System Dynamic Simulation Approach for Supply Chain with Capability Limit

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Abstract—**Supply chain simulation is always an important subject in recent years. According to the deficiency of simulation research on the capability limit, this paper simulates supply chain through system dynamics method in order to bring forward some valuable viewpoints. Firstly, the capability limit can have great influence on the operation of supply chain. Secondly, the effects caused by the capability limit may disappear when the threshold arrives. Thirdly, some profits maybe be produced with the improvement of the capability limit under the threshold, such as transporting ability limit, and as a difficult problem, the exact value can be gained through that simulation method. Fourthly, the whole supply chain may be affected by the capability limit, sometimes, an investment carried on by an enterprise for the others maybe brings out great profit to itself, and the wise decision can be made.**

Index Terms—**supply chain management, supply chain simulation, system dynamics, Simulink tools,**

I. INTRODUCTION

With the development of information technology and the formation of economic globalization, enterprises are affronting more and more vehement competition. They try to cooperate with each other to gain some advantages in the market, and supply chain management (SCM), a new paradigm helps them to obtain more profit[1, 2].

SCM is brought out firstly by Oliver, R. Keith and Michael D. Webber (1982), which is defined as the “to design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand, and measuring performance globally” in the APICS Dictionary.

Many enterprises have got great achievement through SCM. For example, Nokia Networks has implemented a program called “breakthrough inventory rotation days” (BIRD), which aimed at developing the company’s supply chain processes together with a large number of its customers. In 1.5 years, by the end of the year 2000, Nokia Networks had achieved about 40% average reduction in inventory levels while also achieving significant increase in sales[3]. Wal-Mart excels in terms of speed and cost by locating all domestic stores within one day's drive of a warehouse while owning a trucking fleet through SCM. This creates distribution speed and economies of scale that competitors simply cannot match. When K-Mart executives decided in the late 1990s to compete with Wal-Mart head-to-head on price, Wal-Mart's sophisticated logistics system enabled it to easily withstand the price war. Unable to match its rival's speed and costs, K-Mart soon plunged into bankruptcy [4].

However, it causes serious harms if supply chain fails to be managed. In 2003 Motorola was unable to meet demand for its new camera phones because it did not have enough lenses available. That lost not only potential profit but also the trust of the customers [5].

It can be concluded that SCM has played an important role for the enterprises in today’s vehement competing environment. Just as what Wood(1997) has stated, since the supply chain represents 60 to 80% of a typical company’s cost structure, a 10% reduction can yield a 40 to 50% improvement in pre-tax profits [6].

For SCM, simulation is a widely and useful method, because it is easy to grasp the impact of supply chain dynamic and doesn’t need to take great risk or spend large expense for the failure of SCM projects when they are actually carried out. In this paper, system dynamics (SD) simulation is applied to study the supply chain with some capability limits, such as transportation limit and production limit. Through the SD simulation, some influences on final sale amount, customer satisfaction, inventory level, and so on, can be shown when the capability limits are changed. It’s good to realize that the enterprises in supply chain are integrated as a whole, and the limit of capabilities can cause some damages to the cooperation of enterprises in the view of SCM. Sometimes, the improvement of capability limit not only can bring profits to enterprises themselves but also to collaborators in supply chain. In this way, that’s useful to evaluate some investment systematically and establish good investment policy for the enterprises.

The rest of the paper is organized as follow. In section II, the relevant literature on supply chain simulation is reviewed. In section III, two level supply chain simulation model using SD method is established. In section IV, Simulink tool is adopted for the above simulation model. In section V, the results expected from the simulation are described. In section VI, the conclusion is presented finally.

II. LITERATURE REVIEW

Dynamic simulations are necessary to analyze the supply chain because it is interactive and incorporates hierarchical feedback processes [7,8]. Dating back to early 1960s, Forrester has built a system dynamics model of the three-echelon production distribution system and demonstrated how market demands are amplified through the transactions in the supply chain[9]. That bullwhip

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effect causes great interest and many scholars work on the coordination within different enterprises in supply chain through simulation approach.

