Decision Strategies Based on Meteorological Forecast Information in a Beer Distribution Game

Ki-Kwang Lee* · In-Gyum Kim** · Chang-Hee Han***

Abstract

With the corporate environment nowadays being surrounded by plenty of information, the sharing of information among businesses through mutual cooperation tops the list of hot issues. Predictions of demands from the customer, business, or consumer by sharing information can affect the inventory and order production system. However, notwithstanding the importance of sharing information, empirical studies on quantitative use of information still remain insufficient in spite of many a discussion now being made on the sharing of information. This paper proposes to examine the ways meteorological information may affect the rises in the achievements of supply chains in distributive businesses, the kind of information that noticeably affects the consumer behavioral patterns in the distributive businesses but rarely perceived as a form of information shared by businesses. This study is based on a model in which meteorological information has been added as the one used to predict demands, after the beer distribution game has been modified to fit the current status, and simulations under an assumptive situation, where decisions are made on a daily basis, were conducted 50 times for a period of 1000 days for the generalization of the results, while at the same time a Duncan Test was conducted to determine the threshold to use the meteorological information that will be most profitable to the retailer, wholesaler, supplier and the supply chain as a whole. Our findings indicate that corporations have thresholds that vary from business to business depending upon the ratio of backlog costs to inventory costs. At the same time, our findings also show that there existed effective thresholds depending upon the ratio of backlog costs to inventory costs for the performance of the overall supply chain.

Keywords : Meteorological Information, Information Sharing, Beer Distribution Game, Supply Chain Management

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1. Introduction

The distribution industry has developed from the livelihood-dependent type such as traditional markets and small-and medium-sized supermarkets into an entrepreneurial type of distribution such as department stores, discount stores, convenient stores and so forth. Aggravating competition within the industry coupled with the trend of small businesses being incorporated has caused changes in the way the decision-maker manages the business.

The traditional way of management held on to the method where each corporation attempted only to add values to the customer or the supplier directly related with each other while each one is free to manage independently on its own. Furthermore, most of the innovative activities aimed at lifting productivity and efficiency, cost reduction, and so forth were limited to within the business concerned. [McCormack et al., 2003]. However, with new environmental variables such as rises in the consumer demands, curtailed product life cycles and of market response times and globalization emerging nowadays, the method to focus on the innovative activities of a single business works no longer.

Ultimately, viewing businesses as a network organically related with each other, decision makers tried to acquire a competitive edge of the network as a whole by maximizing the effects of integrating individual corporate capability, rather than individual corporate competitive edge [Lee, 2000]. Under such circumstances, the supply chain management concept emerged as a new approach to solutions for business-to-business relationships [Cooper et al., 1997; Mentzer et al., 2001].

The supply chain management (SCM) includes all the activities within a supply chain where all the activities related to the procurement, acquisition and conversion of resources, and the schedule management. Furthermore, the SCM manages all the cooperative activities with the partners within the supply chain including the supplier, wholesaler, retailer and consumer [Ayers, 2006]. Previous studies on the business process innovation activities through the supply chain management mostly include two approaches. One concerned an inventory policy to minimize the costs by means of a quantitative or mathematical inventory control model. The other tried to show that effects are maximized by cooperative information sharing among businesses.

On the other hand, most of the previous studies were made on the flow of distribution, inventory policy and optimized production plan with a focus on individual objects that constitute the supply chain in an effort to remove disturbing factors from the outside of the supply channel. However, a supply chain is currently to be understood and approached as an integrated system. Thus, the tasks of modeling and analyzing are required under the assumption that all the activities from the purchase of raw materials down to the customer are considered as a process of continuous flows.

However, there exists a limit to the mathematical approach to the supply chain embedded with uncertainty, and thus modeling and analyzing tasks by means of simulations are required. The previous studies based on the simulation include the modeling concept that uses simulations with respect to various roles of the distribution center between the customer and the factory [Takakuwa et al., 2000], an analysis of supply chains with the aid of simulations under an uncertain environment [Petrovic, 2001], and an integrated approach of the simulation and the mathematical method [Ray et al., 2005].

This study conducts the simulation to verify that the suggested inventory policy in the supply chain contribute to the optimization of the system. As discussed earlier, the supply chain management in the distribution industry may make it possible to cut back on the inventory and transportation costs by predicting consumer demands and maintaining an optimal level of inventory. However, in order to cope with rapidly changing consumer demands, prediction of demands based on the only information shared by the related businesses is not sufficient. We should consider various environmental variables noticeably affecting consumer demands. The meteorological information is a specific example, which is gaining momentum in recent corporate activities for predicting consumer demands in particular distribution industry.

