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論 文

Design of Simulation System for Port Resources Availability in Logistics Supply Chain[1)]

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항만자원 계획 적합성 검증을 위한 시뮬레이션 시스템 설계

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ABSTRACT : *This paper aims to apply a supply chain modeling and its analysis framework to the supply chain in the port industry, each of which has its own objective. The simulation approach serves two purposes: to model a supply chain network in quantity approach and to evaluate its supply chain performance based on proposed strategies. The simulation model will be applied to quantifying the flow of a supply chain, the involved information and material flow and conducted to simulate the supply chain operations. The model will also be used which strategic and operational policies are the most effective in smoothing the variations in the supply chain .*

Key words : supply chain, simulation, partnership, information penetration

요약 : 항만산업의 관련기관들은 각기 다른 목표를 가지고 있다. 본 논문은 상이한 목표를 가지는 항만산업체의 최적활동을 달성하기 위한 공급연쇄 모델링 과정을 제시하며, 이를 분석하는 프레임을 제공하고자 한다. 연구의 목표를 달성하기 위해 시뮬레이션 방법을 사용하였으며, 시뮬레이션 변수로서 정보공유와 파트너쉽을 설정하였다.

핵심용어 : 공급연쇄, 항만시뮬레이션, 협력업체 전략, 정보공유전략

I. Introduction

A supply chain is essentially a business process that links manufacturers, customers, and suppliers in the form of a "chain" to develop and deliver as one "virtual" organization of pooled skilled and resources. The objective of a supply chain is to obtain benefits by streamlining the movement of manufactured goods from the production line into the customer's hands, by providing early notice of demand fluctuations and coordination of business processes across a number of cooperating organizations. At the highest level, a supply chain management crystallizes into three key processes: planning, execution, and performance measurement. Its common theme is the need to optimize processes that extend beyond narrow functional areas, taking into account the needs of a customer. However, one of the difficulties in introducing a supply chain management is how to evaluate the supply chain performance, a measure of goods and information flow, a design of supply chain process. In addition, the research and case study on the supply chain has been focused on the manufacturing industry.

This paper tries to apply a supply chain modeling and its analysis framework to the supply chain in port industry,

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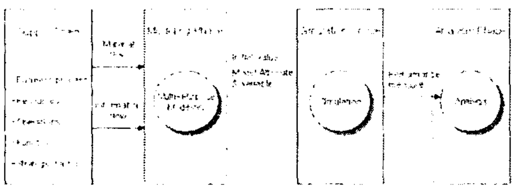
each of which has its own objective. It focuses on modeling of supply chain with multiple objectives by using a simulation approach. The simulation approach is helpful to achieve two purposes: to model a supply chain network and to evaluate the performance of a supply chain by applying the proposed strategies.



[Fig. 1] Research framework, Source : drawn by authors

II. Literature Review

This section presents a brief review of the literature relevant to the supply chain management, models of supply chain management, and simulation systems. The approach and scope of existing research in the design and analysis of supply chains illustrate a number of issues that have not yet been addressed in the literature. Beamon[3] suggests a research agendum for supply chain design and analysis in: (1) the evaluation and development of supply chain performance measures, (2) the development of models and procedures to relate decision variables to the performance measures, (3) consideration of issues affecting supply chain modeling, and (4) the classification of supply chain systems to allow for the development of rules-of-thumb or general techniques to aid in the design and analysis of manufacturing supply chains.

For modeling and analyzing both a structure and processes of an enterprise, multi-agent systems are developed and implemented in other research domain[8, 10, 18, 41, 46]. They are collection of, possibly heterogeneous, computational entities, having their own problem-solving capabilities which are able to interact in order to reach an overall goal[15]. They should be adaptable to reconfiguration of different business processes, and integration of chain components into the supply chains. Lin and Shaw[29] suggest a multi-agent information system for supply chain network and simulate the performance of order fulfillment process. Sikora and Shaw[42] present a multi-agent framework for agent coordination, which characterizes the different control structures that are possible in a multi-agent systems and leads to a useful taxonomy of the interdependencies among the agents and a taxonomy of the coordination mechanisms.