Various simulation models with different structure are established. For example, Umeda and Lee describe a design specification which is applied for a generic, supply-chain-simulation system. The proposed simulation system is based on schedule-driven (pull) and stock-driven (push) control methods to support the supply chain management. The approach is also discrete-event simulation and does take into account the hidden dynamics of supply chain[10]. Henri Pierreval, in a continuous worldview, brings out a simulation approach based on SD for supply chain in the automotive industry to show the concrete benefits that can be achieved[11]. Roy presents a system SD based experimental method for designing a supply chain structure for a volatile market of short lifecycle product[12]. Luis Rabelo presents a novel approach that integrates the analytic hierarchy process (AHP) technique, system dynamics (SD), and discrete-event simulation (DES) to model the service and manufacturing activities of the global supply chain of a multinational construction equipment corporation.

A general analysis about various parameters also appears in the simulation model. For example, Beamon utilizes two different predominant performance measures to analyze the operation of a supply chain system, which are cost, i.e. cost and the combination of cost and customer responsiveness[13]. Gavirneni, from the viewpoint of information distortion, simulates an overall supply chain model, that emphasizes the value of information and extended existing inventory theory [14]. Ganeshan studies the impact of selected inventory parameters on the performance of an expanded and comprehensive retail supply chain using simulation. The study concludes that information sharing between echelons in the supply chain yields a higher level of service [15]. Towill from system dynamics perspective also demonstrates that supply chain integration with exchange of information was as beneficial as lead time reduction throughout the supply chain via JIT [16]. Gunasekaran et al. discuss the need for selecting the appropriate measures in the evaluation of supply chain performance. Their work concludes by providing a long list of metrics such as cost per operation hour, information carrying cost, capacity utilization, total inventory in different forms, supplier rejection rate, etc. that can be used to assess the supply chain performance at the operational level [17].

Meanwhile, policies or strategies are discussed through the simulation in some works. For example, Sanghwa and Maday investigate effective information control of a production-distribution system by automatic feedback control techniques [18]. Minegishi and Thiel make a system dynamics simulation for a food supply chain system. This work sheds light on the complex nature of this specific type of supply chain and in particular on the coordination of variables controlling the food production[19]. Toru Higuchia and Marvin D. Troutt, use scenario-based dynamic simulations to study the short product life cycle case, exemplified by Tamagotchi^{TM}, and through their dynamic simulation research, some recommendations are derived, including the control of diffusion speed, the importance of repeat purchasers as a buffer and identifying phantom demand[9]. Xu Lee puts forward an inventory controlling policy based on the principles of system dynamics which uses estimated mean value and estimated standard deviation of errors to determine order quantity, in the meanwhile, all the policy parameters are made a combinatorial analysis which are involved in inventory strategy, in order to optimize inventory service level and inventory cost[20].

In current research, a lot of parameters have been analyzed in the supply chain simulation models and the relative optimal policies and strategies are discussed. However, capability limit is omitted by most scholars. They generally suppose that capability of transporting commodities is limitless, and some of them also assume the ability of yielding production is enough, and so on. That is not concerned with the practicality. Taking an example, for some companies, they have not enough vehicles to transport the goods from the train station, port or suppliers directly, even under the help of logistic companies, there's also some restriction of transporting capability. That can influence material flows in supply chain. Thus, customer satisfaction, inventory level, sale amount, and so on, can also be affected, so capability limit is an important parameter needed to be studied in the supply chain simulation.

What's more, there is no investment policy study in current simulation research basically. Because the effects caused by the change of capability limit are shown through the simulation, it's very good to evaluate an investment systematically. For example, the addition of a truck for transportation can't improve the production directly, but in the view of SCM, it may cause the change of sale amount and inventory level in some degree, that can bring profits to not only the enterprise itself but also other enterprises in the supply chain. In this way, through the supply chain simulation, the investment decision can be made wisely, which's ignored by most scholars.

According to the above two ignoring aspects in current research, system dynamics simulation approach is adopted in this paper to study the supply chain with capability limit, which is meaningful to the research of supply chain simulation.

III. SIMULATION MODEL

A. Main features of SD

System dynamics (SD) is a powerful methodology and computer simulation modeling technique for framing, understanding, discussing and analyzing complex issues and problems. It is created during the mid-1950s by Professor Jay Forrester of the Massachusetts Institute of Technology. He suggests four main concepts, which are as follows[11]:

- Stocks or levels, which describe the accumulations within the system, and are resulted from the

accumulated difference between inflows and outflows.
- Flows, which transport the content of one level to another.
- Decision functions, which control the rates of flows between levels.
- Information channels, which connect the levels to the decision functions.

