BOOK SUPPLY CHAIN MODEL BASED ON SYSTEM DYNAMICS

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Abstract: Research on the book supply chain has always been a topic of discussion. This paper uses system dynamics theories and models to simulate the key part of supply chain of book industry in real-life. Firstly, the paper describes the purpose of book supply chain model and methods. Secondly, control the relationship between sales and returns on the basis of analyzing the workflow of book supply chain, and then establish the book supply chain mode. Finally, test the rationality of book supply chain mode through inputting the data of parameters in model.

1 INTRODUCTION

Our society is now in the information age, because of special varieties of goods and market demand, an increasingly shorter life cycles of books, the turnover rate of returned books and cycle time have become important issues in the book supply chain management. The distribution system reform of Book supply chain has been from "Order book to ensure sales" to "No sales of the book to ensure return". Publishing house has been from the initiative into a passive position. Shortening of product life cycle and the transfer of power of supply chain generate a large number of return books within supply chain and the distributor inventory backlog of serious books. "The relevant data show that the inventory of publications there are at least 50 billion to 60 billion Yuan of the scale, about 90% of the stock books can only be denominated in dealing kg" (Li Xianglan 2005, p.66-68) . Obviously, the reverse logistics of China's book market has become an important issue that needs to be explored and studied to find some optimal solutions to these problems.

Yang Jianzhong (2001), taking the computer books for example, analyzed the reasons that publishers have a large number of returns and Countermeasures that publishers reduce the returns and pointed out the main cause of book returns that is the increasingly fierce market competition and the extensive mode of marketing. Finally he gave the eight-pronged approach to reduce return books. Liu Haiyan and Lv Qingxian (2004) put forward the causes that the book supply chain has a "bullwhip effect", analysed the impact that "bullwhip effect" brings, and proposed some suggestion to solve the problem. Chen Li and Lin Quan (2006) studied that information technology improve the reverse logistics model in the publishing industry's applications under the network environment. Tan Weifeng (2005) recapitulated the reason that book reverse logistics is in crisis in China from the point of the publishers, distributors and retailers of view and proposed five kinds of optimization programs. Ding Weifei (2009) proposed that the book reverse logistics with the high rate of return and a large quantity of stock had become a bottleneck in the development of book industry, and explored a few points to propose reverse logistics in theory.

In the quantitative analysis, Dobos (2003) proposed a model of inventory management of deterministic logistics activities. He presumed that the demand and recovery are known for a given function, and the cycle of all logistics activities are known. He proposed the optimal control problem which contains two state variables (the state of two stocks) and three control variables (production rate,re-manufacturing rate and processing rate). Mi Zhongchun, Miao Mianyun [8] proposed a waste home appliances recycling model for reverse logistics system managed by fund management agencies, and made a parameters evaluation of this

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mathematical model.

At present the study of Chinese book supply chain only remains in the stage theory and stage measures, and the vast majority of theories and measures are based on the implement changes in forward book supply chain. The reverse rarely involved quantitative research less. Computer simulation has provided us with new ideas for research. It can abstract the objective world, and find relevant information resources from the simulation results to make decision. Therefore, we need to simulate the book supply chain, so we can take forward and reverse process as a system together in the model, use this model as a platform for the systematic study of book supply chain. We can identify the intrinsic relationship of various elements and quantify the relationship between their respective information through the parameter settings and changes to solve a large number of return books in book supply chain and its related issues.

2 FEASIBILITY ANALYSIS TO MODELING OF THE BOOK SUPPLY CHAIN BASED ON SYSTEM DYNAMICS

System dynamics is a subject to analyze information feedback system, was founded by Professor Jay W. Forrester at the Massachusetts Institute of Technology in 1956. System Dynamics based on system theory, with both essence of cybernetics and information theory. The way of SD solve problems is the unity of qualitative and quantitative analysis. Take qualitative analysis as a guide; with quantitative analysis in support .Two complement each other. “SD analyzes system to model from internal mechanism and micro-structure of the system. It analyzes relationship of dynamic behavior and the internal structure of system to find solutions to these problems using computer simulation techniques (Wang Qifan 1988, p.1).

Both the SD subject characteristics and systematic nature of book supply chain activities decide SD can apply to the field of library supply chain issues.

(1) Book supply chain system is dynamic. There are a numbers of states changing over time in the system, such as wholesalers’ inventory, retailers’ inventory, inventory in transit, etc. The corresponding cost and the number of goods in logistics activities related to dynamic change over time too. The system dynamics build a structure - functional simulation model, it is best used to study the complex system structure, function and dynamic relationship of behavior.

