DEVELOPMENT AND EVALUATION OF VISUALIZATION SYSTEM OF GLOBAL CONTAINER FLOW FOR INTERNATIONAL MANUFACTURERS

Hisashi Takizawa^(a), Hiromichi Akimoto^(b), Kenji Tanaka^(c), Jing Zhang^(c)

^(a)Ministry of Land, Infrastructure, Transport and Tourism, Japan (At the time of study, The University of Tokyo) ^(b) Korea Advanced Institute of Science and Technology ^(c) The University of Tokyo

> ^(a)<u>hisashi.takizawa.info@gmail.com</u>, ^(b) <u>akimoto@kaist.ac.kr</u>, ^(c) <u>kenji tanaka@sys.t.u-tokyo.ac.jp</u>, ^(c) <u>chou@sys.t.u-tokyo.ac.jp</u>,

ABSTRACT

Because of the increase of the number of worldwide manufacturers especially those have their factories in Asia and major markets in Europe and the US, the lead time of transportation in manufacturers' supply chain is increasing. However, for shippers, status information of their container cargos and container ships are limited. It prevents the shippers from optimizing their logistics operation. Accordingly, the authors have developed a global logistics simulation of containers based on multi-agent method. The developed visualization system enables international manufacturers to support logistics management and comprehend container transportation. The simulation result shows that the proposed system can reduce shippers' logistics cost by 17%.

Keywords: logistics simulation, visualization, supply chain, multi-agent simulation, container flow

1. INTRODUCTION

1990, many of Japanese world-wide Since manufacturers have been developing their production sites in Asia. Therefore, the importance of supply chain management, which can administrate whole procurement process of product from factories to consumers, has also been increasing because lead time between factories and consumers in distant major markets has been increasing. Hence, the use of information management system, such as Enterprise Resource Planning system, is expanding.

However, since the development of factories in Asia attributes to long lead time between production and consumption places, demand fluctuation in distant market causes opportunity losses and dead stocks. This problem is caused by unshared information among many agents of global supply chain although they already implemented information technology in their other part of supply chain. Particularly, ocean shipment makes it difficult for manufacturers to catch instantaneous information of product because they receive information indirectly from shipping line and third party logistics companies, whereas ocean shipment lacks punctuality more than other transportation due to the delay by marine condition and offshore queue. This fact made manufacturers outsource transportation to third party logistics. As a result, information of time loss and time fluctuation is less transparent, which is unacceptable to factories and vendors.

To deal with this problem, radio-frequency identification device (RFID) has been introduced in order to capture real time information of cargo and incorporate them in production and transportation plan. In fact, there are movements for visualization of cargo in many parts of the world. In Japan, Ministry of Economy, Trade and Industry conducted an experiment of visualizing the transportation between Japan and the Netherlands. However, it has not achieved real-time visualization of cargo information. Therefore, it is necessary to develop a visualization system which enables the shippers to share cargo information with logistics companies, support their decision making of logistics simultaneously and to evaluate the effectiveness of the system.

Existing researches for these problems include Supply Chain Management (SCM). Since Oliver and Webber (1982) discussed SCM in 1982, many researchers have studied production and distribution for SCM, such as bullwhip effect and optimum inventory policy (Lee et al. 1997). As a recent study, Venu Nagali (2008) indicated that quantification of demand and price risk enabled Hewlett-Packard to reduce 300 million dollars manufacturing cost by proposing three different scenarios of risk and contracting suppliers with the proposition. Although transportation lead time is assumed to be fixed in these researches. Chandra Charu(2008) indicated that optimum stock volume and procurement volume depend on lead time. Thus, we should consider variable lead time in order to implement optimum supply chain.

On the other hand, some researchers had succeeded in the reduction of transportation cost by optimizing route and fleet of shippers' firm. As an example of the study of transportation network, Sato and Miyata (2006), Sato et al. (2007) and Kimura et al. (2008) modeled dynamic simulation of transportation and selection of lowest total cost route. However, these studies focused on only transportation of whole logistics. Although there are researches of applying RFID, most of them are focused on only direct effect, such as reduction of labor cost, labor hours, and mistakes by labor(Wang and Lin 2007, Chow and Choy 2007). There are not so many researches which showed effect of RFID on whole logistics. A particular example which is focused on the effect of RFID on whole logistics is by Bill C. Hardgrave(2008) It reduced the risk of stock shortage by implementing RFID in Wal-mart as an experiment. Also, Young (2009) demonstrated that introducing RFID make it possible for manufacturers, distribution centers and retailers to reduce average stocks when they can share visible information of inventory. However, those researches didn't include visibility of cargo during transportation.