In the SD approach, the feedback loop is used to show the operation of complex system. Normally, decision function gives out some directions according to the information about stocks or flows, then stocks and flow changes with the direction, in this way, feedback loop is produced and the behavior of the entire system is shown. That's very fit for the operation of supply chain, in which, enterprise inventory is considered as the stocks, order is as inflow and sale is as outflow.

B. Model Mechanism

Through the SD approach, a simple two-stage supply chain model is established, which is shown in Fig.1. There are two basic roles in supply chain: a retailer and a manufacturer. The retailer orders the goods from the manufacturer and then sales them to customer. The manufacturer orders relative materials from the supplier. The activities such as ordering, transporting, producing, stocking and selling are included in that procedure basically. The variables in that model are following:

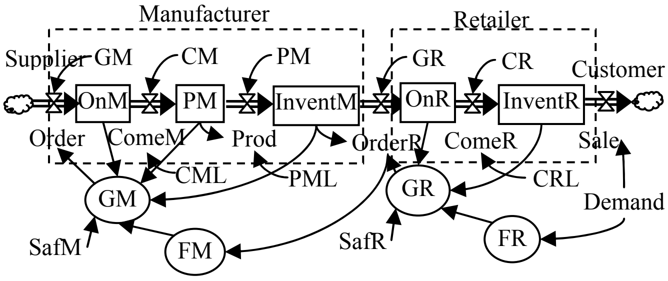

Figure1. Two-stage supply chain simulation model

- *OrderM*: the rate that manufacturer orders raw materials for goods from the suppler (Flow).
- *GMT:* the delay of ordering raw materials.
- *OnM:* the stock of ordering raw materials on the route from the suppler to the manufacturer (Stock or Level).
- *ComeM:* the rate of raw materials coming to the manufacturer (Flow).
- *CMT:* the delay of transporting raw materials on the route to the manufacturer.
- *CML:* the limit of transporting capability for manufacturer.
- *PM:* the stock of goods being produced for the manufacturer (Stock or Level).
- *ProdM*: the rate that manufacturer produces the goods (Flow).
- *PMT:* the delay of producing the goods.
- *PML:* the limit of producing capability
- *InventM:* the manufacturer's inventory level (Stock or Level).
- *OrderR*: the rate that retailer really orders the goods from the manufacturer (Flow).
- *GRT:* the delay of ordering the goods.
- *OnR:* the stock of ordering the goods on the route from the manufacturer to the retailer (Stock or Level).
- *ComeR:* the rate of the goods coming to the retailer (Flow).
- *CRT:* the delay of transporting the goods on the route to the retailer.
- *CRL:* the limit of transporting capability for the retailer.
- *InventR:* the retailer's inventory level (Stock or Level).
- *Sale*: the rate of selling goods to the customer (Flow).
- *Demand*: the customer's demand.
- *FR:* forecasting value of selling goods for the retailer.
- *SafR:* safety coefficient for the retailer.
- *GR:* ordering value for the retailer.
- *FM:* forecasting value of selling goods for the manufacturer.
- *SafM:* safety coefficient for the manufacturer.
- *GM:* ordering value for the manufacturer.

C. Operation Rule

The demand of customer is stochastic, and the sale amount fulfilling customer's satisfaction depends on the retailer's inventory level. In this way, the sale amount is the minimum between the demand and the inventor level of retailer in a special time *t* (fundamental simple time). The sale rule equation is as follow:

$$Sale_t = Min(Demand_t,\ InventR_t) \tag{1}$$

The retailer makes ordering decision through exponential smoothing method according to the summation of sale value over some time before, such as a week. What's more, in order to guarantee the enough inventories to fulfill the customer satisfaction, the retailer multiplies the forecasting value through exponential smoothing method by a safety coefficient and considers that multiplied value as the forecasting sale amount next period. Then, the retailer subtracts amount of the goods on the route and inventory amount from that forecasting sale amount to order from the manufacturer. If the result is larger than zero, the retailer orders that amount, else doesn't order. In Fig.1, variable *FR* is the forecasting value through exponential smoothing method, variable *SafR* is the safety coefficient, and *GR* is the ordering value for the retailer. The ordering rule equations for retailer are as follows:

$$GR_t^{'} = SafR \times FR_t - OnR_t - InventR_t \tag{2}$$

$$GR_t = \begin{cases} GR_t^{'} & (GR_t^{'} > 0) \\ 0 & (GR_t^{'} \le 0) \end{cases} \tag{3}$$