In fact, the distribution industry proves highly sensitive to weather conditions. For example, a self-analysis conducted by Bokwang Family Mart, a Korean convenience store chain, indicates that every outlet under its management marked an average of 10% fall in sales on a rainy day, compared with those on a fine day. This hopefully makes it possible to cut down on backlogs and inventory costs through the more accurate prediction of consumer demands based on the meteorological information provided. At the same time, the use of quantitative meteorological information from the retailers who are in close contact with the consumer makes it possible for each and all players in the supply chain to predict the quantity of orders. Consequently, every player can grips with orders from his upstream supplier and downstream customer, ultimately elevating overall efficiency of the supply chain as a whole [Lee et al., 2007]. In addition, the result of Lee et al. [2007] indicated that a synergy effect can be created from the two sources of information, i.e., the meteorological forecast information and the inventory and backlog information shared by the players within the chain. The synergy from two types of information enables the overall efficiency of the supply chain to be elevated, compared with when a single source of information was used.

However, while there is nothing wrong with the corporate decision-maker when he uses the inventory and backlog information as supplied, chances are that each player will make a decision differing from the others, when it comes to the meteorological information. For instance, suppose a precipitation forecast predicts a 30% chance of rain for the next day. If a retailer makes a decision under the assumption that it will rain tomorrow, while at the same time a wholesaler makes a decision with the opposite assumption, the use of meteorological information will not go far.

In Lee et al. [2007] simulations were conducted under the assumption that all the players in a supply chain would make the decisions under the same interpretation of the meteorological forecasts. On the other hand, this study assumes that the players including the retailer, wholesaler, and supplier to make different decisions based on its own interpretation through threshold. With a view of the likelihood that the threshold for decision-making could differ, then a statistical analysis is followed to examine if there exists a combination of thresholds where the efficiency of the supply chain is optimized.

This study has adopted as a hypothetical supply chain model known as the beer distribution game, which had been developed by MIT in 1960's and was utilized by numerous researchers thereafter. The beer distribution game was originally aimed to prove the bullwhip effect within a supply chain. Later it was utilized for the inventory policy problem by Cho and Kim [2001], and was revised for analyzing three factors, i.e., inventory, backlog, and bullwhip effect by Lee et al. [2007]. Accordingly, the beer distribution game has been adopted as the study model.

Section 2 explains a study model which adopts a revised beer distribution game. In Section 3 a framework of the experimental simulation method is described to analyze efficient decision strategies. Section 4 shows the results of a simulation of the proposed study method for real forecast data. Finally, section 5 gives the conclusion.

2. Study model : a revised beer distribution game

While the original beer distribution game model includes 4 tiers, i.e., the retailer, the wholesaler, the distributor and the supplier, this study has adopted the revised beer distribution game proposed by Lee et al. [2007]. The revised model assumes consumer demands vary depending upon the presence or absence of precipitation, rather than upon independent probability distribution. The assumption is not only in accord with the industrial characteristics of the distribution industry, where sales vary depending upon the presence or absence of precipitation, but is related with the sales pattern of beer as a commodity. At the same time, the availability of the precipitation forecasts in a probabilistic form enables to analyze the business decision-making pattern by using thresholds.

The revised beer distribution game differs from the original one in that the original 4-tier supply chain was curtailed down to a 3-tier chain in the revised version. The revised model reflects that the supplier, the wholesaler, and the retailer are actual players in the beer sales chain, while the large-sized distribution part makes a decision about orders without actually carrying commodities. Also, the precipitation forecasts in Korea are usually provided in terms of probability covering only 24 hours to go. Accordingly, in the case of original 4-tire supply chain, the most upstream supplier cannot use the 24-hour forecast information due to the lead time taken in transporting the commodities.

Lastly, in the revised model, the lead time taken for order processing upwards in the supply chain has been amended from one day to the real time basis. The real time based order processing is more realistic for modern business environment with current information systems.

The revised model of the beer distribution game is shown in Figure 1. Notice that t day and t-1 day referred as the lead time in the order flows shown in <Figure 1> simply represent the day at the point of time the decision is made, not the actual order processing time. The decision-making in each player proceeds in the following steps. First, commodities arrive from the upstream supplier; second, new orders are received from the downstream customer; third, if the inventory is sufficient to meet the orders, sales are made as they stand : otherwise, the remainder is processed as backlogs; fourth, orders are made to the upstream supplier in consideration of backlogs and inventory [Croson and Donohue, 2006]. The quantities of commodities transported and inventories for each player can be obtained by the following equations.