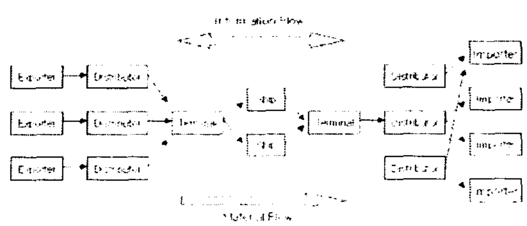
Owing to complex interaction between entities and the multi-tiered structure of supply chains, it makes difficult to utilize analytical approaches. A simulation approach provides an effective pragmatic approach to effectively and efficiently analyze and evaluate a supply chain design and management alternatives.

Generally speaking, the port and maritime industry has been an area for simulation. In other words, due to the costs and complexity of both ports and vessels, the use of simulation has been justified in this area for many years. There is a wide range of papers [31, 32, 37, 38] devoted to different aspects of port container terminal simulation. Therefore, a simulation model has been a useful tool to determine which strategic and operational policies are the most effective in smoothing the variations in the supply chain.

III. Design of a Port Supply Chain with Multiple Objectives

3.1 Design of a Port Supply Chain

A port is a place where cargo is loaded onto the ship, unloaded from the ship, and stowed on the pier where the receipt and delivery of freight happen. A port management system consists of ship operation system, cargo moving system, storage systems, receipt and delivery systems, gate operation systems, and management and operation information system. As a supply chain can be decomposed into many levels, it is a simple linear chain as shown in [Fig. 2], which represents a proposed port supply chain. It consists of supply chain entities, information and material flow across the supply chain, and inbound and outbound logistics with regard to export and import operation.



[Fig. 2] Schematic diagram of a port supply chain

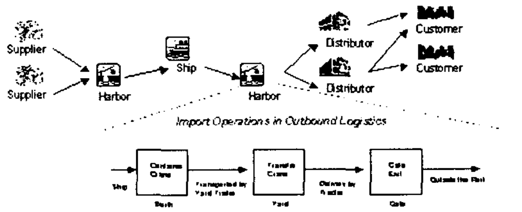
Generalized from the variety and complexity of a supply chain, the characteristics of a supply chain are distinguished not only by the physical connections (i.e., the number of tiers, the number of nodes, and the types of participants) but also by the operations, objectives, and other attributes. The important attributes include (1) objective in business entity, (2) value-added business process, (3) objective in business process, (4) initiative in business process, (5) business entity, and (6) interdependency. Having those attributes been considered, it is identified that a port supply chain is differentiated by (1) product characteristics, (2) logistics characteristics, (3) strategic and operational policies, compared to a manufacturing supply chain. (See [Table 1])

[Table 1] Comparisons manufacturing with port via its characteristics

	Manufacturing Supply Chain	Port Supply Chain
Objective in Business Entity	Same Objective (Low Conflict) -Supplier: Inventory - Manufacturer: Inventory -Distributor: Inventory	Different Objective - Shipper: Order Fulfillment -Ship: Delivery and Load/Unload -Port: Resource Management
Value-added Business Process	Manufacturing and Assembly	Logistics (Included Load/Unload)
Objective in Business Process	Lower Inventory Cost	Lower Order Fulfillment Cycle Time
Initiative in Business Process	Manufacture	Ship and Port
Business Entity	Supplier, Manufacturer, Assembler, Distributor, and Custom	Supplier, Ship, Port, Distributor, and Custom

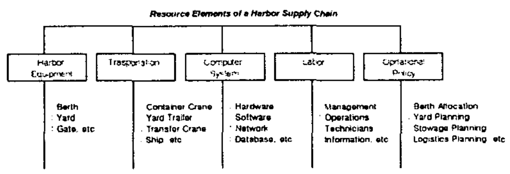
3.2 Operations and Resources of a Port Supply Chain

For the import flow in [Fig. 3], ships arrive at the container port, receive the service at the berth, and then de-berth after completing the activities of the unloading and loading the containers. Containers are unloaded by the gantry cranes from the ships, and then transported by yard trailer to the yard. At the yard, the transfer crane load/unload the container to the yard and the tractor moves the container to the gate for outside the port. For the export containers, the reverse process applies.