The same is the manufacturer's decision function, but it's a little complicated. Here, supposing raw materials ordered from the supplier is measured as same as the goods, i.e. a unit raw material need to be ordered when a unit goods is to be sold. What's more, when ordering amount is calculated, the amount of goods being produced is also needed to remove. If the result is larger than zero, the manufacturer orders that amount, else doesn't order. In Fig.1, variable *FM* is the forecasting value through exponential smoothing method, variable *SafM* is the safety coefficient, and *GM* is the ordering value for the manufacturer. The ordering rule equations for manufacturer are as follows:

$$GM_t^{'} = SafM \times FM_t - OnM_t - PM_t - InventM_t \quad (4)$$

$$GM_t = \begin{cases} GM_t^{'} & (GM_t^{'} > 0) \\ 0 & (GM_t^{'} \le 0) \end{cases} \quad (5)$$

However, although the retailer orders the goods from the manufacturer, the amount it really can get depends on the manufacturer's inventory level in a special time, but the ordering amount of manufacturer for raw material is uncontrolled from the suppler. The real ordering rule equations are as follows:

$$OrderR_t = Min(GR_t,\ InventM_t) \quad (6)$$

$$OrderM_t = GM_t \quad (7)$$

For the retailer and the manufacturer, the capability limits both exist. The transporting capability of the retailer is limited (*CRL* in Fig.1), and there may be piled up on the route, which is the same as the manufacturer's (*CML* in Fig.1), what's more, the manufacturer's producing capability is limited too (*PML* in Fig.1). Here, the rule of 'first in first out (FIFO)' is abided by in transportation and production, which is shown in Fig.2.

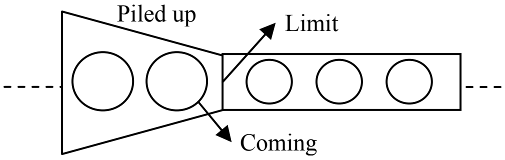

Figure2. The rule of FIFO

The relative equations are as follows:

$$ComeR_t = Min(CRL,\ OnR\_coming_t) \quad (8)$$

$$ComeM_t = Min(CML,\ OnM\_coming_t) \quad (9)$$

$$ProdM_t = Min(PML,\ PM\_coming_t) \quad (10)$$

In this way, with the material flows in and out, the retailer's and manufacturer's stocks change (*OnM, PM, InventM, OnR, InventR* in Fig.1), which depend on the summation of inflows and outflows in some periods. The stock rule equations are as follows:

$$OnM_T = OnM_0 + \sum_{t=0}^{T} (OrderM_t - ComeM_t) \quad (11)$$

$$PM_T = PM_0 + \sum_{t=0}^{T} (ComeM_t - ProdM_t) \quad (12)$$

$$InventM_T = InventM_0 + \sum_{t=0}^{T} (ProdM_t - OrderR_t) \quad (13)$$

$$OnR_T = OnR_0 + \sum_{t=0}^{T} (OrderR_t - ComeR_t) \quad (14)$$

$$InventR_T = InventR_0 + \sum_{t=0}^{T} (ComeR_t - Sale_t) \quad (15)$$

IV. SIMULATION THROUGH SIMULINK

A. Simulation establishment through simulink

Simulink tool is adopted for the above SD simulation model (Fig.3), which is an environment for multi-domain simulation and Model-Based Design for dynamic and embedded systems. At first, some simulation variables are determined. Supposing:

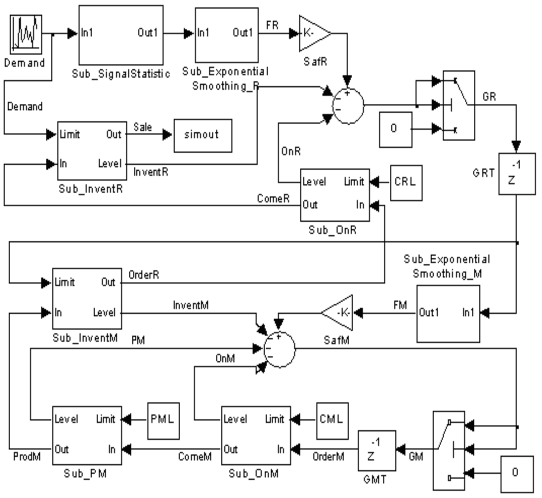

Figure3. Supply chain simulation through Simulink

$$OnM_0 = PM_0 = InventM_0 = OnR_0 = InventR_0 = 0 \quad (16)$$

$$CMT = PMT = CRT = 2 \quad (17)$$

$$GMT = GRT = 1 \quad (18)$$

It means that there are not raw materials and goods which are transported, produced and stocked in the initial conditions, and it takes 1 day for both retailer and manufacturer to exchange the ordering information and 2 days to transport or produce the raw materials and the goods to the destination.

