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Simulation Study of Two Supply Chain Collaboration Programs: Consignment and VMI*

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Abstract

Purpose – This study examines how consignment and Vendor-Managed Inventory perform as supply chain collaboration programs. By using three key collaborative features, this study defines the collaboration programs and develops theoretical models of different supply chain systems.

Research design, data and methodology – This study conducts sophisticated analysis on the supply chain systems by applying simulation modeling based on time-phased operations. The simulation model represents a two-stage supply chain system where a supplier sells a single item to a buyer, and it incorporates various operations.

Results – In general, the simulation outcomes support that more advanced collaboration programs outperform less advanced ones. The analysis on the simulation outcomes identifies the significant value of information sharing in both collaboration programs. The specific conditions where the particular collaboration system outperforms the others are recognized.

Conclusions – The outcome of this study supports that the supply chain system can improve its performance by having more collaborative features. This study provides business practitioners with guidelines to identify the circumstances that the specific collaboration program can fully exploit its advantages.

Keywords: Supply Chain Management, Simulation Model, Supply Chain Collaboration, Vendor-Managed Inventory (VMI), Consignment.

JEL classifications: M11, M19, M21.

1. Introduction

Supply chain collaboration has been the noteworthy topic of supply chain management, once the potential to improve supply chain performance is recognized by both academic researchers and industry practitioners. Accordingly, there have been various supply chain programs designed to build collaboration among supply chain members, and for example, Quick Response, Continuous Replenishment, and Vendor-Managed Inventory consequently lead to effective supply chain management. (Danese, 2006; Derrouiche et al., 2008; Sadeghi et al., 2014a; Xu & Leung, 2009). Meanwhile, many past studies about supply chain collaboration chose only particular programs and examined their performances in only special situations (Chakraborty et al., 2015; Egri & Vancza, 2013; Rad et al., 2014). Cross examination among different programs under various conditions is essential to identify the true nature of supply chain collaboration.

This study investigates how different supply chain collaboration programs perform. Among diverse collaboration programs, this study focuses on the consignment and Vendor-Managed Inventory (VMI) that have been broadly applied to industries. This study defines the consignment and VMI programs with three key elements of collaboration including information sharing, cost payment, and decision authority. Based on the claim that more portion of decision making or cost payment is done by one member under more advanced collaboration program, VMI is considered to be more advanced collaboration program than the consignment. This study intends to compare overall performances of these two collaboration programs. The value of information sharing is also evaluated under different collaboration programs. By directly comparing two collaboration programs and testing the impact of information sharing under different collaboration programs, this study can provide good ideas to develop a new collaboration program that brings better supply chain performance than any existing ones.

For the sophisticated analysis, this study employs simulation modeling based on time-phased operations. The simulation model represents a two-stage supply chain system where a supplier sells a single item to a buyer, and it incorporates various operations including demand forecasting, inventory controlling, manufacturing, and delivering. The simulation models consider six op-

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erational and environmental factors, and they are the collaboration program, information sharing level, demand pattern, lead-time, production capacity, and costs. The supply chain performance is accessed in terms of profits, service levels, and bullwhip effect. Two collaboration programs are compared with the traditional non-collaborated system as a basis, and their performances are further analyzed to examine the impacts of operational and environmental factors on the supply chain performance. In general, the simulation outcomes support that more advanced collaboration programs outperform less advanced ones. The results also show that information sharing is not just a component of supply chain collaboration but it is essential for successful collaboration.

2. Theoretical Background

VMI is originally designed as the buyer-supplier partnership to improve the supply chain performance (Simchi-Levi et al., 2000). Under the VMI program, a supplier is fully responsible for managing buyer's inventory. Based on the detailed VMI contract, the supplier controls inventories stored at buyer's warehouse by placing orders and setting the inventory level based on the demand data that he receives directly from the buyer. After all, the VMI program is (Kim et al., 2014)beneficial to the buyer and he is free from the burden of replenishment and inventory control. The VMI also enables the supplier to synchronize replenishment, shipment, and production activities based on real-time information of market demand, and he can systematically save the relevant costs.

Past studies have considered diverse issues regarding VMI such as the power game among supply chain members (Yu et al., 2009b; Zheng et al., 2009), information sharing (Vigtil, 2007), contract terms (Guan & Zhao, 2010; Wong et al., 2009), and algorithm development for inventory and distribution problems (Sadeghi et al., 2014b; Seifbarghy & Gilkalayeh, 2012). In the past studies, VMI is compared with other systems such as the non-collaborated system (Kiesmuller & Broekmeulen, 2010; Wang, 2009), Point-Of-Sales (Kim et al., 2011), and Collaborative Planning, Forecasting, and Replenishment(Sari, 2008a, b), and their performances are evaluated in terms of the inventory level (Moon & Kim, 2007; Sari, 2007) and economic values(Song & Dinwoodie, 2008; Yu et al., 2009a),.