[Fig. 3] Outbound logistics of a container port supply chain

Therefore, full utilization of resources and proper management of operational policies are major concern in the port supply chain (see [Fig. 4]). To analyzing the complexity of port operations, simulation has been widely used and applied for the planning and management of port management system. In this paper, the simulation model develops for berth allocation and crane assignment policies. The berth allocation policies simulate the movement of the ship to the berth and assignment of the ship to the berth with certain rule. The crane assignment policies simulate the assignment of the cranes to the ship at the berth with based on a number of rules.



[Fig. 4] Structure of a port supply chain element

3.3. Performance Measures of Port Supply Chain

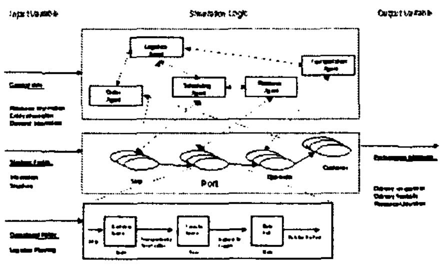
A performance measure is used to evaluate the effectiveness of an existing system or to compare different design alternatives. In this paper, in case of container terminal, the performance of the entire supply chain can be optimized with respect to: delivery time, and resource utilization. Average delivery time, which is measured by average ship turn around time from ship arrival to departure at berth. Resource utilization, which is composed of container crane utilization and yard tractor utilization, is measured by percentage of time that CC is active.

3.4 Strategic Factors of Port Supply Chain Management

The proposed strategies for improving a port supply chain are based on the dimensions of managing supply chain network, such as the structures, information infrastructure of the supply chain. [Table 2] summarizes the proposed strategies.

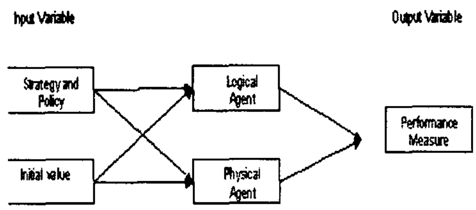
[Table 2] Strategic factors for improving port supply chain

Dimensions	Strategies	Description
Supply Chain Relationship	Maintaining a stable partnership	This strategy improves to understand partner's situation
Supply Chain Information	Penetrating information to each partner	This strategy increases supply chain visibility, to reduce uncertainty in the decision making



[Fig. 5] Simulation models of port supply chain

[Fig. 6]. It consists of global, input, and output variables. Especially, global variable for running simulation should be given in advance, i.e., demand fluctuation, number of agent, capacity information for system dependent variable, and number of simulation runs, simulation time for simulation dependent variable.



[Fig. 6] Implementation model for simulation

IV. Model of Simulation of Port Supply Chain

To design and implement port supply chain, four implementation models such as input mode, strategy model, operational policy model and performance model which acts as agent interaction are to be established for improving supply chain decisions.

The input model consists of order, resource, entity, and demand information for providing a basic input variable to physical and logical agents. The strategy model consists of information penetration between business entities, partnership in supply chain structure. The operational policy model is for setting objectives such as cost reduction, lead time reduction. Finally performance model to measure a supply chain performance on simulated situation, the performance measure consists of. delivery flexibility, resource utilization.

Based on the implemented model as discussed above, a simulation model can be developed as can be seen in

In order to calculate the SCM performance in container terminal, it is essential to have a through understanding of the most important elements in a port system including ship berthing and de-berthing, crane allocation per ship, yard tractor allocation to a container and crane allocation in stacking area [47]. As described on the above section, the scope of simulation, strategy and initial value and performance measure will have to be defined. In addition, the operational aspect such as machine failures to have a direct impact on ship, crane and vehicle will have to be considered.