In this simulation system through Simulink tools, there are mainly four kinds of subsystem: the subsystem for signal statistic, the subsystem for exponential smoothing forecasting method, the subsystem for transportation or production, the subsystem for the inventory. Those subsystems have different functions.

B. Subsystem for signal statistic

The Sub_SignalStatistic module in Fig.3 is this kind of subsystem, which is for calculating the demands in some time before. In this module, input is the customer's stochastic demands and output is the summation of demands in some periods, which is shown in Fig.4

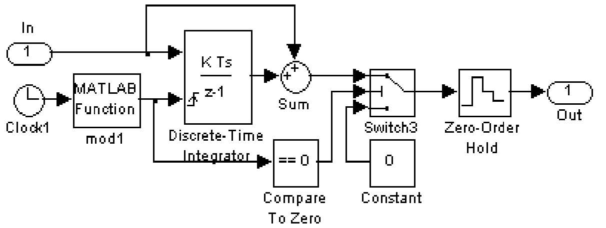

Figure4. Subsystem for signal statistic

Supposing the retailer orders the goods from the manufacturer every week, it must calculate the summation of demands this week, and then consider that statistic amount as some basis to forecast the probability sale amount next week. A summation pulse signal every 7 day is produced in this subsystem.

C. Subsystem for exponential smoothing forcasting

The modules of Sub_ExponentialSmoothing_R and Sub_ExponentialSmoothing_M in Fig.3 belong to this kind of subsystem, which are made in order to forecast the sale amount next week. Here, exponential smoothing method is adopted.

The raw data sequence is often represented by $\{Yt\}$, and the output of the exponential smoothing algorithm is commonly written as $\{St\}$ which may be regarded as our best estimate of what the next value of Y will be. When the sequence of observations begins at time $t = 0$, the simplest form of exponential smoothing is given by the following formulas:

$$S_0 = Y_0 \tag{19}$$

$$S_t = \alpha Y_t + (1-\alpha) S_{t-1} \tag{20}$$

Where α is the smoothing factor, and $0 < \alpha < 1$, here supposing $\alpha = 0.6$. The exponential smoothing module is shown in Fig.5, through that, the forecasting sale value is output, and then, Supposing safety coefficient *SafR* and *SafM* are both 1.05, the retailer and manufacturer considers that multiplication as the needed sale amount next week.

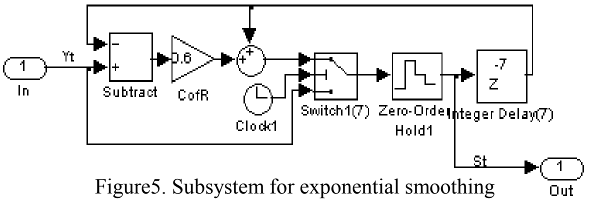

Figure5. Subsystem for exponential smoothing

C. Subsystem for for transportation or production

The modules of Sub_OnR, Sub_OnM and Sub_PM in Fig.3 belong to this kind of subsystem, which is for describing output and level condition of transportation or production. In those modules, Inputs are some material inflow and capability limit, and outputs are material outflow and the stocking level, such as the goods on the route and the goods which is being produced. Here, there are some delays in transportation and production in supply chain that are supposed as 2 days in equation (17), and the FIFO rule is adopted to shown in that procedure, which is shown in Fig.6.