(2) The book supply chain system is a causal feedback system. The state variables changing over time in system are caused by some kind of factors. In other words, it is suitable for using system dynamics approach to analyze issues in book supply chain because the activities in book supply chain can be formed a variety of causal feedback relationship.

(3) The system dynamics can still research under the conditions lack of data. The complexity of book supply chain has led to some of the parameters relationship are difficult quantified or lack of data. But due to the structure of system dynamics model is based on feedback loop-based, SD focused on concern about the logical relationship between the variables. The existence of multiple feedback loops makes the system behavior model for most parameters are not sensitive. Thus, although lack of data, as long as the estimated parameters in the context of its setting, the system dynamics can still carry out some research work.

In summary, the system dynamics is suitable for studying book supply chain issues. it can construct that can reflect the non-linear, multi-feedback dynamic model according to abstract the causal relationship between various factors in book supply chain system, achieve dynamic system the movement process with computer simulation method, and analyze the human factors that decision-making factors on the system movements.

3 BOOK SUPPLY CHAIN MODELING

3.1 The Process Analysis of Book Supply Chain

The forward process of book supply chain is usually from printing to the publishing house and then publishers shipped to wholesalers at all levels to form wholesalers’ inventory. All levels wholesalers send books to the retailers at all levels to form retails inventory. At last retailers sell books directly to final consumers. The reverse process of book supply chain, in China, is generally level-return. Retailers return the books that did not sell or defects to their

superiors wholesalers. Wholesalers put the books from all retailers together and then return to their corresponding superiors publishing house. Publishing house, based on the actual situation, let the books that still have some market demand and will be no quality problems have a second delivery and the other books become pulp. This paper emphasize on the relationships of order, sales and returns, use of demand-driven type and select a part in the end of the entire supply chain, that is from market demand to retailers then to wholesalers to explain the model construction. This paper assumes that printers send books directly to wholesalers. There is no delay in orders. In order to simplify the supply chain to highlight the key construction, we just select one wholesaler and one retailer. The paper mainly discusses how to define the relations among ordering, sales and returns and how to achieve convergence between forward and reverse logistics.

3.2 Causal Loop Diagram of Book Supply Chain

According to the process and characteristics of book supply chain mentioned above, we can establish a causal loop diagram of book supply chain shown in Figure 1.

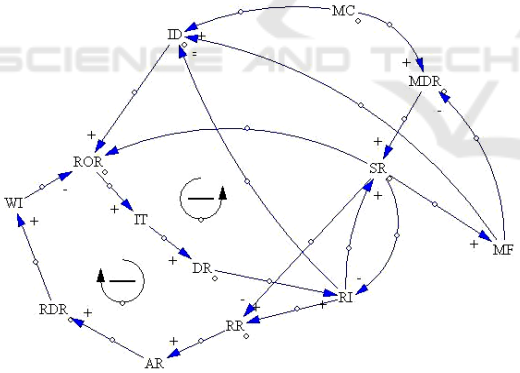

Figure 1: Causal loop diagram of book supply chain.

Through the sign of the figure we can find two negative feedback cycles. It is such a negative feedback so that the inventory of whole supply chain can be adjusted.

3.3 Book Supply Chain Modeling based on SD

After analyzing the logical structure, we can have this as a basis for the establishment of book supply chain model, shown in Figure 2.

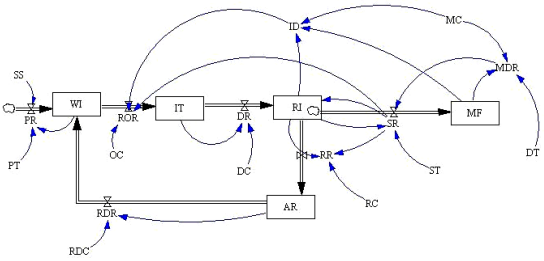

Figure 2: The system dynamics simulation diagram of book supply chain.

Market capacity is the overall capacity of the market for books in a period of time. Generally, retailers according to the historical records of customer needs make predictions, and then retailers determine their own objective inventory based out of this forecast demand, and determine their own order rate depending on the inventory differences, that is the difference between the target inventory and the retailers real inventory. Other processes are in line with the preceding analysis.

A brief introduction of each variable and their equations in this model as followed. The abbreviations of each variable and constant are showed as table1.

