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A Study on Discrete-Continuous Modeling Methodology for Supply Chain Simulation

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ABSTRACT

Most of supply chain simulation models have been developed on the basis of discrete-event simulation. Since supply chain systems are neither completely discrete nor continuous, the need of constructing a model with aspects of both discrete-event simulation and continuous is provoked, resulting in a combined discrete-continuous simulation. Continuous simulation concerns the modeling over time of a system by a representation in which the state variables change continuously with respect to time.
In this paper, an architecture of combined modeling for supply chain simulation is proposed, which presents the equation of continuous part in supply chain and how these equations are used supply chain simulation models. A simple supply chain model is demonstrated the possibility and the capability of this approach.

Key word : supply chain simulation, discrete-event modeling, continuous modeling

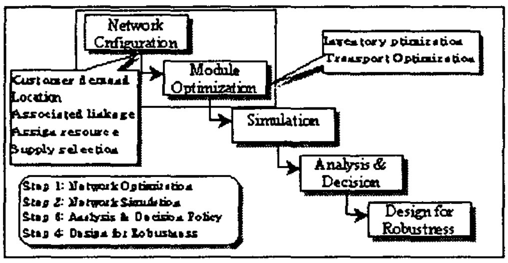
1. Introduction

Since the term Supply chain management(SCM) was coined by Houlihan in 1984, it seems to have taken a life of its own. Those of us who research and teach SCM agree that the concept refers to a set of networked organizations that work together to source, produce, and distribute products and services to the customer(Ram, Tonya, Alan, 2000). SCM is a paradigm that maximized enterprise profit by efficiently integrating and managing the flow of material and information through multiple stages of manufacturing, transportation, and distribution until it reaches the customer.
That is to say, SCM can be called strategic planning to increased efficiencies and earnings of organization by optimized speed and certainty and maximized value that is added up by each and every related process.
Enterprises, research groups are has been researching in large quantities about SCM for satisfy customer's various needs. But there have not efficiently research result, on account of many uncertainty factors in supply chain and enormous supply chain model scale.
Namely, existing analytical method could not treat variables with stochastic property supply chain, so these methods are able to present optimal value about partial supply chain. It is impossible that we treat various variables changed dynamic as a time in supply chain by

means of existing analytical methods. Also, These methods are judged unreasonable aspect, which presents optimal values entire supply chain. Only presented local optimal value in each component. Simulation is presented best efficiency methods dealing with stochastic variables existing within supply chain. Existing research estimated that simulation is able to effectively analysis tool of dynamical changed internal supply chain variables. Moreover, simulation has merit capable of optimization about planning entire supply chain as finding local optimization values within each component. When settle a problem as simulation, we begin modeling in accordance with two methods. One is a discrete event simulation modeling and the other is continuous simulation modeling method. In spite of product flow and information flow have clearly continuous factors within supply chain, existing research solved most of problems as discrete-event simulation modeling. In this research, propose using combined modeling method. It is mixed that discrete-event simulation and continuous factors.

2. Supply chain simulation

Supply chain strategic planning problems involve decisions about how a companys internal supply chain and external linkages are fundamentally organized. Most strategic decision and planning activities involve either proposed changes to the supply chains structure, or else modifications the supply chains policies. The point of the four step methodology is to help guide users to decide what techniques are appropriate for each type of decision(Hicks, 1999).



<<Figure 1 : Four step methodology>>

Step 1: Network Optimization(Hicks, 1999)

The objective of step one is to arrive at an overall network structure that is efficient, meets all current demands, minimizes structurally based cost issues, and supports any other management constraints. To do this, a linear-mixed integer (LP-MIP)programming model is formulated, then solved.

Step 2: Simulation(Hicks, 1999)

While step one will produce an optimal supply chain structure. In order to predict exactly how a proposed supply chain design will operate, the design must be simulated in step 2 of the Methodology. In this network simulation step, a simulation model is built to replicate the design that was produced in step 1.

Step 3: Analysis & Decision Policy (Hicks, 1999)

While simulation is an extreameky accurate modeling approach, capable of predicting system performance, it does not in itself help to improve system design. The design can be improved through attempting to optimize the policy choices used to govern the network's behavior.

