Supply-chain Simulation Integrated Discrete-event Modeling with System-Dynamics Modeling

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Abstract

This paper describes a novel simulation framework that integrates discrete-event modeling with system-dynamics modeling. The former has strength in system performance evaluation; meanwhile, the later has an advantage of representing feedback mechanisms in complex systems. We are currently developing a hybrid-modeling framework, which combines discrete-event modeling with system dynamics modeling. The objectives of this framework are: (1) to simulate feedbacks of supply-chain activities in social system mechanisms, (2) to enable management simulation in long time terms, and finally (3) to clarify requirement specifications towards supply-chain management gaming. This paper summarizes this framework and represents application examples.

Keywords

Supply-chain management, Enterprise modeling, Production control, System-dynamics simulation, Discrete-event simulation.

1 Introduction

A supply-chain is a network of autonomous and semi-autonomous business units collectively responsible for procurement, manufacturing, distribution activities associated with one or more families of products.

Supply chain planning is, in a sense, restructuring a business system for supply chain members to collaborate with each other by exchanging information. Supply chain managers, in both planning phases and operational phases, face various kinds

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of problems, such as capacity planning, production planning, inventory planning and others. Systematic approaches are needed to support planning and control of such supply chain systems.

Simulation is an effective tool for system performance evaluation. Many commercial simulation software products have been developed and used for manufacturing and logistics systems, when practitioners evaluate system performances in "what-if" scenarios. These software products belong to discrete-event types that represent target system behaviors as a set of events and activities. Meanwhile, system dynamics has been mainly used to predict social systems' behaviors such as urban transportation systems, national growth and its effect on environmental problems [1][2]. These are very well known as "Urban dynamics" and "Environment dynamics". Discrete-event simulation has strength in system performance evaluation; on the other hand, system dynamics simulation has an advantage to represent feedback mechanisms in target systems.

The authors are developing a new simulation-modeling framework based on a hybrid modeling approach, which combines discrete-event modeling with system dynamics modeling. The objectives of this framework are: (1) to simulate feedbacks of supply-chain activities in social system mechanisms, (2) to enable management simulation in long time terms, and finally (3) to clarify requirement specifications towards supply-chain management gaming. This paper describes its modeling framework and an application example.

2 Supply-chain simulation model

2.1 System views and Features-elements model

Any system modeling requires clarifying system view. This effort proposes modeling a supply chain system from different views relevant for its performance management. We introduced four views for supply chain systems that the stakeholders of implementation of supply-chain models may be interested in [3]. These views are "Organization", "Control", "Activity", and "Communication".

"Organization view" clarifies the roles of members that belong to a supply-chain system. Although various supply-chain members, the types of these members are countable. We defined six categories of chain members' organizations. These abstracted types are as follows.

- *Supplier*: A member gets and provides materials, parts, or products in the chain.
- *Source*: A member provides primal materials or parts in the chain. This member would be a start point of material-flows in the chain.
- *Storage*: A member stores materials, parts, or products.
- *Consumer*: A set of members that send purchase orders and acquire products.
- *Deliverer*: A member transports products, parts, and/or materials between chain members.
- *Planner*: A member that controls material-flows and information-flows in the chain.

"Control view" elucidates material management control policies. Two types of broad operational policies are introduced to control operations of members in a supply chain system: "Schedule-driven control" and "Stock-driven control". The former is a "*push*" control method, which is based on a central "Master Production Schedule" (MPS), meanwhile, the later is a "*pull*" control method, which is based on stock volume information in the down-stream supplier.

"Activity view" defines core activities that are classified into following seven groups: these are *Resources and facilities management, Planning, Manufacturing, Transportation, Storing, Material management, and Communication.*

"Communication view" clarifies the role of communication that activates chain member. The communication would be a driving force for sharing information and exchanging data among chain members. The collaboration among chain members is activated through information sharing and data exchanges. Supply chain systems usually own a special member (Planner), which plays a central role in communication among chain members. The planner produces processed data and information, which are needed to manage all over the chain. These major data items are used for planning and control in both production and inventory management activities. The communication data can be classified as below.