As it can be seen in the above researches, approaches to manufacturing and retailing, and to transporting are separated and they didn't implement dynamic system which supports both shippers and shipping firms by integrating information. Thus, it is necessary to develop a system which integrates information of both shipper and shipping firms and visualizes them dynamically for global manufacturers.

In this paper, we will accomplish modeling of global production, transportation and consumption, and visualizing comprehensive container flow which can support management of logistics using actual operation data of a company. In the system, we consider the stock in transportation as well as the stock at the manufacturer and retailer because most of the lead time involved in logistics is marine transportation. The supposed users of the system are shipping firms and shippers.

In this study, we use actual data of a Japanese international electric manufacturer. The company has several product models, which are manufactured in three Asian areas, and shipped to vendors in North America, Europe, Japan, and other Asian countries.

In order to accomplish the above objective, we will construct a multi-agent and time-discrete simulation modeling manufacturing, transportation, and vendors described in the 2^{nd} chapter, implement visualization of shipper's dynamic logistics, the results of which are given in the 3^{rd} chapter, and evaluate validness of the simulation in the 4^{th} chapter.

2. MODELLING OF SIMULATION

2.1. Overview of Simulation

Since there are many agents in global transportations, we model each agent in the simulation. We also implement time scale in the simulation in order to model the dynamic and complex activities in container flow as in Figure 1. By utilizing the simulation of container transportation network by Takizawa (2010), we implement the multi-agent and time-discrete simulation which models international logistics.

We divided the simulation into 4 subsystems; Database, Operation, Management, and Viewer. Database subsystem holds the whole static and dynamic data of the system. Operation subsystem consists of players of global logistics, such as ports, vendors, and container ships and they have their own elements and functions. Management subsystem makes decision, such as demand forecasting and transportation schedule planning. Viewer subsystem is independent from other parts and it visualizes whole flow of container and analyzes the time variation of stock. In this system, the simulator notifies each subsystem of updating their status each time step. After updating all subsystems, Simulator increments time step. With synchronizing all subsystems, Simulator repeats this loop until the end of simulation.



Figure 1: Schematic Diagram of Simulation

2.2. Database subsystem

Database integrates and controls all information of production, transportation, and sales. One type of data is static data which is necessary to build up elements of Operation. The other type of data is dynamic data which writes and reads all agents in simulation. Our simulation saves latest information in Database, updates predictions of logistics and inventory and then supports management of logistics.

Static data includes data of area, factory, vendor, port, container ship, road transportation and demand. Dynamic data includes estimated container route schedule, actual container route schedule, sales forecasting and actual sales.

2.3. Operation subsystem

Operation models company's logistics in the real world. However, it is necessary to discrete each composing elements and model them in order to simulate nonlinear event, like logistics. Elements of logistics are cargo, container, container ship, road transportation, factory, vendor, and port, and the simulator includes them. We will construct the simulator by Java, one of the object-oriented languages, and define the above model of elements as Class, which packages both attributes and operations.

Cargo class models a group of products in the real world, thus, it has only attributes, no operations. Attributes are composed of a name of products, density, and the number of products. Container class is a unit of cargo when cargo can be transported on network, and has only attributes. Attributes are composed of a container ID, product list, maximum volume, current volume, estimated container route schedule, and actual container route schedule.

Containership class models a link whose concept is travelling around nodes in transportation network with discrete schedule. The attributes are composed of a name of a container ship, schedule list including time and place of both departure and arrival, and velocity. Operations are composed of updating schedule and updating global position.

Road class is a concept of a link which connects two nodes and provides continuous transportation. The difference of road transportation and container ship is whether their schedule is discrete or successive and the schedule is independent or not from clients. Attributes are composed of velocity, positions of origin and destination, and a container list. Operations are composed of updating the global position. In this simulation, we assume road transportation as trucks.

Factory class is a node which manufacture product based on plan. Attributes are composed of the global position and manufacturing plan. Operations are composed of producing, packaging product into containers, and loading containers on a link.