Step 4: Design for Robustness(Hicks, 1999)

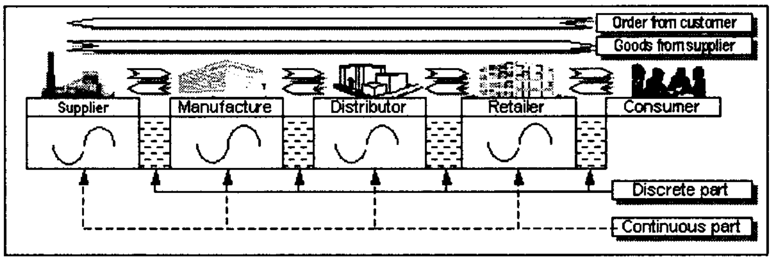
The final step in the four step methodology is design for robustness. The objective of this step is to ensure that the final selection of the supply chains network structure and policies will operate well under a wide variety of situations. During the first three steps of the Methodology, the user assumes that the design is being improved to operate as efficiently and effectively as possible

3. Combined modeling

3.1. Usage of combined modeling in supply chain

3.1.1 Three levels for supply chain management

Needed activity of enterprises for supply chain management are classified into three levels(operation level, tactical level, strategic level) through interested province. Particularly,



<<Figure 2: Discrete and continuous portion in supply chain>>

supply chain management focused on strategic level, which is a higher rank, among three levels (Ricki, 1988). Following are solution of problem about such three levels..

1) Operation level : Traditionally, mathematical optimization model showed good result within this level. such as LP(Linear Programming), IP(Integer Programming), MIP(Mixed Integer Programming).
2) Tactical level : Range of resource is expanded to single machine to single factory and it is a interesting field which products are manufactured, or which factory produced. Here, uncertainty of demands and simplicity of models bring about problems. such case, It is offer better performance that simulation deal in stochastic model
3) Strategic level : Make decision is difficult because customer demands very uncertain. Stochastic modeling and analysis are needed, because of factor being variability.

3.1.2. A characteristic of discrete event and continuous modeling within strategic level

Combined modeling in supply chain model methodology gives convenience supply chain analyst. These convenience are on the following.

① Explaining the dynamic behavior of an existing system.
② Confirming validity of proposed system modification.
③ Predicting new types of system behavior.
④ Benchmarking competitive improvement strategies.
⑤ Checking out of novel adaptive control systems.
⑥ Benchmarking improvement programs carried out within an electronic product supply chain.
⑦ Convenient to approximate a discretely changing variable by using continuously changing variables.

But, discrete-event simulation modeling in supply chain model methodology gives difficulty supply chain analyst. These difficulty are on the following.

① Do not reflect the continuous nature of the process being modeled.
② Do not represent the interaction that may occur among those components.
③ Having complication for more detail model.
④ Having too simplicity for small scale model

3.1.3 Application level from combined modeling in supply chain

A feature of modeling above mentioned are applied to each levels for supply chain management, and then operation levels, there get a optimal value by analytical optimization theory. Another levels, tactical level, it is said that using discrete event simulation is fitted choice. (Ricki, 1988) but, strategic level is needed output data through more detail modeling and larger size simulation model for enterprise plan. if these model be constructed using discrete event modeling, model shell require larger scale and large quantities of input data. This have an influence on expense follow model construction. but, if we use combined modeling, we can know continuous feature, interaction, trend of rate

<<Table 1 : Application methodology for each level>>

Level	modeling method	detail grade	model scale
Operation	Mathematical model	Very detail	Small
Tactical	Optimization /Simulation	Normal	Normal
Strategic	Combined modeling simulation	Simple	Very Large

3.2. Discrete and continuous factors in supply chain system

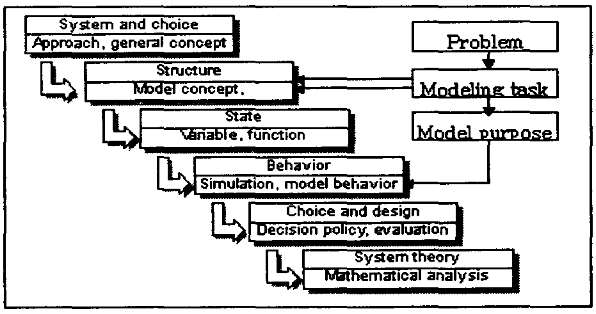
It is depend on individual ability that divide its into discrete and continuous factor in supply chain system. These discrete and continuous factor in supply chain system are to classify supply chain component(supplier, manufacture, distributor, retailer, customer) and connection between each component. Information about order from customer, information flow each supply chain component, inventory level in distributor, each manufacture for product are continuous factors. Beside transportation are discrete factor.