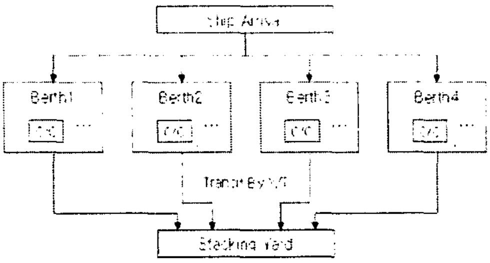
The simulation scope in this paper can be presented by following diagram.

[Fig. 7] Scope of simulation of Scope

To make a simulation model, PECT in Busan Korea was surveyed during June in 2001 and June in 2002. The model descriptions for simulation are follows:

■Ships berth at one of 4 berths randomly according to arrival distribution

■Once ships arrive at each berth, 2, 3 or 4container cranes dependent on board containers, will be available on each ship.



■To move containers from apron to stacking area, four tractors are provided for each container crane.
■It takes 7 minutes from apron to stacking area including unloading time, 2.5 minutes, by transfer crane and 3 minutes for returning in empty. The average velocity is 416.6m/m.
■The distance between apron and stacking area is assumed to be 700 meters.

The initial value for simulation is follows:
■ Time for ready to simulate (minute): 5 minutes
■ Recurrence numbers for simulation: 5 times
■ Total time of simulation(minute) : max container to be handled

To define resources for simulation, the arrival pattern and service ratio have to be defined. The arrival pattern of ships is usually a random process described by some type of probability distribution[48]. In the result of PECT survey for 1 year, the Erlang distribution of inter-arrival times is fitted with minimum square errors. Ship turnaround time involves the arrivals of ships expecting to use port facilities and the duration of occupancy of a berth(service time). The Normal distribution of Ship's time at berth is fitted with minimum square errors. The distribution container handling per crane is Gamma with least square error. Finally, speed of yard tractor is assumed to be constant.

V. Result of Simulation according to various strategies

To simulate the port terminal resource in view of supply chain with different purposes, it is necessary to set up simulation procedure. For the import containers, ships that arrive at the port are handled at the appropriate berths, and unload the container to the berth, and then de-berth after completing the activities of the unloading and loading the containers.

Let's make one hypothesis. The deeper partnership between ship operator and terminal operator, the shorter time for container handling will be taken. The reason for the mentioned is that the deep partnership is used to supply enough resources for the ship to keep the customer loyalty.

If we select the information penetration strategy through the supply chain, its concrete images will be for terminal operator to obtain ship arrival information in advance and he can prepare the resources in a fixed schedule. So we can set up the hypothesis that the more information the operator have, the more vessels can be handled efficiently.

5.1 Analysis of Partnership Strategic Factor

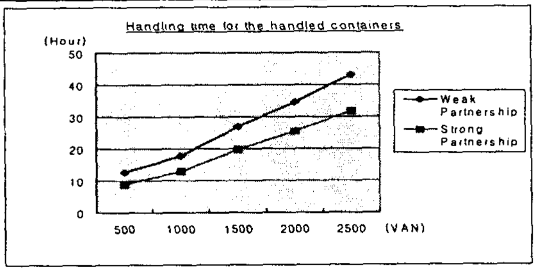
To demonstrate the simulation on port supply chain, we conduct experiment on the change of proposed strategy. First of all we'd like to analyze the partnership strategy of supply chain structure, which divides into reliable and unreliable partnership. Simulation executes the port supply chain based on the selection of partnership strategy to measure the potential effects on the performance of port supply chain based on the given supply chain environment. [Fig. 8] show the performance measures respectively under the two partnership strategies in port supply chain. From our results we can draw several conclusions on simulation. Firstly, the reliable and strong partnership strategy supplying enough resources is more effective strategy than the other partnership strategy. So, we can affirm the hypothesis that the reliable partnership between ship operator and terminal operator shorten the cargo handling time (see [Table 4]).