Vendor class is a node which sells products and consumes them in later based on daily demand. Attributes are composed of the global position and a demand list. Operations are composed of consuming products and loading containers on a link.

Port class is a node which is on the way of transportation and also handles containers. Attributes are composed of the global position and hold a container list. Operations are composed of loading and unloading container.

In order to initialize Operation subsystem, Management subsystem creates every element when the simulation starts. After simulation started, each element acts independently and represents complex container flow for the following.

- 1. Each factory produces a product in each time step and packages it into a container.
- 2. Road transportation delivers the container to a port.
- 3. The port loads the container on a container ship when it stopped the port.
- 4. After the container ship reached the destination port, the destination port unloads the container and delivers it to the vendor, the destination, by road transportation.
- 5. Upon arriving at the vendor, the container is unpacked and consumed on the time of demand. Products will disappear from the simulation when they are consumed.

2.4. Management subsystem

Management subsystem models a scheme that shippers make a decision of future logistics based on the past

records and simultaneously order plans to Operation subsystem. Thus, it has 4 functions; prediction of demand, planning of transportation, planning of production, and ordering plans.

In this study, we assume that the prediction of demand is accurate. When we have to consider the limited accuracy of prediction in the future study, we will apply non-linear sales forecasting which predicts future demands based on the past records in the simulation as indicated by Tanaka (2010).

Planning of transportation has three steps. Firstly, we detect practical transportation in order to limit the number of searching results of schedule. Since calculating every available schedule consumes much time and thus is unrealistic, we exclude the schedule which transit via hub ports. Secondly, we creates possible schedule by selecting several transportations between origin and destination, then calculate lead time and fee of transportation. Thirdly, we examine each schedule by the sum of fee and multiplication of lead time and time value. The optimum schedule is defined as minimum sum of the above.

In this study, planning of production is assumed to be deadline list of daily production which is calculated by planning of transportation and based on delivery date.

Ordering plans is a function which submits all the results of the decisions by Management subsystem to Operations subsystem.

3. VISUALAIZATION OF INTERNATIONAL CONTAINER FLOW

3.1. Visualization for supporting global manufacturing companies

Visualization which enables us to comprehend whole stock in a supply chain instantaneously can assess accurate stock and accomplish avoiding dead stocks and opportunity loss, and securing the most effective transportation route.

In this system, we implemented the following visualization methods developed by Nomura (2008) and Chou (2008).

3.1.1. Time series analysis

Figure 2 is an example of time series analysis of stock, arrival and sales of a certain product at a certain vendor. The upper graph is the time history of stocks in the inventory, and the lower graph is that of accumulated stocks. The red vertical line indicates current time and the right part of the line indicates the predicted future behavior. It is possible because we can visualize the future state by sharing information of containers in transportation and of prediction at the vendor. In addition, the accumulated curve enables us to assess the characteristic of a demand trend for each product model easily after the sales started. This information is useful for sales forecasting. As a result, this analysis may help us to avoid ordering ineffectual production plan because managers of manufacturers are able to see future stock and characteristics of selling.

3.1.2. Shipping lead time analysis

Figure 3 is an example which visualized stock in transportation with the same route. Colors show the time of places where containers have stayed, such as factory, port, and ocean. The horizontal line is ordered by the manufacturing time of each container. This analysis may help planning of production and transportation by assessing the dead stock based on manufacturing time and assessing characteristic of lead time each year.

3.1.3. Tracing analysis

Figure 4 shows an example of tracing analysis of a product for a vendor in order to assess stock in transportation based on their time of manufacturing. Each graph shows the progress of stock of the place, in order of process of logistics. Each layer is colorized by the week when they were produced. Therefore, when we find overstocking, it is easy to detect when the excessive group was produced and which part of logistics caused the problems. In general, the fast decrease of the thickness in a layer indicates fast turnover rate of the product. On the contrary, if a certain layer keeps its thickness longer time, we can easily assess whether the problem came from transportation, like emergent air transport, or came from the wrong production plan in the factory.

3.2. Visualization of container flow on globe

In the previous section, we visualized progress of stock at each place from upper stream to lower stream of the supply chain. In this section, we will visualize both a position and volume of cargo in transportation.

Figure 5 is an example of visualizing all of 1049 container ships, and volume of products in logistics on a plain map. This allows assessing the whole container ship and products on the earth instantaneously.