Table 1: Abbreviation.

wholesalers inventory	WI	printing rate	PR
retailers inventory	RI	retailers order rate	ROR
inventory in transit	IT	distribution rate	DR
safety stock	SS	sale rate	SR
the amount of return	AR	return rate	RR
market fulfill	MF	reverse distribution rate	RDR
market capacity	MC	the market demand rate	MDR
inventory differences	ID	return cycle	RC
printing time	PT	reverse distribution cycle	RDC
order cycle	OC	demand time	DT
distribution cycle	DC	sale time	ST

（1）Stock

Wholesalers inventory (WI) is a stock, that is, the current stock of wholesalers' inventory center. PR and RDR are the inputting rate of WI; ROR is the outputting rate of WI.

$$WI=\int (PR+RDR-ROR)dt$$

$$RI=\int (DR-RR-SR)dt$$

$$AR=\int (RR-RDR)dt$$

The market fulfill that is the amount of market capacity has been met.

$$MF=\int SR dt$$

Inventory in transit is r in-transit cargo from the wholesalers to the retailers.

$$IT=\int (ROR-DR)dt$$

（2）Flow

First to introduce this function: IF THEN ELSE ((condition), (ontrue), (onfalse)).The meaning is first judge the condition in parentheses, if met, then take ontrue value, the other hand, take onfalse value.

The Vensim equations and mathematical relationship of all rate variables as follows:

`ROR=IF THEN ELSE ((ID<=0): AND :( SR<=0), 0, ID/OC+SR)` that is:

$$ROR=\begin{cases}0, & ID\le 0 \text{且} SR\le 0\\ ID/OC+SR, & \text{others}\end{cases}$$

`SR=IF THEN ELSE(MDR=0, 0 , RI/ST)` that is:

$$SR=\begin{cases}0, & MDR=0\\ RI/ST, & MDR\neq 0\end{cases}$$

`RR=IF THEN ELSE ((RI>0): AND: (SR<=0), RI/RC, 0)` that is:

$$RR=\begin{cases}RI/RC, & RI>0 \text{且} SR\le 0\\ 0, & \text{others}\end{cases}$$

`PR= (SS-WI)/PT`

`DR=IT/DC`

`RDR=AR/RDC`

（3）Other variables and constants

`MDR=IF THEN ELSE (MC<=MF, 0, (MC-MF)/DT),` that is:

$$MDR=\begin{cases}0, & MC\le MF\\ (MC-MF)/DT, & MC>MF\end{cases}$$

`ID=MC-MF-RI`

SS, MC, PT, OC.DC, ST, DT, RC, RDC are constants.

4 BOOK SUPPLY CHAIN MODEL ANALYSIS

This paper simply describes the model of book supply chain operations. We need to analyze whether the model is feasible to be used for follow-up study.

Firstly, the logical relations whether can be established. After the causal loop diagram of book supply chain established, you can clearly demonstrate the relationship among each variables. From the major aspects of it is:

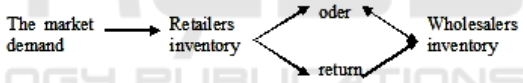

Figure 3: Logical relations.

Then the parameter validation test followed. In general, the paper is based on previous studies related to literature and specific cases, combined with my own model characteristics, and can not match the real-world supply chain system with setting the parameters involved in some special cases. In practice, before inputting a function need considering we should have extreme conditions tests. Extreme conditions tests are to test the matching degree between the dynamic behaviors the model showing and the real world in the case of extreme conditions input. The main purpose is to test the robustness of the model. Extreme conditions tests of this paper are no needs test and a constant step taking place needs test.

No need test is that the market demand is 0.In this model, market capacity is 0. In this case, because of demand-driven, the number of books won't change. When the demand is 0, there was not any logistics activities happened in the model.

In the real world, order is generated by the end customers' demand .Only the actual demand happen, retailers will order from their up nodes, followed by wholesalers ordering from their up nodes .Information flow will then pass, it will bring distribution, sales and return phenomenon. The simulation models in this paper is consistent with the real-world systems behavior, that is, there is no ordering, distribution, sales and returns occur when demand is 0.

After analyzing the situation of the entire supply chain are in a quiescent state, now we analyze the situation of the market demand is a constant in the beginning and occur a step change after running for some time.

In this case, if the model is correct, the market capacity change will cause differences in changes in inventories, which led to the occurrence of retailer order rate. Order rate associated with the occurrence of market demand rate will cause an increase in retail inventories, thereby increasing the sale rate and narrowing the difference between stocks. With the market saturated, the market fulfill tends gradually to meet the market capacity, inventory difference will be smaller, order rate and sale rate will have a reduced trend. When inventory differences disappeared the market will saturate and order rate and sale rate will no longer occur, reduce to 0.If the retailers have excess inventory, they should be returned, so return rate occur, and gradually reduced until it is 0 .

