

DEVELOPMENT OF WEB-BASED SIMULATOR FOR SUPPLY CHAIN MANAGEMENT

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ABSTRACT

Designing and planning of supply chain network (SCN) is one of the most important decisions to be made in dynamic business environment. Under today's dynamic circumstances, SCN is too complex to allow realistic models to be evaluated analytically. For this reason, we have developed a new simulator. This simulator provides most of the features needed to build a simulation model and can be accessed through the internet. Java Server Page is used to allow users to run this simulator through the internet, and MS-SQL is incorporated to save the computational results and input data.

1 INTRODUCTION

Supply Chain Management (SCM) is defined as a method that manages a network of interconnected businesses and its overall process involved in product provision and distribution to provide customer services. In large, Supply Chain Network (SCN) is a collection of functions and activities related to the product flow from factories to Distribution Centers(DCs), and from DCs to retailers, and the objective of SCM is to secure profit maximization through effective integration and management of SCN (Lee et al. 2002). As shown in Figure 1, Kim, Jeong, and Lee (2003) dealt with a 3-layer SCN consisted of numerous factories, retailers and one single DC. However, in the actual SCN, DC can be divided into a multi-layered central distribution center and regional distribution center (Yoo, Kim, and Rhee 1997). Given this, Kim, Jeong, and Lee (2003)'s 3-layer SCN may not completely reflect the actual SCN. This research provides a look at i-layer SCN (i stands for the number of SCN layers ($i \geq 3$)). Provided that j is the number of DC layers ($j=i-2$), Kim, Jeong, and Lee (2003)'s SCN is equivalent to $j=1$, and the range of j discussed in this paper is over 1. As seen in Figure 2, which is an example of 4-layer SCN($j=2$), 3 DCs are consisted of 2 layers while SCN in total involves 4 layers. The product passes via the layers from the factories in Layer 1 through DCs in Layer i-1 to the retailers located in Layer i.

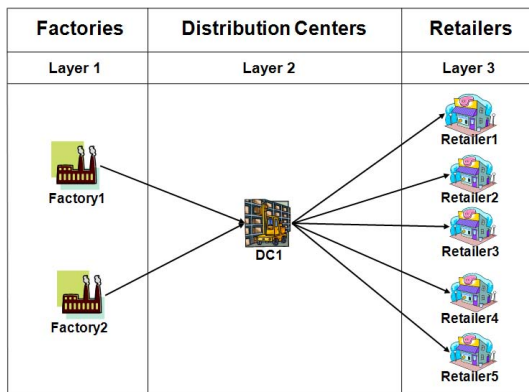


Figure 1: An example of 3-layer supply chain network

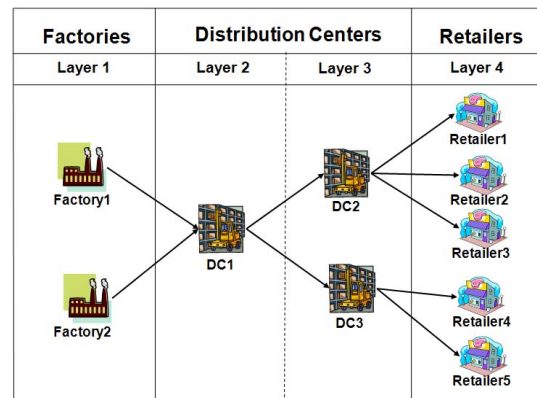


Figure 2: An example of 4-layer supply chain network

Sengupta and Turnbull (1996) predicted that the improvement in traditional logistics network could save about \$10 billion in distribution costs and reduce 41% of the inventory. Mathematical models and simulation methods have been used to

make decisions about SCM. SCN is usually referred to as a network and involves dynamic behavior while its activities include probability characteristics. Given SCN's large scale, it is difficult to deduce the optimal value through mathematical models. Thus there have been developments and researches on SCM simulators (Lee et al. 2002, Anderson, Evans, and William 2006). Realistic models can be built and evaluated by using developed simulators. NOKIA research center developed LOGSIM (LOGistics SIMulator) for its SCM simulation. The developed simulator is based on a discrete-event simulation model and involves suppliers, factories and customers. The factory consists of production and construct on processes, and supports MRP (Material Requirements Planning). IBM also developed a simulator called SCS (Supply Chain Simulator) (Bagchi 1998). SCS also utilized a discrete-event simulation model and evaluates the simulation model by using various measures such as average inventory, total profits and expenses, as well as resource utilization rate. SCS enables the optimization of inventory and supply through its Inventory Optimizer and recommends optimal product allocation in its factories and warehouses by using the Supply Optimizer. SCS also offers animation. Other simulators include SM2ILE (Moynihan et al. 1995), LSD (Ronen 1998) and LOCATE4 (Cleveland Consulting Associates).