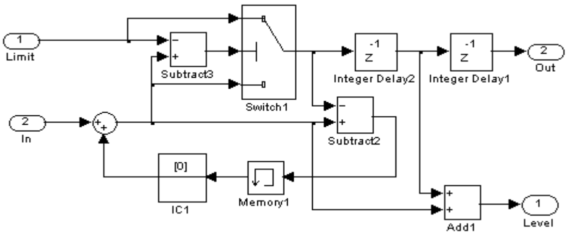

Figure6. Subsystem for transportation or production

C. subsystem for the inventory

The modules of Sub_InventR and Sub_InventM in Fig.3 belong to this kind of subsystem, which is mainly for showing the change of the inventory level and the selling status to customer or retailer. In those modules, the inputs are the coming goods and the capability limit, and outputs are inventory level and sale amount really.

Here because there is no time delay for inputting, transmitting and outputting the goods in the storehouses of the retailer and manufacturer, the FIFO rule is not adopted in those modules but blending rule, i.e. any goods are picking up at the equal possibility only if they are inputs into the storehouse, which is different with the above subsystem for transport or production modules at some degree. It is shown in Fig.7.

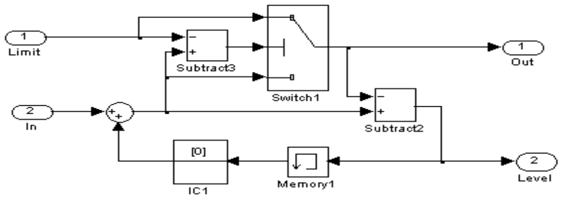

Figure7. Subsystem for the inventory

V. SIMULATION ANALYSIS

A. Influences with the limit changed

In the above simulation system, the simulation start time is 0 and stop time is 70, the solver type is Fixed-step, the solver is adopted in discrete solver, and the fix-step size (fundamental sample time) is 1. In the simulation, the random demand of the customer is shown as follow (Fig.8), which is between 0 and 0.1 (the sale amount unit is 10 thousand).

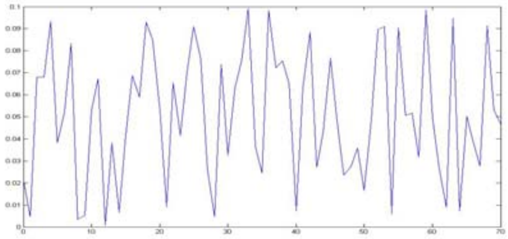

Figure8.The random demand of customer

The retailer, according to summation of the random demands and exponential smoothing forecasting method, orders the goods every week from the manufacturer, and manufacturer does too from the supplier, but capability limits *CRL, CML and PML* control the material flowing, which are supposed with different values together: 0.01, 0.05, 0.5 and 100. Many aspects are influenced which are shows as follow:

Firstly, the final sale amount to the customer changes with the capability limit, which is shown in Fig.9. Here, the line with '+' represents the selling situation when limit 0.01, the line with '*' is for limit 0.05, the line with 'x' is for limit 0.5, and the line with 'o' is for limit 100. Those reflect the influence of capability limit. It's shown that the sale amount grows up with the improvement of the capability limits, however, when they increase to some degree, the sale amount is not affected again. In Fig, the lines for limit 0.5 and 100 overlap completely, that means the transporting and producing capability has grown up to upper threshold in a saturating condition and doesn't play important role again.

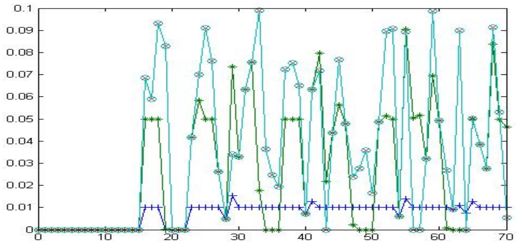

Figure9. The change of sale amount

Secondly, the customer satisfaction changes with the capability limit too. The customer satisfaction can be reflected on many aspects, but here, the difference between real sale and customer's demand is simply considered for it, which is shown in Fig.10.

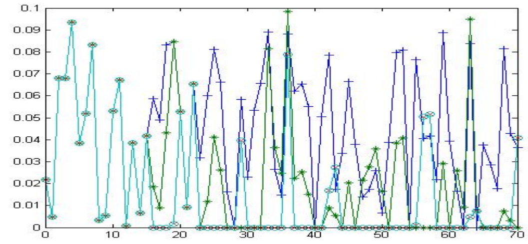

Figure10. The change of customer satisfaction

The lines' types are the same as the above. The smaller the difference is, the higher the satisfaction is fulfilled and the customer satisfactions are equal when capability limits are 0.5 and 100.