Notations.

S_t^i : quantity shipped to the downstream customer from player i in period t.

D_t : retail demand in period t.

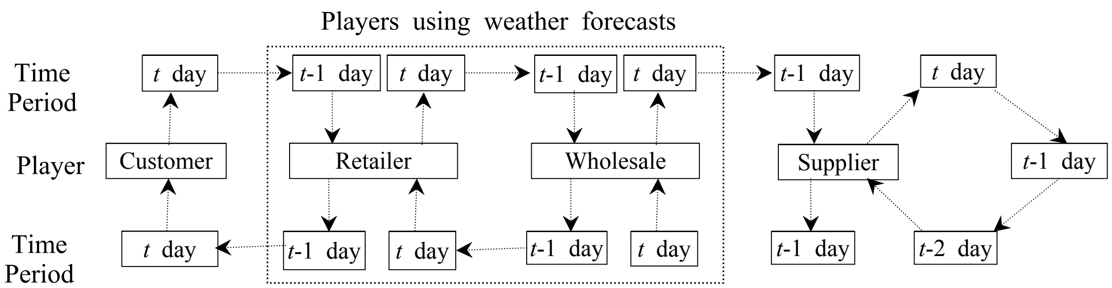
O_t^i : order placed to the upstream supplier from player i in period t.

I_t^i : inventory at player i in period t, where $I_t^i \geq 0$ represents on-hand inventory and $I_t^i < 0$ represents orders in backlog.

$$\begin{aligned} S_t^i &= \min\{D_t, \max\{I_{t-1}^i + S_{t-2}^{i+1}, 0\}\} \text{ for } i=1 \\ &= \min\{O_{t-1}^{i-1}, \max\{I_{t-1}^i + S_{t-2}^{i+1}, 0\}\} \text{ for } i=2 \quad (1) \\ &= \min\{O_{t-2}^{i-1}, \max\{I_{t-1}^i + S_{t-3}^{i+1}, 0\}\} \text{ for } i=3 \end{aligned}$$

$$\begin{aligned} I_t^i &= I_{t-1}^i + S_{t-2}^{i+1} - D_t \text{ for } i=1 \\ &= I_{t-1}^i + S_{t-2}^{i+1} - O_{t-2}^{i-1} \text{ for } i=2 \quad (2) \\ &= I_{t-1}^i + S_{t-3}^{i} - O_{t-2}^{i-1} \text{ for } i=3 \end{aligned}$$

The meteorological data applied to the model were derived from the actual probability forecasts for the Seoul area during the 3-year period of 2003 through 2005, which is gene-



〈Figure 1〉 Revised model of the beer distribution game rated from Korea Meteorological Administration.

It was assumed that it actually rained when the precipitation marked 0.254mm or over. The criteria for determining the presence or absence of precipitation was also adopted by Lee et al. [2007] and Mylne [2002].

Due to the difficulty to gather actual consumer demand data unlike rainfall data, a set of hypothetical data about beer demands was generated by assuming that beer as a commodity is sensitive to weather conditions. Thus, the demands were determined to be low or high depending on the rain or not. The low retail demand was assumed to be uniformly distributed between 1 and 3 when it rains. The high retail demand was followed by a uniform distribution of U(7, 9) in case of no precipitation. Finally, the supplier who does not use meteorological forecasts may make a prediction for demands through an exponential smoothing technique.

3. Study methods

In many cases that businesses face, it is difficult or impossible to predict exactly for the future. It is because the information available to the decision-maker itself is uncertain [Fishburn, 1965] and because the other party feels uncertain since the decision-maker's criteria for judgment is uncertain [Lee, 1990]. However, the decision-maker in a business environment is requested to make the best choice even in situations where uncertain information is provided. Many a study suggested various ways of lifting the efficiency of the supply chain by sharing information [Cooper et al., 1997; Croson and Donohue, 2006; Hsiao and Shieh, 2006; Lanzenauer and Glombik, 2002; Porter and Mullar, 1985; Steckel et al., 2004; Stock, 1990; Thonemann, 2002; Zhao and Wang, 2002]. The previous study of Lee et al. [2007] and Mylne [2002] expanded the scopes of the previous studies by adding the concept of threshold concerning the use of meteorological uncertain information. Based on the Lee et al. [2007] and Mylne [2002], this study tries to show that businesses within the supply chain have different criteria for thresholds and to get the optimal threshold combination that brings about the best performances of the supply chain as a whole.