3.3. Combined(Discrete-Continuous) modeling

The complete process of systems analysis from model development to simulation to behavioral analysis and system design proceeds in several stages: (Pegden et al. 1990)(Bossel et al., 1994).

① Development of the model concept
② Development of the simulation model
③ Simulation of system behavior
④ Policy analysis and system design
⑤ Mathematical systems analysis

Modeling task defines both determine the model concept and the model purpose. The model concept is developed into the simulation model which allows the simulation of system behavior. The simulation model is used to study policy options or to design the system to meet given criteria. Mathematical systems analysis and the experience with similar systems help in developing and understanding the system and in improving its performance. Combined models incorporate both discrete and continuous change variables within the same model. To model such systems, we must be able to represent both the discrete and continuous components of system, as well as the interactions that may occur among those components. As a consequence of using combined model in supply chain management we are able to generate added insight into system dynamic behavior and particularly into underlying casual relationships(Bossel et al., 1994).

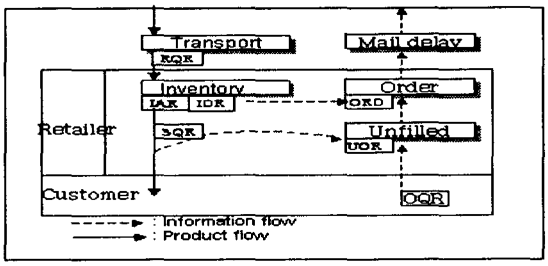


<<Figure 3: Behavior analysis and system design proceeds>>

3.4 Organization of supply chain system

We shall concentrate on the main channel of material flow from supplier to consumer and on the principal stream of information flow in the form of orders moving from consumer toward suppliers. The structure of the system is shown in Figure 4. This defines in a general way the problem we are choosing to consider. Refinements of these could be handled later.

3.4.1 Retailer section



<<Figure 5: Retailer section>>

Common Index
j : former time
k: present time, but k = j+1

Given value
IDR : Inventory desired level at retailer(volume)

Parameter
UOR : unfilled order at retailer(rate)
IAR : Inventory actual level at retailer
ORD : Order quantity, from Retailer to Distributor

There unfilled order rate at retailer a point of time k

$$UOR_k = 1 - \left(\frac{shipped\ quanitity}{order\ quantity}\right) = 1 - \left(\frac{SQR_j + SQR_{j+1}}{OQR_j + OQR_{j+1}}\right) \quad ..(1.1)$$

and inventory level at retailer a point of time k

$$IAR_k = \frac{shipped\ quantity}{received\ quantity} = \frac{SQR_j + SQR_{j+1}}{RQR_j + RQR_{j+1}} \quad ....(1.2)$$

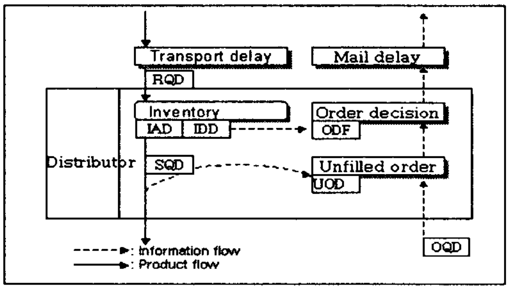
The next is order quantity, from retailer to distributor. It is order quantity, from Retailer to Distributor that reflected by inventory optimization module. A numerical formula is as follows

$$ORD_k = IDR_k - \{ IAR_k - (1 - UOR_k) \} \quad IAR,\ UOR\ are\ volume(1.3)$$

That is

$$ORD_k = IDR_k - RQR_j - RQR_k + OQR_j + OQR_k ....(1.4)$$

3.4.2 Distribution section



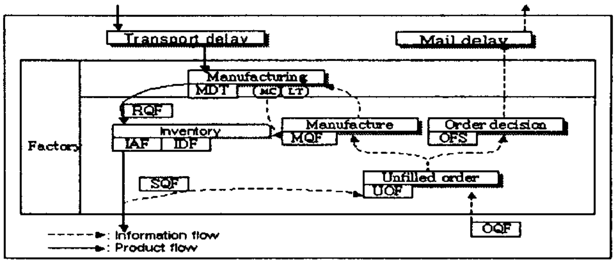
<<Figure 6: Distribution section>>

Given value
IDD : Inventory desired level at distributor(volume)