[Table 3] Vessel callings and yard operation

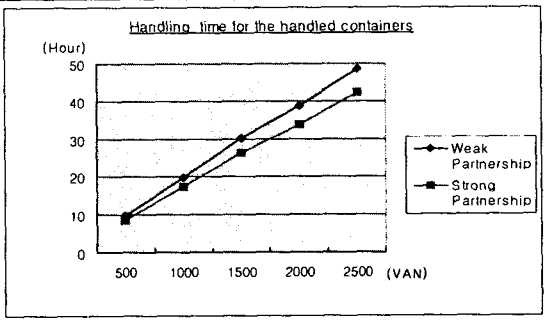
Number of handled containers	500	1000	1500	2000	2500
Weak Partnership	12.59	17.74	26.86	34.46	43.26
Strong Partnership	8.86	12.83	19.64	25.41	31.67

[Table 4] Cargo handling time for the handled containers,
unit : hours

Summary statistics	Inter-arrival time	Ship's time at berth	CC's container handling	Yard tractor
Number of Data Points	999	1010	1006	speed 416.6m/s
Sample Mean	524	1130	940	
Sample Std Dev	536	565	583	
Min Data Value	5	160	20	
Max Data Value	3250	620	3120	
Distribution	Erlang	Beta	Gamma	Not applicable
Expression	5+ERLA(591,1)	160+6040*BETA(3.33,17.2)	20 + GAMM(441, 2.08)	
Square Error:	0.000897	0.004	0.0019	
Chi Square Test				
Number of intervals	18	13	24	
Degrees of freedom	15	10	21	
Test Statistic	21.6	93.3	41.4	
Corresponding p-val	0.1	0.0	0.00504	



[Fig. 8] Performance measures for partnership : the case of enough resources



[Fig. 9] Performance measures for partnership : the case of speedy crane

Second, the reliable and strong partnership strategy with speedy container crane is more effective strategy than the other partnership strategy. So, we can affirm the hypothesis that the reliable partnership between ship operator and terminal operator shorten the cargo handling time (see [Table 5]).

[Table 5] Handling time for the handled containers, unit : hours

Number of handled containers	500	1000	1500	2000	2500
Weak Partnership	9.9	19.88	30.09	38.72	48.39
Strong Partnership	8.66	17.42	26.28	33.85	42.28

6.2 Analysis of Information Strategic Factor

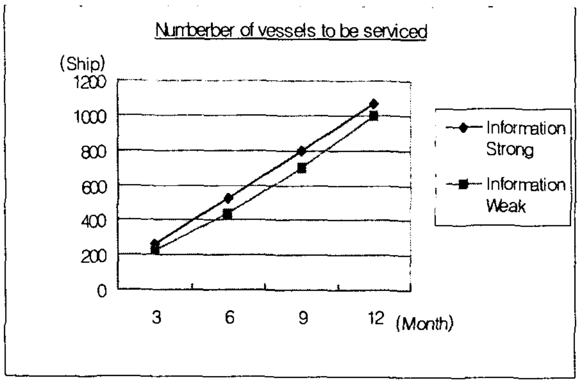
To analyze the depth of information penetration strategy of supply chain information, the depth of information penetration divides into low and high depths. Simulation executes the port supply chain based on the selection of information penetration strategy to measure the potential effects on the performance of harbor supply chain based on the given supply chain environment.

From our results we can draw several conclusions on simulation. That is to say, the terminal having deepest depth of information penetration strategy is more effective strategy than other depth of information penetration and enables all performance measure to be enhanced.

First, the strong information penetration strategy having fixed schedule is more effective strategy than the weak information penetration strategy. So, we can affirm the hypothesis that the strong information penetration between ship operator and terminal operator increase the number of vessel to be serviced (see [Table 6]).

[Table 6] The number of vessels to be serviced by quarter, unit : number of vessel

Quarterly	3months	6months	9months	12months
Information Strong	264	529	795	1072
Information Weak	225	436	698	999

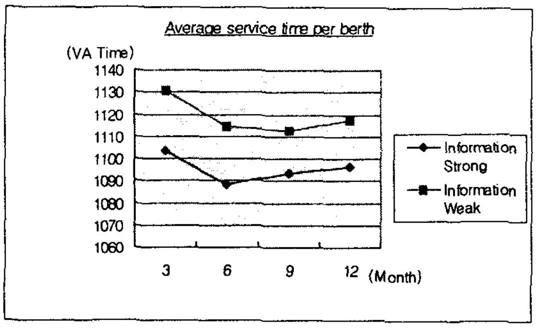


[Fig. 10] Performance measures for information penetration : Number of vessels to be serviced

In the result of second simulation, the strong information penetration strategy between ship operator and terminal operator decrease average service time per berth in comparison with the weak information strategy [Table 7].

