In general, there are several forms of market demand changes: cyclic variation, gradually increasing (or decreasing), step sudden increasing (or decreasing), stochastic volatility and so on.

![Fig. 3 Simulation Result of Supply Chain Management System Model before Information Sharing](image2)

In Fig. 3,
- Curve 1: Market Demand Rate Units: package
- Curve 2: Retailer Order Rate Units: package
- Curve 3: Distributor Order Rate Units: package
Here, we consider the demand and inventory of each enterprise in supply chain when the market demand is abrupt changed. We rewrite the equation of ‘Market Demand Rate’ in Fig.1:

Market Demand Rate = 100+STEP (100, 80)

The simulation results are shown in Fig. 4 and Fig. 5.

Fig. 4 and Fig. 5 show that the system still shows oscillation of convergent state before first divergent state, and oscillation amplitude is still large. When market demand is stochastic volatility, it will produce similar results with these conclusions. From here we can see: supply chain management modes before information sharing, some minor fluctuations of demand could lead to greater volatility of each supply chain members’ inventory and demand continuous increase in a variety of common market demand situations. Therefore, the supply chain system is instability before information sharing and the system is easier to produce bullwhip effects. If retailers can timely share dynamics demand information of market with distributors and manufacturers, so that other members in the supply chain can also quickly grasp market trends and clear demand state of downstream members in the supply chain, each member’s inventory and orders in supply chain will not be apparent demand amplification phenomenon, and thus alleviate bullwhip effects. Next, we establish supply chain management system model after information sharing.

Fig. 4 the Comparison of Each Supply Chain Members’ Demand under Market Demand Abrupt Change

In Fig. 4,
Curve 1: Market Demand Rate Units: package/week
Curve 2: Retailer Order Rate Units: package/week
Curve 3: Distributor Order Rate Units: package/week
Curve 4: Manufacture Demand Rate Units: package/week

Fig. 5 the Comparison of Each Supply Chain Members’ Inventory under Market Demand Abrupt Change

In Fig. 5,
Curve 1: Retailer Ending Inventory Units: package
Curve 2: Distributor Ending Inventory Units: package
Curve 3: Manufacturer Ending Inventory Units: package
2.3. Supply Chain Management System Model after Information Sharing

Supply chain management system flow graph after information sharing

After information sharing, retailer timely share merchandise sale information and market demand information. The order rate of retailers and distributors and the production demand rate of manufacturers no longer depend on their own sales forecasting, but depend on market sales rate delivered from retailers. Fig. 6 is supply chain management system flow graph after information sharing.

Simulation and Analysis of the Model

In order to better simulate actual market demand, we rewrite ‘Market Demand Rate’ in Fig. 1 and Fig. 6:

\[
\text{Market Demand Rate} = 300 + \text{IF THEN ELSE} (\text{Time} \geq 5, \text{RANDOM NORMAL} (-200, 200, 0, 50, 4), 0)
\]

Comparison the simulation results as shown in Fig. 7 and Fig. 8.
In Fig. 7 and Fig. 8,
Curve 1: Retailer Order Rate Units: package/week
Curve 2: Distributor Order Rate Units: package/week
Curve 3: Manufacture Demand Rate Units: package/week
Comparing the simulation results, we can find: the amplification level of each supply chain member’s order demand is obviously decreased after information sharing.

3. Conclusion

This paper quantitatively explains the importance of information sharing in supply chain management by comparative analysis supply chain management system dynamics model before information sharing and after information sharing under market demand change. Market demand information sharing plays an important role to various factors’ coordination in supply chain, which can help each supply chain member to make a variety of management decisions. But the paper only considers market demand change factors and does not consider other factors that impact supply chain management, such as price volatility and manufacturers production capacity etc. In the future work, we will consider various factors, refine and perfect the model for making the model more realistic value.

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