The development of the internet technology and the expansion of infrastructure promote the need to develop web-based simulators. However, stand-alone simulators suffer drawbacks in that software installment is required to use a simulator, thus making them only available in computers with related software. Meanwhile, since web-based simulators run on web servers, they secure competitive edge in that they can be deployed in any computer connected to the internet.

In their review on web-based simulation, Kuljis and Paul (2000) presented environments for web-based simulation such as DEVJSJAVA (Sarjoughian and Zeigler 1998) and JSIM (Miller, Ge, and Tao 1998). This served as a base for other web-based simulators in the manufacturing (Baker, Parunak, and Erol 1999; Seo, Kim, and Suh 2006; Rohrmeier 2000) and military (McGlynn and Timian 1999) sectors as well as in SCN (Kim, Jeong, and Lee 2003). Kim, Jeong, and Lee (2003) implemented ASP and MS Access97 on the web to create a 3-layer SCN simulator. However, as described above, the simulator of Kim, Jeong, and Lee (2003) only enables 3-layer SCN, thus cannot create and simulate a SCN model with more than 4 layers on the web, or 2 DC layers. For this reason, a simulator able to produce and simulate an i -layer SCN model ($i \geq 3$) on the web should be developed.

A web-based simulator with the capability to create and simulate a SCN model on the web is developed, in this research. The developed simulator supports a multi-layer DC design and users can see the results on the web. Users can also analyze the simulation results and deduce better alternatives by varying the parameters. The second chapter of this paper covers the SCN simulation model, which is the main focus of this research. The third chapter describes the newly developed web-based simulator. Lastly, the fourth chapter summarizes the web-based simulator and touches on researches that are additionally required.

2 SCN MODEL

A SCN usually consists of factories, DCs, retailers and transportation vehicles. The real world SCN may include other complex agents such as suppliers that provide raw materials to the factories, but the SCN in this paper only takes factories, DCs, retailers and transportation vehicles into account while handling different types of products of specific sizes. The SCN presented in this research involves factories, DCs and retailers as shown in Figure 2, and DCs only can have more than 1 layer. The explanation of each agent described in this paper's SCN is as below.

1) Factory

Factories make products to satisfy consumer demand in SCN, and ship them to DCs. The preconditions of the factories are as follows.

- One factory produces only one type of product and has Per Hour Production Capacity.
- Production policy follows to MTS (Make-To-Stock). MTS is a process where a fixed quantity of goods is produced within a certain period of time.
- The factory has warehouses to store products and has capacity limits.
- If an upper layer DC places an order, the right quantity of products are taken out from the warehouses and transported to the DCs by vehicles. If the order quantity exceeds the inventory, a backorder is created with the remaining quantity and the products are delivered when there is sufficient inventory.
- Production cost per unit varies according to the factory.

2) DC

DCs, which are located between factories and retailers, can also have a multi-layer structure as shown in Figure 1. DCs receive products from factories or lower layer DCs and deliver them to upper layer DCs or retailers. The preconditions of DCs are as follows.

- DCs have a maximum warehouse capacity just like the factories and can choose between the Q-system (Continuous review policy) and the P-system (Periodic review policy) as their inventory policy. Q-system checks the

remaining inventory for every retrieval and determines the reorder time. P-system reviews the inventory on a regular basis and orders the amount of the difference if the inventory is lower than the maximum inventory level.

3) Retailer

Retailers are where customer demand occurs and consumes products from factories. The preconditions of retailers are as DCs, and the inventory changes according to the demand. Retailers also conduct SCN activities such as order, transportation and production.