The consignment is a conventional business practice with long history (Fenton & Sanborn, 1987), and it has been still broadly used in current businesses (Gerber, 1987). According to the consignment contract, the supplier holds his products on buyer’s premises before the buyer takes them for sales(Harding, 1999). Since the supplier still owns the inventories, the buyer needs to pay for the inventories once they are sold at the market(Gerber, 1991). Many past studies consider the consignment as one of supply chain collaboration programs and show that it improves supply chain performance and solves inherent problems of the traditional system (Battini et al., 2010; Valentini & Zavanella, 2003).

Information sharing has been the famous issue that many researchers address in their studies on the supply chain management(Kim & Song, 2013). While it is widely accepted that information sharing provides the supply chain system with significant benefits, the results of past studies are somewhat mixed. For example, Cachon & Fisher (2000) and Raghunathan (2001) failed to show the significant benefit purely due to information sharing. Chen (1998) and Lee et al. (2000)found out that information sharing gives significant benefits to the supply chain system only on the certain conditions. In Zhao & Xie (2002) study, information sharing gives benefits to only the supplier and hurts retailers. By implication, further investigation is still required to identify the true value of information sharing.

This study directly compares various performances of the consignment and VMI under diverse circumstances by using the simulation model, while most past studies primarily depended on analytical modeling that leads to limited findings about how these collaboration programs work(Chen, 2013; Mateen & Chatterjee, 2015). In addition, this study examines the value of information sharing under two different collaboration programs.

This study follows the series of previous research works on VMI and consignment. Some of them examine how two collaboration programs improve the supply chain performance and demonstrate the benefits of supply chain collaboration (Ryu, 2006b, 2007a, 2013b). The performance of VMI is examined under the different conditions (Ryu, 2013a) and even the combination of two programs is tested to look for more advanced collaboration program (Ryu, 2015). Meanwhile, those studies hold the limited concept of supply chain collaboration and ignore information sharing in the collaboration programs. The assumptions of their deterministic models oversimplify the complex supply chain operations. One study investigates the impact of different cost payment schemes on VMI's performance by using the simulation model with stochastic demand and lead-time (Ryu, 2012). Its simulation applies the time phased processes that are close to the operations occurring in the real supply chain system, and the supply chain model expands the scope of supply chain collaboration by considering the impact of information sharing. This study shares the basic supply chain model and simulation design with one of the previous studies (Ryu, 2012). By using the simulation, however, this study directly compares two different collaboration programs under the various conditions. In addition, this study examines the impacts of operational and environmental factors on the supply collaboration programs.

Since the supply chain collaboration became the main interest of researchers in the business area, there have been so many studies addressed this issue. Meanwhile, many researchers have chosen their own ways to define the supply chain collaboration, and even it becomes extremely hard to find the common features of specific collaboration programs such as VMI in their studies. Literally, there exist various ways to define the collaboration programs, and it may particularly cause the serious problem when different collaboration programs are simultaneously evaluated.

Since this study directly compares distinct types of the supply chain collaboration, first of all, it needs to develop the fundamental concept to define any supply chain collaboration programs. This study analyzes the supply chain collaboration programs based on three elements of collaboration, and they are information sharing, cost payment, and decision authority (Ryu, 2007b).

Information sharing is a typical feature that is found in most collaboration programs. Information sharing indicates that supply chain members actively share information with the purpose of improving the supply chain performance. Many past studies have focused on the value of information sharing (Cachon & Fisher, 2000; Raghunathan, 2001).

Supply chain collaboration is also realized with new cost payment schemes. By changing the cost method such as price dis countor switching the member who pays particular cost items such as consignment, supply chain members can realize collaboration and improve the overall supply chain performance. In general, the supply chain system performs better when a supply chain member who holds decision authority is responsible for paying more cost items (Gumus et al., 2008; Ryu, 2012).

Decision-making is also a key element of supply chain collaboration. In general, the supply chain collaboration happens when a single member holds the full authority to make decisions on the supply chain operations or the operational decisions are made by consensus among different members. Examples of the operational decisions that members make together under the supply chain collaboration are sales price (Weng, 1995), production rate (Weng, 1997), lot size (Weng, 1995, 1997), discounting price (Chen et al., 2001), and inventory control policy (Ng et al., 2001).

Based on the proposed framework, a researcher can recognize the special features of a collaboration program that enables supply chain members to collaborate their operations in the supply chain system. In particular, this framework allows anyone to figure out which is more advanced collaboration program than the others. According to the proposed frame work, the specific collaboration program is more advanced one as more information is shared among supply chain members, as more cost items are paid by one member, as more decisions are made by one member.

This study focuses on decision making and cost payment in the comparison of the consignment and VMI programs. According to the proposed framework, this study claims that VMI that let a single member make more decisions and pay greater portion of the cost is more advanced collaboration program than the consignment.