From the image we should be certain is that the market capacity are two straight-lines which occurred step change, the market fulfill and the market capacity to meet the end-overlap, order rate, sales rate and the return rate were not simultaneously, retailers inventory is a first increased and then decreased until to 0 curve.

This step function selected to test the function, the market capacity = 1000 + STEP (500, 50), before time of 50 the market capacity, that is, market demand is a constant that is 1000, and in time of 50 occurs a step to 1500 , the state variable initial value is 0.

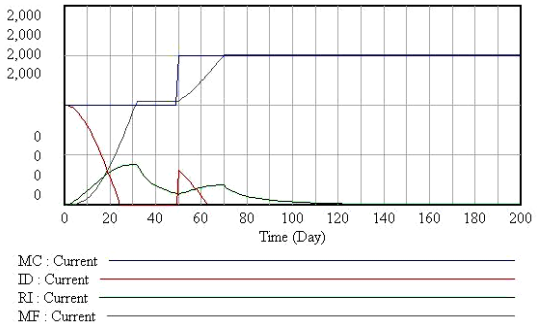

Figure 4: After step occurs the demand for inventory differences and related variables variation.

From Figure 3 we can see, the market fulfill becoming more and more to meet the market capacity, and after a step change the phenomenon happened again. Eventually the market fulfill coincides with the market capacity, which indicates the market has reached its saturation. At the moment 0, the inventory difference is the market capacity. With the occurrence of ordering, retailers' inventory is gradually increasing. The amount of the market meet increased and inventory differences gradually reduce until it is 0. At the moment 50, due to a abrupt increase in market capacity, inventory differences increased again. Since retailers keep a certain stock at that moment, inventory differences is smaller than the market capacity. At the moment 70, the market capacity is equal with the market fulfill, so no longer for sale. The retailers begin to return excess inventory, and retailers' inventory down to 0.

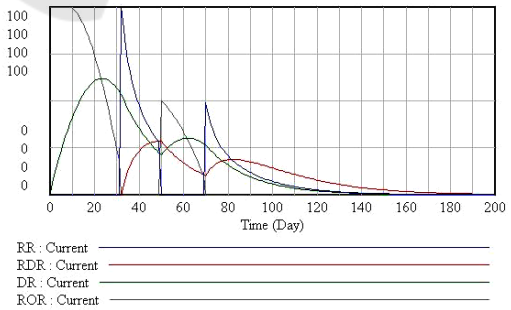

Figure 5: After step occurs the rate variables variation.

From Figure 4 we can see, before the moment 50 and after it two almost identical curve models are shown. The right one is smoother than the left one and by the values expressing is also smaller. From

the moment 0, the order rate shows a decline curve and the sales rate is a rising one, which indicating sale rate kept rising, with the retailers inventory increasing and inventory differences reducing, the order rate is declining. At the moment 30, the sale rate and the order rate are 0, indicating a saturated market and no sales and orders happened. At this time retailers maintained excess inventory, so retailers begin to return and return rate came to maximize. With this happened, the reverse distribution rate is also beginning to increase. With retailers inventory reduced due to return, return rate gradually came to 0. At the moment 50, due to increased market demand, inventory differences inventory increased, the order rate begun to reach max, return rate reduced to 0. At this time reverse distribution was still at work, so the reverse distribution rate only reduced and would not immediately drop to 0. In the process of the reverse distribution rate dropping to 0, return rate began at the moment 70.So the reverse distribution rate began to increase again at 70, and then decreased with the return rates reducing, until to 0.

The relationship among return rate, sale rate and order rate Figure 4 shows is in line with objective reality, indicating that the model simulated the key aspects of reverse logistics that is the logical relationship among return rate, sale rate and order rate. The model is reasonable.

5 CONCLUSIONS

This paper build a book supply chain model using system dynamics and simulate this model using Vensim. Basically reflects the overall state of the system. Through the parameters reasonableness test, we can intuitively see a corresponding change of the variable curves. We can analyze the simulation results and explain the reasons for system behavior whether essentially in line with the actual situation.

The book supply chain simulation system in this paper provides multiple levels of abstraction, coordinate a key part of the forward and reverse supply chain, that is, when orders begin ,when return begin ,when the implementation of return, the ordering and sales must be turned off and the implementation of orders and sales, the return must be turned off. We can expand this base model to create the entire book supply chain simulation model. We can also build the supply network involving multiple suppliers, vendors and make optimum design based on the simulation results. Finally we can apply to the operation management of the supply chain, such as inventory management, order processing, transportation management and decision-making design. System Dynamics provides a simulation laboratory of future system activities and provide a good method for simulating the system development trends more accurately, expecting future logistics cost and making policy.

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