"Feature-elements model" is a set of activity models that represent business processes by using abstracted descriptions of the chain members. This is also a set of library of simulation models based on commercial simulation software. Each member's model is classified into two types by generic control methods: "Schedule-driven" control and "Stock-driven" control [4].

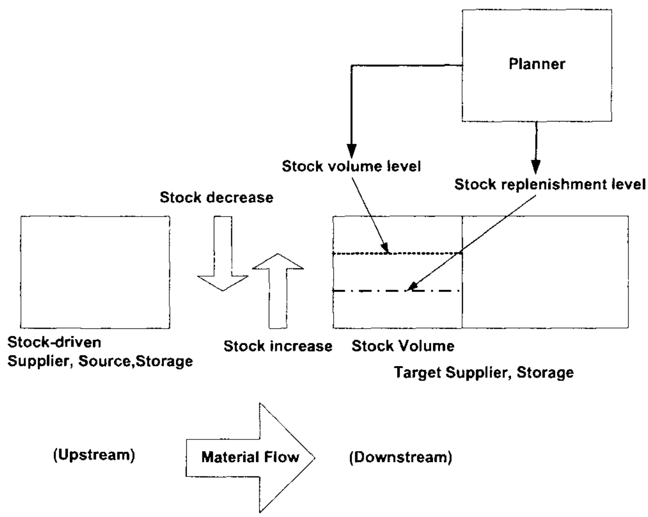

Figure.1 Stock-driven control

The schedule-driven control uses a production schedule, which is a so-called "Master Production Schedule" (MPS), generated by a supply chain planner. The chain planner periodically collects demand data from marketing channels in a constant cycle time, and it updates the MPS by using accumulated, demand prediction data. MPS is a schedule about when finished-goods are delivered to consumers. Meanwhile, the stock-driven control is based on autonomous operations of upstream suppliers using buffer inventory data of its down-streams suppliers (Figure.1). These models are expansions of our previous research and abstractions of material management policies in discrete manufacturing systems [5][6][7]. In the "Feature Elements models" layer, representations of various types of management controls in a chain are available by using combination of these control methods.

2.2 Scenario models

An activity is a sequence of events. Discrete-event models, accordingly, fit with operational activity in business and operational processes such as manufacturing, inspections, shipping, transportation, and their planning. Meanwhile, simulation will need another different modeling methodologies, if the simulation considers the feedback of the simulated activities from the external world. This is because input parameters to simulation are often considered as feedback data from the system behaviors.

Suppose that a supply-chain system realized a high performance and it shortened the consumers' purchase lead-time. The demand volume in a market, in this case, would increase, because the supply-chain could establish customers' satisfaction. The system would be busy for the increased demand, and consequently it would not be able to realize short lead-time operations. Similar scenarios would be appropriate to other supply-chain systems' activities such as quality improvement program in factories; manufacturing processes automation programs, and efficient transportations operations. System dynamics modeling is one of the typical simulation techniques that provide such feedback scenarios (Figure.2).

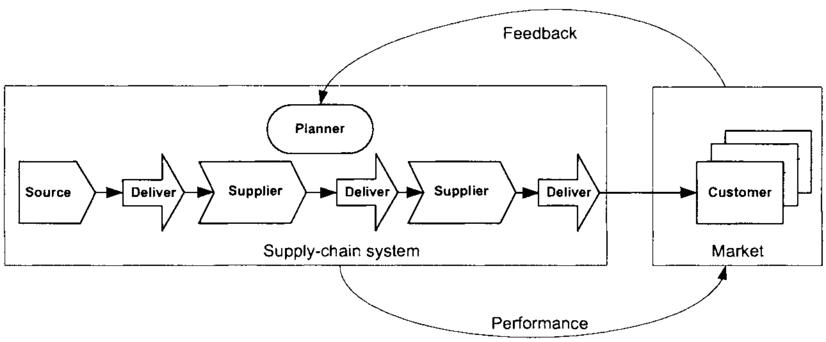

Figure. 2 A relationship between supply-chain performances and feedback from market

Figure.3 shows an outline of scenario of a simple dynamics model. Performance of product manufacturing depends on its manufacturing capacity and order volume from customers. The order volume increases, if customers' satisfaction goes up. Increased order volume would be another constraints on manufacturing and shipment process. This will be a cause of lead-time reduction and a downturn of customers' satisfaction. The average demand will be periodically going up and down.