4) Transportation vehicle

Transportation vehicles are allocated to factories and DCs, and deliver products among agents to fill the orders. The preconditions of transportation vehicles are as below.

- All vehicles have capacity limits.
- Vehicles cannot go to different agents simultaneously and can only transport products to one single destination.
- Vehicles return to their initial bases after each transportation and ship products to one of the destinations based on the order.

Operating costs of SCN include production, inventory and transportation costs. Each production cost is calculated as follows.

- Production costs = (Unit production cost) × (Total output)
- Inventory costs = (Unit inventory cost) × (Inventory per day)
- Transportation costs = (Transportation cost per 1km) × (Distance)

SCN can be evaluated with various measures such as operating costs, car utilization and backorder, which are deduced from the SCN simulation.

3 FORMATTING THE FIRST PAGE

The developed web-based simulator is to create and simulate SCN described in chapter 2 for effective decision making. The new simulator differs from others in that the simulation is employed on the web. Traditionally, exclusive software such as SCS, LOGSIM as well as other software such as Arena and AutoMod that were used for SCN simulation took up too much storage space and required expertise for the users. However, the new web-based simulator has advantages in that simulation can be conducted anywhere where there is internet connection and is designed for easy simulations. In real life, as the market becomes globalized and distribution structure complex, products pass through many channels. In fact, products go through several DCs in between factories and customers. Thus the developed simulator supports a multi-layer DC design close to the real model.

The new simulator is developed by using JSP (Java Server Page) and MS-SQL, and is run with Tomcat 6.0 and Apache server. As shown in Figure 3, the web-based simulator for SCN mainly consists of Supply Chain Model Generator, Simulation Engine, and Results DB. The simulation engine includes the Event Generator, Rule DB and the Event Calendar. Supply Chain Model Generator designs the model based on users parameters while the Simulation Engine produces an outcome through simulation. The simulation model and outcome are then saved in the Results DB, and users check the simulation model and its result through a web browser.

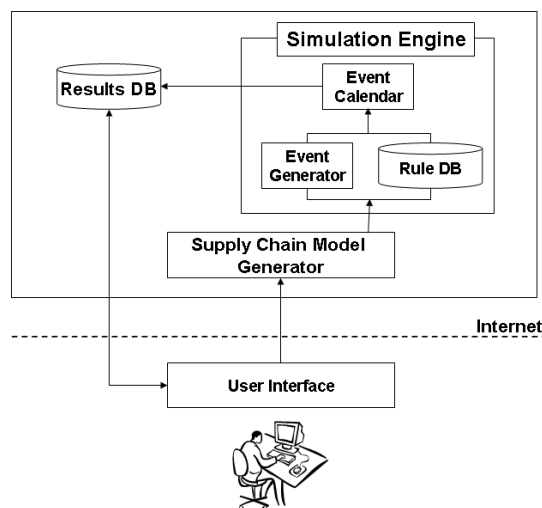


Figure 3: Architecture of the web-based simulator

3.1 Supply Chain Model Generator

The Supply Chain Model Generator builds the simulation model by receiving the parameters required to create the SCN model. The simulation parameters are determined in 3 steps through the web browser. The parameters for each step are as follows.

In step 1, the basic parameters required for the SCN simulation is determined through the web browser.

- Number of factories, DCs, and retailers
- Number of product types, simulation days, and the number of layers

The ‘number of layers’ that appears on the web represents the number of SCN layers. For instance, the users input ‘4’ for the ‘number of layers’ and ‘3’ for the ‘number of DCs’ on the web to create a 4-layer SCN model as in Figure 2. The users also input DC1 in Layer 2, DC2 and DC3 in Layer 3, ‘2’ for the ‘number of factories,’ and ‘5’ for the ‘number of retailers.’ The determined factories and retailers are automatically placed in Layer 1 and Layer 4.

In step 2, the following is determined according to the parameters determined in step 1.

- Agents, product information, and customer demand by simulation days
- Vehicle maximum capacity, vehicle speed, and transportation cost per distance
- Locations of factories, DCs and retailers, and size of each product
- Production type of factories, inventory policies of DCs and retailers, number of vehicles

The locations of factories, DCs and retailers are inserted as x-y coordinates, and the production type for each factory is selected MTS. The inventory policies for each DC and retailer follow either the Q-system or the P-system.