Parameter
UOD : unfilled order at retailer(rate)
IAD : Inventory actual level at retailer
ODF : Order quantity, from distributor to factory

UOD_k, IAD_k, ODF_k is the same methods in retailer section.

3.4.3 Factory section



<<Figure 7: Factory section>>

Given value
IDF : Inventory desired level at factory(volume)

Constant
LT : manufacturing lead time
MC : manufacturing capacity

Parameter
UOF : unfilled order at factory (rate)
IAF : Inventory actual level at factory
OFS : Order quantity, from factory to suppler
MQF: Decision manufacture quantity at factory
MDT: Manufacture delay time

UOF_k, IAF_k, is the same methods in retailer section.
also, it is decided as follows , how much quantity are produced.

$$MQF_k = \begin{bmatrix} MQF_k & \text{if } MQF_k \le MC \\ MC & \text{if } MQF_k > MC \end{bmatrix} \quad MC\ is\ capacity...........(3.1)$$

The next is manufacture quantity. It is quantity that reflected by inventory optimization modules.

$$MQF_k = IDF_k - \{ IAF_k - (1 - UOF_k) \} \quad IAR,\ UOR\ are\ volume(3.2)$$

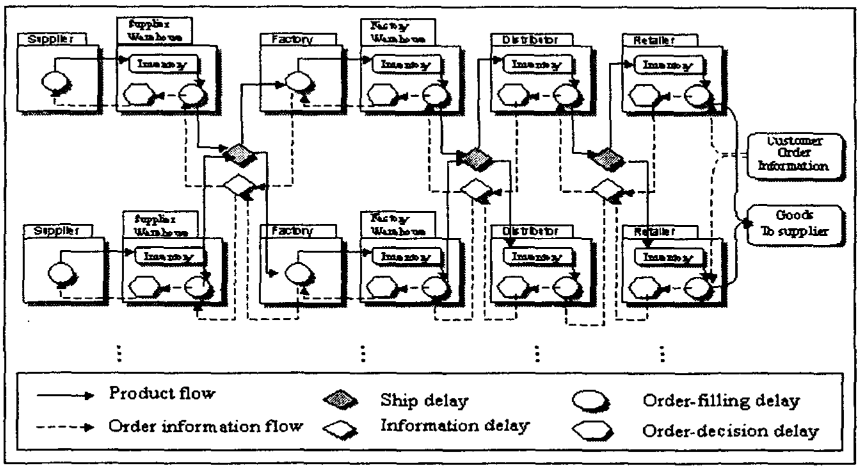
and $MQF_k = OFS_k$

than MQF_k is

$$IDF_k = RQM_j - RQM_k + OQF_j + OQF_k (3.3)$$

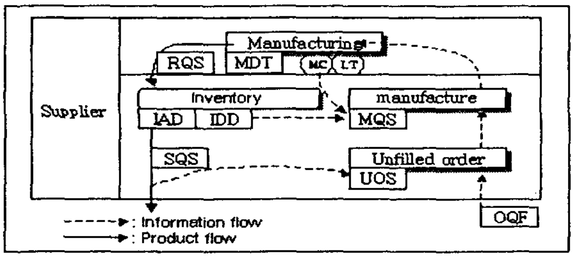
Besides, $N(OFS_k)$ could be a order quantity to supplier if it was that ratio of goods versus parts is 1 against N.
Lastly, a numerical formula is as follows as to manufacture process

$$MDT_k = LT\left(\frac{ROM_j + ROM_{j+1}}{MQF_j + MQF_{j+1}}\right) \quad LT\ is\ Lead\ Time..........(3.4)$$