Simulations were made assuming that decisions for orders take place everyday for over 1000 days during the period of 2003～2005, and environmental variables like holidays and seasonal factors have not been taken into account. In order to make decisions from probability forecasts, the decision maker transforms each probability forecast to a categorical (i.e., yes/no) forecasts of adverse weather according to the magnitude of the forecast probability [Mylne, 2002]. In effect, a decision to send a short message is made when the probability p% of the precipitation exceeds a chosen threshold p_t. Accordingly, the choice of p_t determines the decision strategy and the value of the forecast. Simulations were conducted while altering the (p_{rt}, p_{wt}) combinations, where the criteria for the retailer's decision-making on the meteorological information were expressed as 'p_{rt}' and that of the wholesaler as 'p_{wt}'.

Total 81 combinations include (0, 0), (0, 10), (0, 20), …, (90, 80) and (90, 90), where combinations having 50 do not exist since there exists no forecast of 50% in an actual forecast probability. The averages of backlogs and inventory recorded at retailer, wholesaler and supplier are calculated from the results of the simulations with each of 81 decision strategies, that is, threshold combinations.

Even if this study focuses on the commodity of beer, in reality, the costs of backlog and inventory are varied according to the types of commodities. Thus, simulations are repeated under various ratio of backlog to inventory cost under the same conditions. The cost ratio of (backlog : inventory) concerned includes (3 : 1), (2 : 1), (1 : 1), (1 : 2), and (1 : 3). Since the foregoing simulations represent the data value resulting from hypothetical demands generated by the uniform distributions and random numbers rather than actual consumer demands, 50 simulations were repeated for generalization. To derive an optimal combination, a Duncan grouping test was conducted by using SPSS 12.0 as a statistics package.

4. Experimental results

Results of the simulations are shown in <Table 1>. (3 : 1), (2 : 1), (1 : 1), (1 : 2), and (1 : 3) on top of <Table 1> represent the ratio of backlogs to inventory costs of each retailer, and the figures at the bottom represent the most effective threshold combinations belonging to group 1 derived from the Duncan test for each retailer, wholesaler, supplier and average of all the three players.

For instance, in the column of the cost structure of backlog and inventory with 3 : 1, the figure 38 in the first row of retailer's column means the retailer can get the optimal performance when the retailer and wholesaler have a threshold of 30% and 80% in respect for probabilistic forecast.

Likewise, 38 and 39 is shown under the wholesaler's column in the cost ratio of 3 : 1. The two figures mean that the Duncan test generated (30, 80) and (30, 90) threshold combinations for group 1, elements of which is statistically the most efficient decision strategies. That is, when the ratio of backlogs to inventory stands at 3 : 1, the threshold combinations of the retailer and wholesaler of (30, 80) and (30, 90) make the wholesaler most advantageous. The overall supply chain column provides the threshold combinations to maximize the overall efficiency of the supply chain, which is expressed by the average cost of backlog and inventory retained by the retailer, wholesaler and supplier.

<Table 1> indicates that in case the ratio of backlogs to inventory costs stands at 3 : 1 and 2 : 1, it best serves to achieve the overall efficiency of the supply chain to choose the threshold combination that complies with the retailer's criteria. This seemingly indicates that due to relatively high backlog cost, every individual player can get the most benefit from complying with its customer's decision

criteria, ultimately serving the best interest of the overall supply chain.

In the case of the 1 : 1 cost ratio, while the threshold combinations that serve the interests of retailer and wholesaler differ, it is more profitable to comply with the retailer's criteria in order to achieve the overall efficiency of the supply chain. This implies that in an environment where the backlogs and inventory costs happen to concur, it may be profitable for each player to follow its own decision criterion for befitting each individual player. However, this concept does not serve to achieve the overall interest of the supply chain as a whole. Rather, overall performance can be maximized when every player follows the retailer's decision criterion.

In the cost ratio of 1 : 2 and 1 : 3, each and all threshold combinations benefited to the individual player alone, only to fail to achieve the overall efficiency of the supply chain. This is caused by the fact that each individual player tries to minimize the level of inventory considering high inventory costs, rather than make a concerted and organized effort. The lack of integrated view of individual players could not lead to the overall efficient performance of the whole supply chain.

Note that there existed threshold combinations that lead to the best performance of the overall supply chain in all of the cost structures, namely, (30 : 80) and (30 : 70). The two threshold combinations represent that the retailer has a threshold of 30% for the precipitation forecast information and the wholesaler 70% or 80%, respectively.