In the last step 3, the following is determined according to the parameters determined in steps 1 and 2.

- Manufactured product type of the factory, per hour production capacity
- Parameters required for the determined DC and retailer inventory policies
- Network design and distance among agents

In step 3, the parameters required for the inventory policies are determined. For example, when the P-system is selected in step 2, the inventory review interval and the maximum inventory level are determined; when the Q-system is selected, the reorder point and order quantity are determined. The network is designed by inputting the distances among factories, DCs and retailers.

	Factory1	Factory2	DC1	DC2	DC3	Retailer1	Retailer2	Retailer3	Retailer4	Retailer5
Factory1		70	100							
Factory2			80							
DC1				120	160					
DC2						70	60	80	0	0
DC3						0	0	0	70	110
Retailer1							50	40	0	0
Retailer2								80	0	0
Retailer3									0	0
Retailer4										83
Retailer5										

Figure 4: Input network design and distance among agents

The SCN simulation model is completed by the combination of parameters determined in each stage, and the results are evaluated via the simulation engine.

3.2 Simulation Engine

The simulation engine performs the simulation of the SCN model created in 3.1. As shown in Figure 3, the simulation engine consists of the Event Generator, Rule DB and the Event Calendar. The simulation is operated by the Event Generator and the Rule DB, and the simulation results are recorded in the Event Calendar.

In order to perform a simulation, event generating rules that occur in the SCN needs to be decided. Events such as ordering, transportation and product production are generated according to the inventory and production policies. The Rule DB stores these rules, and functions as the platform for creating simulation events. The example rules used for the given simulation are as follows.

- The simulation business hours are from 08:00AM to 08:00PM. The vehicle operation hours need to be within the simulation timeframe for the vehicles to start transporting. If the vehicles operate outside the simulation timeframe, they will operate the next day.

The Event Generator creates events according to the simulation rules during the simulation operation. The following events are generated for each agent.

- Factories: product production, product storage
- DCs: product storage, ordering
- Retailers: product storage, ordering, customer demand management
- Vehicles: standby, prepare for transportation, transportation, arrival, returning

The total cost (the sum of inventory, production, vehicle operation and other costs) for the SCN can be estimated through the simulation, and the following results can be obtained for each agent.

- Factories: operability, inventory levels by time and date, production cost, inventory cost, production output, etc
- DCs and retailers: inventory levels by time and date, backorder size, inventory cost, etc
- Vehicles: availability of each vehicle, distance of each vehicle, vehicle operation cost

3.3 Simulation Results

By using the simulator developed in this research, we built a model and simulation of SCN as shown in Figure 2. The parameter values used in this simulation are as displayed in Table 1, and the users, through the web simulation, can monitor the inventory per time unit in factories, DCs and retailers, the vehicle condition, the customer demand satisfaction rate, as well as the total operating cost of SCN.

Table 1: A set of parameters for experiment

Number of layers		4	Product volume		1	
Number of product types		2	Customer demand		Random generation[100,400]	
Number of factories/ number of DCs/ number of retailers			2/3/5			
Simulation days		7 days				
Vehicle	Capacity	2000	Speed	60		
Factory1	Production type	MTS	Capacity	80 units per a hour		
	Number of vehicles	3 units	Product	Product 1		
Factory2	Production type	MTS	Capacity	100 units per a hour		
	Number of vehicles	3 units	Product	Product 2		
DC1	Inventory policy	P-system	Layer	2	Inventory level	8000
	Number of vehicles	3 units	Review interval	1 day		
DC2	Inventory policy	Q-system	Layer	3	Order quantity	2000
	Number of vehicles	3 units	Reorder point	2500		
DC3	Inventory policy	Q-system	Layer	3	Order quantity	1700
	Number of vehicles	3 units	Reorder point	700		
Retailer1-5	Inventory policy	Q-system	Reorder point	600	Order quantity	1000