<<*Figure 4 : Organization of supply chain system*>>

3.4.4 Supplier section



<<*Figure 8: Supplier section*>>

Given value
IDF : Inventory desired level at factory(volume)

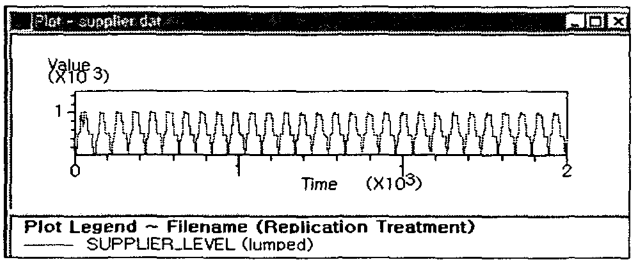
Constant
LT : manufacturing lead time
MC : manufacturing capacity

Parameter
UOS : unfilled order at supplier (rate)
IAS : Inventory actual level at supplier
MQS: Decision manufacture quantity at supplier
MDT: Manufacture delay time

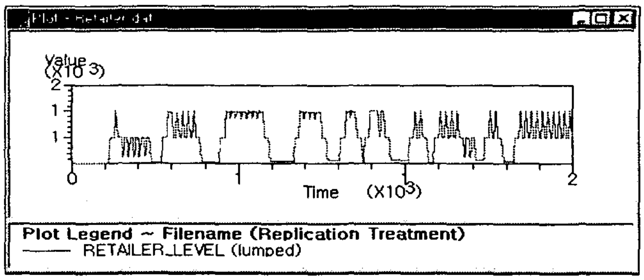
UOS_k, IAS_k, MQS_k, MDT_k are the same methods in Factory section.

4. Experiment

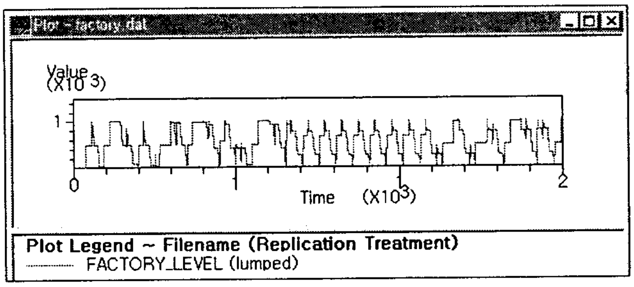
This chapter executes experiments for evaluating model and to being proposed architecture through chapter 3. Experiments using continuous modules in ARENA. Simulation results are as follow.



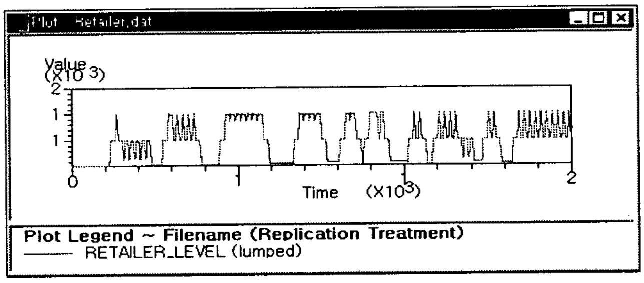
<<*Figure 9: supplier inventory* >>



<<*Figure 10: Distributor inventory level*>>



<<Figure 11: Factory inventory level>>



<<Figure 12: Retailer inventory level>>

It reveals that all inventory level in supply chain can be reflected continuous property.

5. Conclusion

In this paper we have discussed an approach to demonstrating supply chain simulation concepts, and combined modeling for supply chain simulation.

The discrete-event simulation has the advantage of model building. Moreover, discrete-event simulation is in common use method generally. But, it bring about inadequacy of input data or loss of accuracy. Also it is unbecoming of representation of continuous data(inventory level, rate).

In this papers developed the combined modeling representing levels and rate, for solving problem that is mentioned.

We give proof of combined simulation modeling through simple experiment.

Combined simulation modeling helps manages to observe the supply chain macroscopically. In further research, we are in the process of developing much more graphical output of data so that decision-maker see how the supply chain acts over time. Besides, It is necessary that we must develop more detail modeling. Lastly, this paper is just one try to explain and demonstrate the supply chains. No one approach is sufficient, given the general SCM or the broad scope of SCM.

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