That is, the decision combinations where the retailer follows a threshold of 30% and the wholesaler 70% or 80% are able to achieve the overall efficiency of the supply chain regardless of cost structures of backlog and inventory.

Simulation results verified that the retailer, a main entity who responds initially to the

<Table 1> The best threshold combinations for the cost ratio of backlog to inventory

Cost ratio of (backlog : inventory)	(3 : 1)				(2 : 1)				(1 : 1)				(1 : 2)				(1 : 3)			
Player	R	W	S	O	R	W	S	O	R	W	S	O	R	W	S	O	R	W	S	O
Best threshold combinations	38 39	38 39	36 76 38 67 66 37 39 49 69 34	38 39 36 37	38 39	38 66 36 68 37 39 48 46 67 69 49 76	36 38 76 67 37 39 66 49 69 34	38 36 39 37	38 39 37	63 73	38 39 37 76 67 49 66 34 68	38 37 39 34	28 29	73 63	36 38 39 37 76 67 49 69 66 34	36 34 37 38 63 43	28 29	72 73	36 38 39 37 76 67 49 69 66 34	36 34 63 43 37 38

Note) R : retailer, W : wholesaler, S : supplier, O : overall supply chain.

consumer demands in the revised beer distribution game, could achieve the highest level of efficiency by using threshold of 30%. Also, notice that the 30% is the threshold proved to be the optimal decision strategy from Lee et al. [2007] and Mylne [2002]. On the other hand, the wholesaler's threshold doesn't represent 30% but 70% or 80%, which implies a single criterion alone cannot ensure the overall maximal profit of the supply chain where players' business activities are organically related to each other.

Consequently, the results showed that the threshold combinations for meteorological forecast information that will ensure an optimal efficiency of the retailer, wholesaler and supplier might end up varying depending upon the relative costs of backlog and inventory. Furthermore, the optimal threshold combination of the retailer and wholesaler for each player in chain could or could not benefit the overall supply chain depending upon the cost structures of the backlog and inventory.

This means that different threshold combinations are to be applied depending upon the specific cost structures of the commodities concerned within the distribution industry as well as within the supply chain.

5. Conclusion

The previous study of Lee et al. [2007] proposed that quantitative use of meteorological forecast information can have significantly positive effect on the decision-making regarding order via the supply chain and the determination of the level of backlog and inventory. This study expanded the previous result and derived the decision-strategies represented by the threshold combinations that would ensure the maximal efficiency of the supply chain.

We adopted and revised the beer distribution game, which was proved appropriate in modeling in numerous studies on the management of supply chains. The conventional beer distribution game and the revised beer distribution game differ in respects as follows. First, in the revised beer distribution game, consumer demands are designed to be determined by precipitation events by using the appropriate uniform distributions. Second, the four players in the conventional game were curtailed down to three players by excluding the distributor in the supply chain. Third, it was assumed that the orders of each player would be processed in real time. While the consumer demands data was generated hypothetically by using uniform distributions, the weather forecasts data was collected from the database of KMA (Korea Meteorological Administration) in order to enhance the reality of the model.

The corporate decision-making within the supply chain was done by means of a simulation based on the MS Excel macro, assuming that decisions were made every day. The efficiency of the supply chain was regarded as the backlog and inventory, and the ratio of backlog to inventory costs was set variably. This approach makes it possible to apply to various types of commodities and businesses. This paper has a unique contribution that the appropriate decision making strategies can be developed by considering the cost structures of commodities distributed in the supply chain.

The simulation results were analyzed in terms of the relative costs of the backlog and inventory. First, in case the backlog costs relatively run high, it turns out to be profitable for the player concerned and all the players in the supply chain to comply with the decision strategy made by the retailer. Second, when backlog and inventory costs are similar, the optimal decision strategies for each player and for whole supply chain are different. While the each player concerned has its own efficient threshold combinations for using meteorological forecast information, the best threshold combinations for the retailer are proved to be most effective for the whole performance of the supply chain. Third, when the inventory costs relatively run high, the threshold combinations of each player concerned were not related to the profits of the supply chain as a whole. In all the three cases, however, the optimal threshold combinations for the whole performance of the supply chain were derived as (30, 70) and (30, 80), which implies that 30% of retailer's threshold for decision-making and 70% or 80% of wholesaler's threshold might maximize the whole profits of the supply chain.