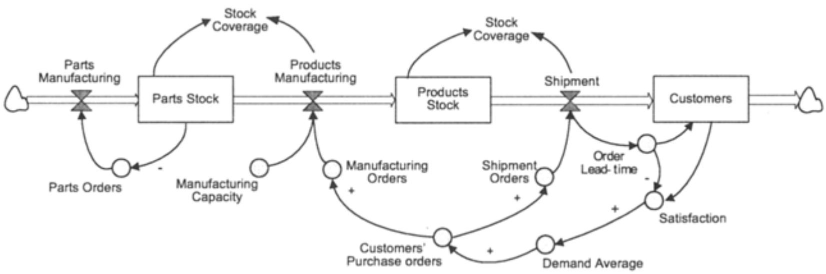

Figure. 3 Supply lead-time reductions and customers' satisfaction

Figure.4 is another scenario model using system dynamics notations. The system is a small chain, which poses two manufacturing resources (Product manufacturing and Parts manufacturing) and two manufacturing buffers (Parts inventory and Product inventory). The products and parts manufacturer work in Make-To-Stock operational strategy. "Desired inventory level" and "Desired WIP level" are major control parameters in this system. In this case, many factors form a complex causal relationship. Desired Production volume, for an example, produces positive effect on the "Desired WIP volume", and the "Desired WIP volume" is effectual on manufacturing cycle-time.

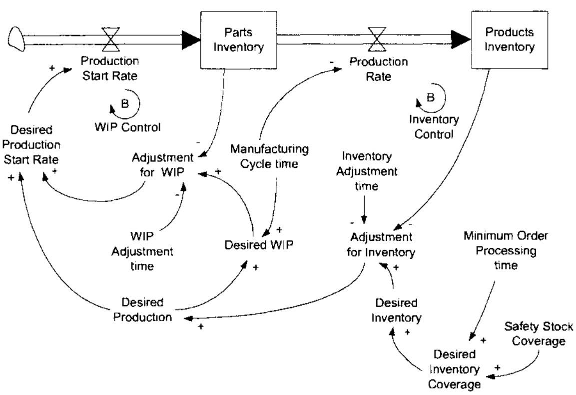

Figure. 4 Decision processes of parts & product inventories in Make-to-Stock supply-chain

3 Application to a manufacturing supply-chain

3.1 Target system

We discuss here an application of the proposed simulation to an actual manufacturing supply-chain. Final assembly factory must keep its DGR (Daily-Going-Rate) on the level from 100 to 250 products. Almost supplier provides part to final assembly in MTO (Make-To-Order) mode. The planner generates schedules on suppliers by using order data from customer. The planning cycle-time is one week. Only one supplier (S3) receives orders every other week and it delivers parts to the assembly factory two times in a week. This means that the order changes often occur in this operation. Particular two suppliers (S2 and S4), meanwhile, provide parts to the final assembly by MTS (Make-To-Stock) mode. A difficulty arises here, because these two are located in long distance from final assembly factory. The delivery lead-time between them will be one of key issues to determine both "Stock volume level" and "Stock replenish level".

System includes two 2nd-tier suppliers. One of them (S41) has a hard resource constraint, because it is a small-sized manufacturer. Its downstream supplier needs to pose much volume of parts inventory as its buffer.