Thirdly, the inventories of retailer and manufacturer also change with the capability limit, which are shown in Fig. 11 and Fig. 12. In both those figure, the lines' types are the same as the first.

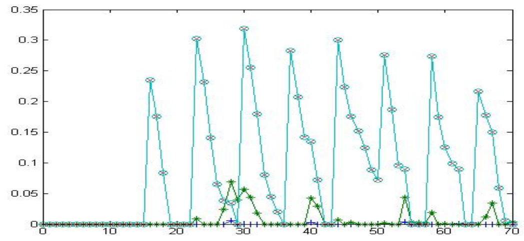

Figure11. The change of retailer's inventory

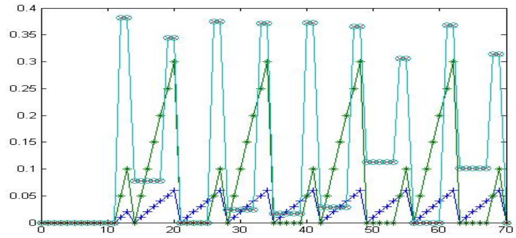

Figure12. The change of manufacturer's inventory

For both retailer and manufacturer, the inventories become larger with the improvement of the capability limits. That's obvious for the retailer specially. When limits are 0.01, because the customer can pick up the goods immediately and the supply is less than the demand, the inventory level is often zero most time, and when limits are improved to 0.5, the inventory level grow up greatly. For the manufacturer, so does the inventory, but there is a little difference. When the limits are small, the inflows are little, in this way, the inventory level fluctuate gently. On the contrary, when the limits are large, the inflows increase, and the inventory level fluctuate suddenly; what's more, the zero inventory levels maybe appear out sometimes. However, no matter what inventory level appears, it may increase with the improvement of the limits and the cost for the enterprise does so until the upper threshold comes.

In fact, there are some other parameters changing as same as the above, such as the forecasting ordering amount and the goods on the route. The capability limits are like strobes that control the flowing of materials. With the improvement of limits, many parameters grow larger until upper threshold arrives.

B. Investment policy

According to the above, some parameters augment when the capability limits are up. The increase of sale amount can bring out the addition of incomings; however, the costs also grow larger with the increase of inventory level. In this way, how to make a good investment decision is needed to consider carefully. Specially, when the limit of transporting capability changes, how much benefits to the enterprise come into being, that is a difficult question because the transport does not produce profits directly and obviously.

Supposing the manufacturer's transporting capability limit *CML* and producing capability limit *PML* are both 0.5 unchangeably, the retailer's transporting capability limit *CRL* is determined with different values as the result of some investment. How to evaluate that investment and make the wise decision? For example, there is an investment in order to improve the transporting ability in supply chain. That investment costs 200 thousand dollar, such as buying a new truck which can improve the limit *CRL* from 0.05 to 0.1 (units: 10 thousand). The profit for retailer that every sold goods can bring out is 50 dollar, and the relative inventory operation cost and transporting operation cost are 0.2 dollar (every goods). If the rate per annum is 3.6%, is it a good supply chain investment in the 2 years?

Through the simulation, the changes of sale amount, inventory level and the goods on the route are shown in Fig.13, Fig.14 and Fig.15. The line with '△' is for transporting limit 0.05 (*CRL*), and the line with '□' is for transporting limit 0.1 (*CRL*).