In conclusion, this study verified that the meteorological information can benefit each of players and overall supply chain. Furthermore, we generated the various decision strategies which are effective for each player and overall supply chain.

Reference

[1] Ayers, J. B., *Handbook of supply chain management* (2nd ed.), Auerbach Publications, 2006.

[2] Cho, M. and Kim, H., "Optimal inventory policy in beer distribution game", *Journal of Society of Korea Industrial and Systems Engineering*, Vol. 24, No. 65, 2001, pp. 11-22.

[3] Cooper, M. C., Lambert, D., and Pagh, J., "Supply chain management more than a new name for logistics", *The International Journal of Logistics Management*, Vol. 8, 1997, pp. 1-14.

[4] Croson, R. and Donohue, K., "Behavioral causes of the bullwhip effect and the observed value of inventory information", *Management Science*, Vol. 52, 2006, pp. 323-336.

[5] Fishburn, P. C., "Analysis of decisions with incomplete knowledge of probabilities", *Management Science*, Vol. 13, 1965, pp. 217-237.

[6] Hsiao, K. M. and Shieh, C. J., "Evaluating the value of information sharing in a supply chain using an ARIMA model", *The International Journal of Advanced Manufacturing Technology*, Vol. 27, 2006, pp. 604-609.

[7] Lanzenauer, C. H. V. and Glombik, K. P., "Coordinating supply chain decisions : an optimization model", *OR Spectrum*, Vol. 24, 2002, pp. 59-78.

[8] Lee, D. J., "Stochastic dominance rules in multiattribute decision making under uncertainty", *Proceedings of the 1st Conference of the APORS*, Elsevier, Amsterdam, Nethelands, 1990, pp. 171-184.

[9] Lee, H. L., "Creating value through supply chain integration", *Supply Chain Manufacturing Review*, 2000.

[10] Lee, K.-K., Kim, I.-G., and Ko, K.-K., "The effect of uncertain information on supply chain performance in a beer distribution game - a case of meteorological forecast information", *Journal of Information Technology Applications and Management*, Vol. 14, No. 4, 2007, pp. 139-158.

[11] McCormack, K. P., Johnson, W. C., and Walker, W. T., *Supply chain networks and business process orientation*, The CRC Press Series on Resource Management, 2003.

[12] Mentzer, J. T., EdWitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., and Zacharia, Z. G., "Defining supply chain management", *Journal of Business Logistics*, Vol. 22, 2001, pp. 1-24.

[13] Mylne, K. R., "Decision-making from probability forecasts based on forecast value", *Meteorological Applications*, Vol. 9, 2002, pp. 307-315.

[14] Petrovic, D., "Simulation of supply chain behaviour and performance in an uncertain environment", *International Journal of Production Economics*, Vol. 71, 2001, pp. 429-438.

[15] Porter, M. E. and Millar, V. E., "How information gives you a competitive advantage", *Harvard Business Review*, Vol. 63, 1985, pp. 149-160.

[16] Ray, S., Li, S., and Song, Y., "Tailored supply chain decision making under price-sensitive stochastic demand and delivery uncertainty", *Management Science*, Vol. 51, No. 12, 2005, pp. 1873-1891.

[17] Stock, J. R. "Managing computer communication and information technology strategically : opportunities and challenges for warehousing", *The Logistics and Transportation Review*, Vol. 26, 1990, pp. 133-148.

[18] Takakuwa, S., Takizawa, H., Ito, K., and Hiraoka, S., "Simulation and analysis of non-automated distribution warehouses", *Proceedings of The Winter Simulation Conference*, 2000, pp. 1177-1184.

[19] Thonemann, U. W., "Improving supply chain performance by sharing advance demand information", *European Journal of Operational Research*, Vol. 142, 2002, pp. 81-107.

[20] Steckel, J. H., Gupta, S., and Banerji, A., "Supply chain decision making : will shorter cycle times and shared point-of-sale information necessarily help?", *Management Science*, Vol. 50, No. 4, 2004, pp. 458-464.

[21] Zhao, W. and Wang, W., "Coordination of joint price-production decisions in a supply chain", *IIE Transactions*, Vol. 34, No. 8, 2002, pp. 701-715.

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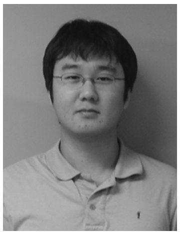

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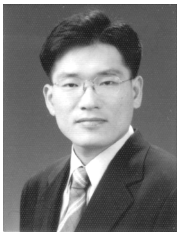

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