However, visualization on a plain map is not always informative for global manufacturers and marine transporters because long distance ocean routes are distorted and containers and ships look congested on the plain map. To solve this problem, we visualized on the globe as in Figure 6. The state of the simulation is displayed on Google Earth simultaneously. On the globe, ship routes are displayed correctly and more information are intuitively comprehensible. In fact, both of Figure 5 and Figure 6 are animation and displayed simultaneously during simulation.

Unfortunately we cannot demonstrate yet, we can propose several solutions which is beneficial both for manufacturers and shipping firms. For instance, implementing several global manufacturers makes it possible for both manufacturers and shipping firms to optimize fleet schedule based on future gross transportation. If one manufacturer has enough containers to charter container ships, marine transporters can optimize lead time and the number of ships based on the trend of products and time-value.



Figure 2 : Time Series Analysis of Stock (An Example of the Vendor in North America)



Figure 3 : Analysis of Shipping Lead Time of Each Container (An example of the Electronics Product)

4. EVALUTATION OF SIMULATION

4.1. Premises of evaluation

To verify the system, we evaluate our simulation by examining the Japanese electric company's actual logistics data. In the actual data, they have lots of dead stocks and inappropriate transportation schedule.

According to our assumptions for this evaluation, our simulation implemented prediction of demand in Management subsystem. Moreover, one effect of visualization, transparency of information by sharing logistics data with factories, transporters, and vendors, is quantitatively assessable. However the other effect of visualization, optical comprehension, is qualitative. Thus, we evaluate the former effect of visualization, sharing information and optimizing network.

Shipper's loss of each product is defined as sum of transportation fee C and multiplication of lead time T_t and time value V. Therefore, shipper's loss of actual data L_{actual} is defined as equation 1, and shipper's loss of simulation L_{sim} is defined as equation 2. In this case, the interval of simulation t_{end} is 2 years and C is either ocean tariff or air tariff. In actual data, the number of production and sales is different because demand prediction is not accurate and there are many dead stocks. On the other hand, the number of production and sales is same in simulation because we assumed demand prediction is accurate. Therefore, we must adjust the difference of number in order to major the

effect of planning transportation by visualization. V is decreasing 0.37[USD/Day], according to Sato (2006). The areas of vendors we have examined are Asia, Europe, and North America.

t end

$$L_{\text{actual}} = \{ \sum_{t=1}^{t \text{ end}} (V \cdot T_t + C) N_{\text{actual}_t} \} \frac{\sum_{t=1}^{t} N_{\text{sim}_t}}{\sum_{t=1}^{t \text{ end}} N_{\text{actual}_t}}$$
(1)



Figure 4 : Tracing Analysis of Shipping Stock (An Example of the Electronics Product; China to North America)



Figure 5 : Visualization of International Logistics on Plane Panel



Figure 6: Visualization of International Logistics on Google Earth

$$L_{\rm sim} = \{\sum_{t=1}^{t \, \text{end}} (V \cdot T_t + C) N_{\rm sim}{}_t\}$$
(2)

4.2. Result of evaluation

The result based on equation 1 and 2 is shown in Figure 7. While Asian sales areas has improved only by 8%, North American sales area has improved by 16%, and European sales area has improved by 20%. Converting to the amount of money, reduction of shipper's loss in Asian area was 2.7 million USD, reduction of shipper's loss in North America was 22 million USD, and reduction of shipper's loss in Europe was 14.5 million USD. The reason why European logistics improved most is that they have longest distance between factories in Asia and vendors in Europe. Thus, the optimization of transportation was effective in long distance logistics because high air tariff was replaced with cheap ocean tariff and ocean lead time become shorter. In total, shipper's loss was decreased by 16% and 39.3 million USD.

Summing up, we demonstrated the validity of the visualization of simulation by reducing shipper's loss, which is achieved by optimized transportation planning through transparent information between factories, transportations, and vendors.



Figure 7: Difference of Shipper's Loss of Cost and Time-value for Each Sales Area

5. CONCLUSION

We developed and visualized the system which models global logistics and supports management for manufacturers. Evaluation of simulation by actual data leads us to conclude that visualization of logistics makes it possible to reduce manufacturers' loss.