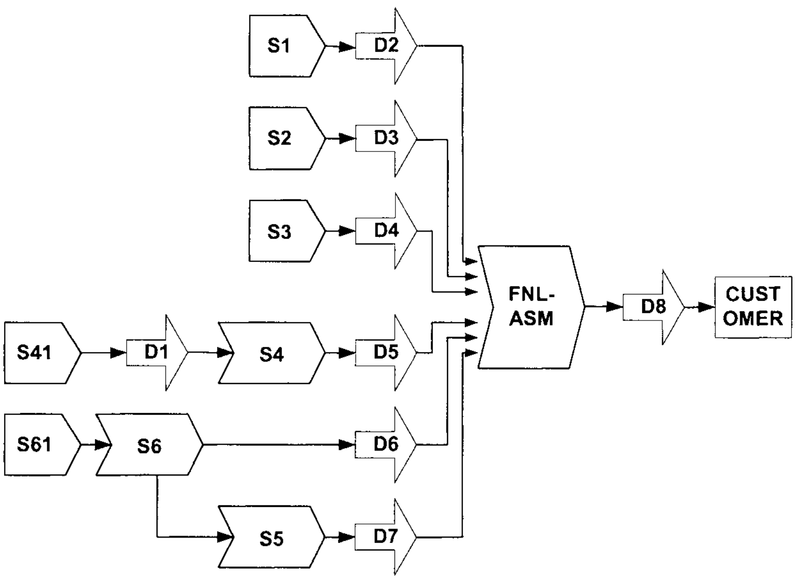

Figure. 5 Configuration of the target supply-chain system

3.2 Potential problems

A previous research discussed typical supply-chain management problems [3]. It would include the following items: "Rough-cut Supply-chain Capacity planning", "Supply-chain Capacity Requirement planning", "Resource planning", "Lead-time planning", "Aggregate Production planning", "Operational production planning", "Supplier selection", "Outsource planning", and finally "Operational strategy selection". We analyzed the target supply-chain system, and found that the lead-time planning problem and operational strategy problem are critical issues in this case.

The term "Lead-time" has basically two meanings: a span of time required to perform a process (or series of operations), and the time between recognition of the need for an order and the receipt of goods. The second one is often used in a logistics context. Individual components of lead-time can include order preparation time, queuing time, processing time, move or transportation time, and receiving and inspection time. We use this term in this paper with its second meaning. This problem directly impacts the inventory planning problems through the Lead-time inventory, the inventory that is carried to cover demand during the lead-time. The examples of this class of problems are:

- When and what suppliers should produce, and associated due dates?
- When and how much volume of products or component parts should be transported?
- Which transportation channels should be used?
- Suppose that all of the factories in the chain use a common database for purchase ordering process, what impacts occur on total lead-time in the chain?

The operational strategy selection problem includes selecting the strategy to operate the supply chain. Suppose that the supply chain designer has solved the primary problems, has selected the best business partners as his/her suppliers and has decided the non-core processes to be outsourced, s/he still needs to decide how to control the flow of products through the supply chain. The problem examples are as follows:

- How to choose between PUSH, PULL, and Hybrid PUSH-PULL?
- How to choose the strategy such as STS, MTS, ATO, MTO, at each stage of the supply chain?

4 Conclusion

The system configuration discussed here has been partially scale-downed from the original configuration. We, however, believe that the configuration poses essential supply-chain management issues. We, here, designed system dynamics models representing interlocking mechanism that couples stock replenishment levels with market demands in stock-driven control operation, and tried a simulation. We used a method that occurs events with a constant interval time to represent implicitly parameters relations described in system dynamics models. We also chose to a method to decompose dynamics models into functions that integrate with discrete-event models.

We got a simulation result, however it is our future work to get more detail results that enable us to clarify systems' characteristics. We used a model that is partially simplified. The scale of the model is still more, vary large, and the mechanism is very complex. The efficient simulation methods and systematic modeling libraries will be needed to integrate discrete models with dynamics models in real system modeling.

5 References

[1] R.G. Coyle, System Dynamics Modeling – a Practical Approach, Chapman & Hall, London, 1996

[2] J.D. Sterman: Business Dynamics – System Thinking and Modeling for a Complex World, Irwin McGraw-Hill, 2000

[3] S. Umeda: SCMM: Supply Chain Maturity Model, Proc. of 2004 PROMAC conference, 2004

[4] S. Umeda and T. Lee: Design specifications of a generic supply chain simulator, Proc. of 2004 Winter Simulation Conference, pp.1158-1166, 2004

[5] S. Umeda: Planning and Implementation of Information system in supply chain system, Journal of Society for Project Management, Vol.5, No.4, pp.42-48, 2003

[6] A. Davis and J. O'donnell, Modeling complex problems: system dynamics and performance measurement, Management Accounting Today, May, pp.18-20, 1977

[7] S. Umeda and F. Zhang, Supply chain simulation: generic models and application examples, Production Planning & Control, Vol.17, No.2, pp.155–166, 2006