Among the results derived from the simulation, the graphs in Figure 5, 6, and 7 represent the inventory level of each factory, the inventory level of product1 in DCs, and the utilization of vehicles operating in between factory1 and DC1 respectively. Figure 5 and 6 demonstrate the change of inventory level in factories and DCs on a time basis, with the x-axis standing for time and y-axis the inventory level, while Figure 7 shows the utilization of vehicles between factory1 and DC1. The utilization of Vehicle k is calculated based on (1), and we assumed that each vehicle operated 12 hours a day in maximum. If $U_k=1$, vehicle k operated for 12 hours, and if $U_k=0$, vehicle k did not operate at all. Provided that in Figure 7 $U_3=0$ during the simulation period, vehicle 3 was considered as unnecessary.

$$U_k = \frac{\text{Transportation times of vehicle } k \text{ per day}}{\text{Maximum transportation times per day}(12 \text{ hours})}, \text{ for } k = 1, \dots, n \quad (1)$$

n represents the number of total vehicles.

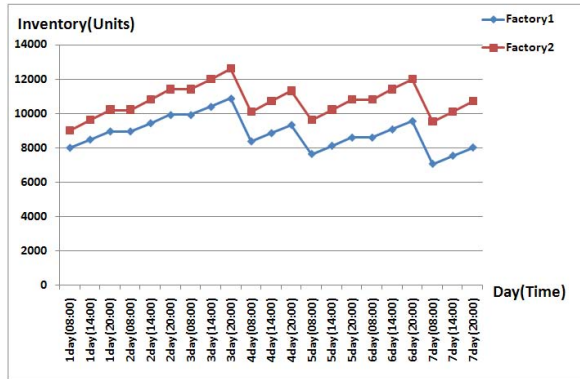


Figure 5: Simulation results for inventory in factories

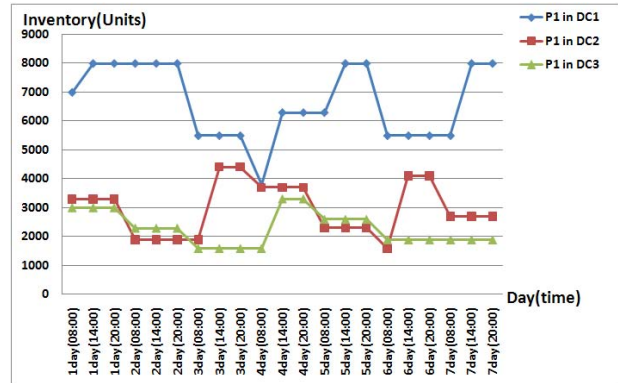


Figure 6: Simulation results for inventory in DCs

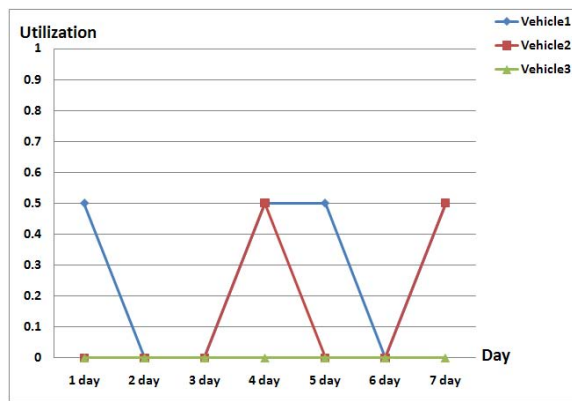


Figure 7: Simulation results for utilization of vehicles from factory1 and DC1

4 CONCLUSION

In this research, we have developed a web-based simulator that can design i-layer SCN on the web and evaluate the model by running a simulation. While conventional SCN simulations required computers that could run exclusive software, the web-based simulator that we have developed in our research provides the merit to the users to conveniently operate it in the internet environment. The users can not only use the new simulator to monitor the change in inventory level, the utilization of vehicles as well as the total operating cost but also to design an optimum SCN on the web by analyzing the simulation results and modifying the parameter values of vehicle numbers and inventory policy.

This research is now on the initial stage, and more research is needed to enhance the simulator. For instance, additional research on the development of an automatic decision support system able to determine the optimum factory, DC, retailer, as well as the number of vehicles to meet the users' needs, which is to minimize the inventory level while maximizing the use rate of vehicles, along with studies to analyze the accuracy of the simulator through comparative experiments with other commercialized simulators are required.

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