[Table 7] Average service time per berth, unit : minutes

Quarterly	3months	6months	9months	12months
Information Strong	1103.41	1088.41	1093.78	1096.26
Information Weak	1130.55	1114.31	1112.83	1117.67

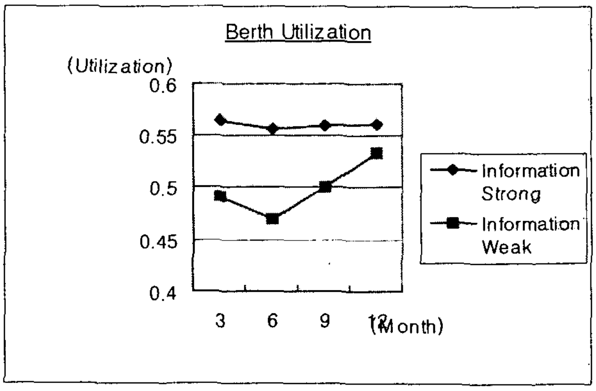


[Fig. 11] Performance measures of average service time per berth for information penetration

In the result of third simulation, the strong information penetration strategy between ship operator and terminal operator increase berth utilization in comparison with the weak information strategy (see [Table 8])

[Table 8] Berth utilization by quarter

Quarterly	3months	6months	9months	12months
Information Strong	0.5645	0.5567	0.5601	0.5614
Information Weak	0.4907	0.4696	0.5007	0.5314



[Fig. 12] Performance measures of berth utilization for information penetration

VI. Conclusion

This paper has presented the modeling and analysis of a dynamics of business processes and interaction between business entities in a supply chain with multiple objectives. It has developed a multi-agent systems and simulation model: to describe a supply chain network, its component, to represent business entities as agents and the involved information and material flows with proposed coordination method for collaborating among agents, and to simulate a strategic factors of supply chain with multiple objectives.

Through the modeling works to improve the performance, the components of simulation model such as input model, strategy model, operational policy model and performance model in port supply chain were identified. Specially, as the inner items of the above model, the details of each model was found out .

The simulation system for port supply chain captures the port supply chain characteristics, such as autonomous entities, multiple layer abstraction, material and information flows, and interdependence among business entities. Through modeling terminal operation in port supply chain and evaluating the potential effective strategies, multi-agent system demonstrates its capabilities of identifying and justifying useful strategies. The effects of various strategies, as illustrated in previous section, can guide the way to administrate the supply chain in the different objectives.

REFERENCES

[1]Alfieri, A. and P. Brandimarte, "Object Oriented Modeling and Simulation of Integrated Production Distribution Systems", *Computer Integrated Manufacturing Systems*, Vol. 10, No. 4, 1997, pp.261-266.

[2]Arntzen, B. C., G. G. Brown, T. P. Harrison, L. and L. Trafton, "Global Supply Chain Management at Digital Equipment Corporation", *Interfaces*, Vol. 25, 1995, pp. 69-93.

[3]Beamon, B. M., "Supply Chain Design and Analysis: Models and Methods", *International Journal of Production Economics*, Vol. 55, No. 3, 1998, pp. 281-294.

[4]Beamon, B. M., "Measuring Supply Chain Performance", *International Journal of Operations and Production Management*, Vol.19, No.3, 1999, pp. 275-292.

[5]Bhaskaran, S., "Simulation Analysis of a Manufacturing Supply Chain", *Decision Sciences*, Vol. 29, No. 3, 1998, pp. 633-657.

[6]Bowersox, D. J., *Logistical Management: the Integrated Supply Chain Process*, McGraw-Hill, 1996.

[7]Bhaskaran, S., "Simulation Analysis of a Manufacturing Supply Chain", *Decision Sciences*, Vol. 29, No. 3, 1998, pp. 633-657.