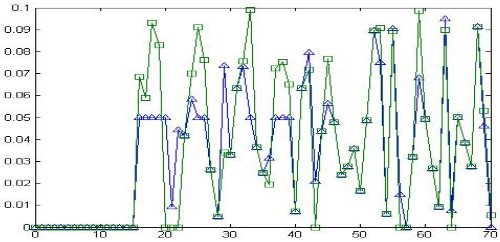

Figure13. The change of sale amount with *CRL*

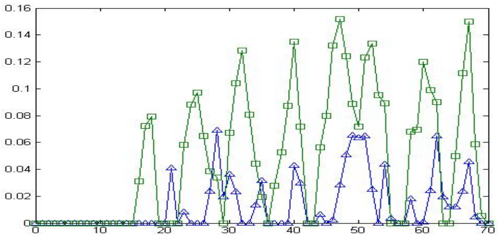

Figure14. The change of retailer's inventory with *CRL*

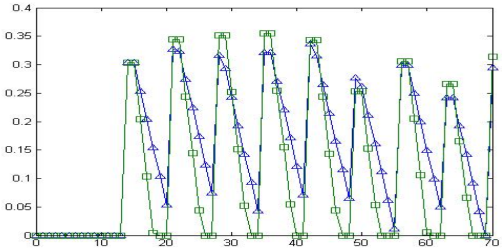

Figure15. The change of retailer's goods on the route with *CRL*

If the retailer's profit is considered as the result that subtracting transporting operation cost and inventory operation cost from the selling profit (the goods' price- the good's ordering cost). In the above simulation, the outcomes in last 30 days are chosen for calculating profit in a month. When CRL is equal with 0.05, the profit for retailer is 62.9074 (1.2815*50-5.2308*0.2-0.6071*0.2), and when CRL is equal with 0.1, the profit for retailer is 63.9847 (1.3032*50-3.8371*0.2-2.0392*0.2). That means the investment can bring out 1.0773 every mouth for addition of retailer's profit (units: 10 thousand).

The rate per month is calculated as the following equation and the outcome is equal with 0.295%.

$$rate_{PerMonth} = \sqrt[12]{1 + rate_{PerAnnum}} - 1 \qquad (21)$$

So according to cash flow method, which is shown in Fig. 16, the net present value can be achieved.

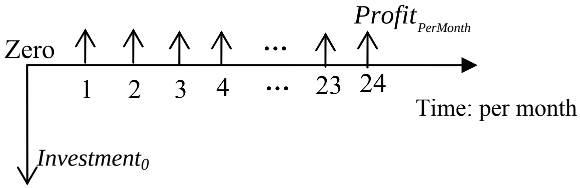

Figure14. The cash flow method

The net present value is equal with 4.9257 followed by equation (22) (23), that means it is a good investment project for the retailer.

$$Profit_T = \frac{Profit_{PerMonth} \times ((1 + rate_{PerMonth})^{24} - 1)}{rate_{PerMonth} \times ((1 + rate_{PerMonth})^{24})} \qquad (22)$$

$$NPV_R = Profit_T - Investment_0 \qquad (23)$$

What's more, the improvement of capability limit can also bring out some profits to the manufacturer. Supposing the profit for the manufacturer that every sold goods can bring out is 20 dollar (the goods' price- the raw material's ordering cost), the production operation cost is 0.3 dollar, and the relative inventory operation cost and transporting operation cost are 0.15 dollar (every goods). In the same way, the outcomes in last 30 days are chosen for calculating profit in a month. When CRL is equal with 0.05, the profit for manufacturer is 26.6764 (1.4119*20-2.135*0.3-2.135*0.15-4.0057*0.15), and when CRL is equal with 0.1, the profit for manufacturer is 28.0148 (1.4829*20-2.2212*0.3-2.2212*0.15-4.2909*0.15). That means the investment can bring out 1.3384 every mouth for the addition of manufacturer's profit (units: 10 thousand). Then, followed by equation (22) (23), the total profit that manufacturer can achieve in 2 years is 30.9669, whose NPV is the same too, because the retailer is responsible for the investment of its transporting capability (units: 10 thousand).

Here, some important viewpoints from the above example needed to be paid attention to. Firstly, the transporting investment also can bring out larger profits indirectly, and the true value can be gotten through the simulation which is a very difficult problem. Secondly, the retailer's investment can bring out the profits not only for itself but also for its cooperator in the supply chain. Thirdly, because the final profit that the manufacturer can achieve is larger than the retailer's investment, it is worth for the manufacturer to invest the transporting capability *CRL* for the retailer. Sometimes, to help the cooperation also can bring out some profits although it's maybe indirect and blurry.

VI. CONCLUSION

This paper simulates the supply chain through the system dynamics method according to the deficiency of capability limit's research. Some valuable conclusions are as follows: (1) the capability limit has a great influence on the operation of supply chain, in which, sale amount, customer satisfaction, inventory level, and so on, can fluctuate in different range; (2) when the capability limit come to the upper threshold, the affects caused by which maybe disappear ; (3) the investment on capability limits under the threshold, such as transporting and producing, can bring out larger profits, and the exact value can be calculated through the simulation although the profits that limit change cause are indirect sometimes; (4) the improvement of capability limit can have good effect on the whole supply chain, sometimes, to invest for the others maybe brings out great profits for an enterprise itself.

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