ACKNOWLEDGMENTS

This study was conducted in the University of Tokyo in 2011. The present affiliation of the first author, Ministry of Land, Infrastructure, Transportation and Tourism, Japan, is not responsible for the contents of this article.

REFERENCES

- Chandra, C., Grabis, J., 2008. Inventory management with variable lead-time dependent procurement cost. *Omega*, 36, 877 – 887.
- Chow, H.K.H, Choy, K.L., Lee, W.B., 2007. A dynamic logistics process knowledge-based system An RFID multi-agent approach. *Knowledge-Based Systems*, 20 (4), 357-372.
- Hardgrave, B.C, Langford, S., Waller, M., Miller, R., 2008. Measuring the Impact of RFID on Out of Stocks at Wal-Mart. *MIS Quarterly Executive*, 7 (4), 181-192.
- Kimura, T., Akimoto, H., Miyata, H. 2008. A design method of the container transportation network between Japan and China. *Conference proceedings*, *the Japan Society of Naval Architects and Ocean Engineers*, 439-442. May, Nagasaki (Japan).
- Lee, M.Y., Cheng, F., Leung, Y.T., 2009. A quantitative view on how RFID can improve inventory management in a supply chain. *International Journal of Logistics Research and Applications*, 12 (1), 23–43.
- Lee, H.L., Padmanabhan, P., Whang, S., 1997. Information distortion in a supply chain: The bullwhip effect. *Management Sci.*. 43, 546-558.
- Nomura,Y., 2008. Guro-bal seizougyou no keiei shien shisutemu no kenkyu[Simulation-Based Business Administration for Global Industrial Companies]. Thesis (Master). The University of Tokyo.
- Oliver, R.K., Webber, M.D., Supply Chain Management: Logistics Catches Up with Strategy, 1982.
- Sato, S., Akimoto, H., Miyata, H., Sato, Y., 2007. Route selection system of the sea-land combined container transport between Japan and China. *Conference proceedings, the Japan Society of Naval Architects and Ocean Engineers.* 487-490, May, Tokyo (Japan).
- Sato, Y., Miyata, H., 2006. Discrete type simulation of sea transportation between Japan and China, *Proceedings of Japan Society of Naval Architects* and Ocean Engineers, pp. 17-18, Tokyo(Japan).
- Takizawa, H., Takechi, S., Akimoto, H., 2010. Selection and evaluation of network and hub ports for international container transportation around

Japan, Journal of the Japan Society of Naval Architects and Ocean Engineers. 11, 173-179.

- Tanaka, K., 2010. A sales forecasting model for newreleased and nonlinear sales trend products. *Expert Systems with Applications*. 37, 7387–7393.
- Nagali, V., Hwang, J., Sanghera, D., Gaskins, M., Pridgen, M., Thurston, T., Mackenroth, P., Branvold, D., Scholler, P., Shoemaker, G., 2008. Procurement Risk Management (PRM) at Hewlett-Packard Company. *Interfaces*.38 (1), 51-65.
- Wang, L.C., Lin, Y.C., Lin, P.H., 2007. Dynamic mobile RFID-based supply chain control and management system in construction. *Advanced Engineering Informatics*. 21, 377-390.
- Zhang, J., 2008. Guro-baru kigyou keiei shien system [System for global industrial administration]. Japan: Zichosya.

AUTHORS BIOGRAPHY

Hisashi Takizawa: Received master's degree from the Graduate School of Engineering, the University of Tokyo in 2011. His research fields are in logistics and multi-agent simulation. Currently he is working in the Maritime Bureau of Ministry of Land, Infrastructure, Transport and Tourism, Japan.

Hiromichi Akimoto: Graduated from the PhD course at the University of Tokyo in 1996. After working at Tottori University and University of Tokyo, Japan, he has been a Visiting Foreign Professor in the Division of Ocean Systems Engineering, KAIST, Republic of Korea, from Oct. 2011. His research fields are in computational fluid dynamics, logistics, renewable energy and high-speed ships.

Kenji Tanaka: After working at McKinsey & Company and Nihon Sangyo Partners, he acquired PhD in Engineering at the University of Tokyo in 2009. His research fields are social diffusion models of rechargeable battery re-use services, sales projection with production and distribution efficiency, and competitiveness assessments of retailers' distribution.

Jing Zhang: Acquired PhD from the University of Tokyo. Currently researching Social logistics and Global Company Management systems.