[8]Brandolese, A., B. Alessandro, and P. S. Alberto, "A Multi-Agent Approach for the Capacity Allocation Problem", *International Journal of Production Economics*, Vol. 66, No. 3, 2000, pp.269-285.

[9]Bruzzone, A., and R. Signorile, "Simulation and Genetic Algorithms for Ship Planning and Shipyard Layout", *Simulation*, Vol. 71, No. 2, 1998, pp.74-83.

[10}Caridi, M., and A. Sianesi, "Multi-Agent Systems in Production Planning and Control: An Application to the Scheduling of Mixed-Model Assembly Lines", *International Journal of Production Economics*, Vol. 68, No. 1, 2000, pp. 29-42.

[11]Christopher, M., *Logistics and Supply Chain Management*, Pitman Publishing, 1992.

[12]Cohen, M. A., and H. L. Lee, "Resource Deployment Analysis of Global Manufacturing and Distribution Networks", *Journal of Manufacturing and Operations Management*, Vol. 2, 1989, pp. 81-104.

[13]Cohen, M. A., and H. L. Lee, "Strategic Analysis of Integrated Production-Distribution Systems: Models and Methods", *Operations Research*, Vol. 36, No. 2, 1988, pp. 216-228.

[14]Davenport, T. H., *Process Innovation: Reengineering Work Through Information Technology*, Harvard Business School Press, Boston, Massachusetts, 1993.

[15]Ferber, J., *Multi-Agent Systems: An Introduction to Distributed Artificial Intelligence*, Addison-Wesley, 1999.

[16]Fox, M. S., M. Barbuceanu, and R. Teigen, "Agent-Oriented Supply-Chain Management", *International Journal of Flexible Manufacturing Systems*, Vol. 12, No. 2, 2000, pp. 165-188.

[17]Gambardella, L. M., A. E. Rizzoli, and M. Zaffalon, "Simulation and Planning of an Intemodal Container Terminal", *Simulation*, Vol. 71, No. 2, 1998, pp.107-116.

[18]Garcia-Flores, R., X. Z. Goltz, and G. E. Wang, "Agent-based Information Flow for Process Industries' Supply Chain Modeling", *Computers and Chemical Engineering*, Vol. 24, 2000, pp. 1135-1141.

[19]Handfield, R. B., *Introduction to Supply Chain Management*, Prentice Hall, 1999.

[20]Harland, C. M., and R. C. Lamming, P. D. Cousins, "Developing the Concept of Supply Strategy", *International Journal of Operations and Production Management*, Vol. 19, No. 7, 1999, pp. 650-673.

[21]Hayuth, Y. M. A. Pollatschek, Y. Roll, "Building a Port Simulator", *Simulation*, Vol. 63, No. 3, 1994, pp.179-189.

[22]Hicks, D. A., "A Four Step Methodology for using Simulation and Optimization Technologies in Strategic Supply Chain Planning", *Proceedings of the 1999 Winter Simulation Conference*, 1999, pp. 1215-1220.

[23]Ingalls, R. G., "The Value of Simulation in Modeling Supply Chain"", *Proceedings of the 1998 Winter Simulation Conference*, 1998, pp. 1371-1375.

[24]Law, A. M. and W. D Kelton. *Simulation Modeling and Analysis*. McGraw-Hill Inc, New York, 1991.

[25]Lee, H. L., and C. Billington, "Material Management in Decentralized Supply Chains", *Operations Research*, Vol. 41, No. 5, 1993, pp. 835-847.

[26]Lee, H. L., V. Padmanabhan, and S. Whang, "Information Distortion in a Supply Chain: The Bullwhip Effect", *Management Science*, Vol. 43, No. 4, 1997, pp. 546-558.

[27]Lee, W. J., and K. C. Lee, "A Meta Decision Support System Approach to Coordinating Production/Marketing Decisions", *Decision Support Systems*, Vol. 25, 1999, pp.239-250.

[28]Li, D., and C. O'Brien, "Integrated Decision Modeling of

Supply Chain Efficiency", *International Journal of Production Economics*, Vol. 59, No. 1-3, 1999, pp. 147-157.

[29]Lin, F., and J. M. Shaw, "Reengineering the Order Fulfillment Process in Supply Chain Networks", *International Journal of Flexible Manufacturing Systems*, Vol. 10, No. 3, 1998, pp. 197-229.

[30]Lin, F., G. W. Tan, and M. J. Shaw, "Multiagent Enterprise Modeling", *Journal of Organizational Computing and Electronic Commerce*, Vol. 9, No. 1, 1999, pp. 7-32.

[31]Merkuryev, Y., J. Tolujew, E. Blumel, L. Novitsky, E. Ginters, E. Viktorova, G. Merkuryeva, and J. Pronins, "A Modeling and Simulation Methodology for Managing the Riga Port Container Terminal", *Simulation*, Vol. 71, No. 2, 1998, pp. 84-95.

[32]Nevins, M. R., C. M. Macal, and J. C. Joines, "A Discrete-Event Simulation Model for Seaport Operations", *Simulation*, Vol. 70, No. 4, 1998, pp. 213-223.

[33]Petrovic, D., R. Roy, and R. Petrovic, "Modeling and Simulation of a Supply Chain in an Uncertain Environment", *European Journal of Operational Research*, Vol. 109, No. 2, 1998, pp. 299-309.

[34]Puterman, M. L., *Markov Decision Processes: Discrete Stochastic Dynamic Programming*, Wiley, 1994.

[35]Pyke, D. F., and M. A. Cohen, "Multi-Product Integrated Production-Distribution Systems", *European Journal of Operational Research*, Vol. 74, No. 1, 1994, pp. 18-49.

[36]Pyke, D. F., and M. A. Cohen, "Performances Characteristics of Stochastic Integrated Production-Distribution Systems", *European Journal of Operational Research*, Vol. 68, No. 1, 1993, pp. 23-48.

[37]Ramini, K. V., "An Interactive Simulation Model for the Logistics Planning of Container Operations in Seaports", *Simulation*, Vol. 66, No. 5, 1996, pp. 291-300.

[38]Razman, M. T., and K. Hussain, "Simulation and Analysis for the Kelang Container Terminal Operations", *Logistics Information Management*, Vol. 13, No. 1, 2000, pp. 14-20.

[39]Sabri, E. H., and B. M. Beamon, "A Multi-Objective Approach to Simultaneous Strategic and Operational Planning in Supply Chain Design", *Omega*, Vol. 28, 2000, pp. 581-598.

[40]Shaw, M. J., "Information-Based Manufacturing with the Web", *International Journal of Flexible Manufacturing Systems*, Vol. 12, No. 2/3, 2000, pp.115-129.

[41]Shen, W., J. P. Barthes, and D. H. Norrie, *Multi-Agent Systems for Concurrent Intelligent Design and Manufacturing*, Taylor & Francis, 2000.

[42]Sikora, R., and M. J. Shaw, "A Multi-Agent Framework for the Coordination and Integration of Information Systems", *Management Science*, Vol. 44, No. 11, 1998, pp. 65-78.

[43]Simchi-Levi, D., *Designing and Managing the SupplyChain: Concepts, Strategies, and Case Studies*, Irwin/McGraw-Hill, 2000.

[44]Slack, T. C., "The Flexibility of Manufacturing Systems", *International Journal of Operations and Production Management*, Vol.4, 1991, pp. 35-45.

[45]Strader, T. J., F. Lin, J. and M. Shaw, "Information Infrastructure for Electronic Virtual Organization Management", *Decision Support Systems*, Vol. 23, No. 1, 1998, pp.75-94.

[46]Swaminathan, J. M., W. A. Haas, S. F. Smith, and N. M. Sadeh, "Modeling Supply Chain Dynamics: A Multiagent Approach", *Decision Sciences*, Vol. 29, No. 3, 1998, pp. 607-632.

[47]PIANC(1992), Overview of simulation techniques, capability ship manoeuvring simulation models for approach channels and fairway in harbors.

[48] F. Fararoui(1989), *Queuing theory and berthing optimization*, PhD Thesis Priority Berthing in congested Port