3. Simulation Model and Design

The simulation model represents a two stage supply chain system where one supplier sells a single item to a buyer (Ryu, 2012). Both buyer and supplier make the decisions on their own operations in a way to maximize their profits. The buyer's profit includes sales revenue at the retail market, ordering cost, inventory carrying cost, and shortage cost. The supplier's profit contains sales revenue from the buyer, set-up cost, inventory carrying cost, backorder cost, production cost, capacity expansion cost, and transportation cost.

The simulation is designed to examine three different supply chain models including traditional system, consignment, and VMI. In each supply chain system, the buyer and supplier have different decision authority and information structure from the other system.

3.1. Three Supply Chain Models in Simulation

In the traditional system, the buyer and supplier manage their processes by making independent decisions based on a limited set of accessible information. With the record of past demands at the retail market, the buyer conducts demand forecasting to prepare ordering. In the replenishment plan, the order quantity and frequency are determined based on the transfer price informed by the supplier. The buyer determines the retail price before forecasting the demand, and the original price is adjusted depending on the newly updated forecasted demands. The supplier forecasts buyer's orders based on the past orders, and he develops production plans to fulfill the orders placed by the buyer. The supplier set the transfer price before the buyer places orders, and then he modifies the original price to reflect the updated information of the replenishment schedule. Both supplier and buyer use the periodic review system (R,Q) as the inventory control policy (Angulo et al., 2004). The buyer forecasts market demands to decide the orders by using Holt's linear exponential smoothing method (Holt, 2004).

In the consignment, the buyer does not have to make payment to the supplier for products until they are consumed. Accordingly, the buyer still has the full authority to make any decisions on replenishment under the consignment. In the simulation model, the buyer is responsible for paying only the stocking cost out of the entire cost to hold inventories at his warehouse. The inventory holding cost is separated into stocking and financing costs (Valentini & Zavanella, 2003). The stocking cost indicates the costs to store, handle, and insure inventories. The financing cost is an opportunity cost that the supplier pays while he invests finances in producing the inventories. Under the consignment, the buyer pays only stocking cost and the supplier is responsible for the financing cost of inventories stored at buyer's warehouse.

Under VMI, the supplier controls inventories stored at buyer's warehouse. Buyer's demand forecast are directly transferred to the supplier who is responsible for the orders. The buyer still decides the retail price and informs this price to the supplier. Based on the retail sales price and forecasted market demand obtained from the buyer, the supplier decides the lot size and order frequency to control the inventories stored at buyer's warehouse. The supplier also develops the production plan according to the order schedules that he makes. The suppler decides the transfer price based on the replenishment plan and inventory levels at two warehouses.

3.2. Operational and Environmental Factors

In the simulation runs, this study considers the operational and environmental factors including the collaboration program, information sharing level, demand pattern, lead-time, production capacity, and costs. By considering different levels of these factors in simulation runs, this study seeks to obtain the generalizable outcomes in diverse circumstances.

Six factors associated with operations and environments of the general supply chain system are chosen to significantly affect supply chain performance. One factor that is considered in the simulation is the collaboration program. The collaboration program represents a specific way that all members in the supply chain system operate their functions and make decisions. In the simulation models, total three different supply chain systems are considered including the traditional system. The traditional system serves as the base compared with the consignment and VMI.

Many past studies support that the collaborative supply chain system out performs the traditional non-collaborative system (Aviv, 2001; Mc Carthy & Golicic, 2002). VMI is considered to be more advanced collaboration program than consignment, because the decision authority (related to ordering) is more concentrated on the one member (supplier).

Information sharing has been addressed as a main topic in supply chain management due to its potential value in supply chain operations. Past studies examined the impact of information sharing when the supply chain members share various kinds of information such as customer demand (Lee et al., 2000; Raghunathan, 2001), forecasted demand (Aviv, 2001; Cachon & Lariviere, 2001), and inventory (Cachon & Fisher, 2000; Zhao & Xie, 2002).In general, extended information sharing enhances visibility of operations in the supply chain system, and consequently allows supply chain members to make better decisions on their operations. According to past studies, when the supply chain members share information more extensively, the supply chain system achieves better performance (Cachon & Fisher, 2000).

The simulation model considers three levels of information sharing (Gavirneni et al., 1999). No information sharing implies that the buyer informs only orders to the supplier, and no other information is transferred between the buyer and supplier. With partial information sharing, the only selected portion of information is shared by the supplier and buyer, and the buyer provides either forecasting or market sensitivity parameters to the supplier. Full information sharing indicates that the buyer and supplier share full information including both market demand and forecast parameters.

In general, the demand pattern is considered as an important input of simulation runs to evaluate the supply chain system. Past studies use diverse demand patterns in their simulation models including the simple probability distribution (Waller et al., 1999), particular demand patterns of trend or seasonality (Zhao & Xie, 2002; Zhao et al., 2002a), autocorrelation (Aviv, 2002; Raghunathan & Yeh, 2001), price-sensitive demand (Mishra & Raghunathan, 2004), and combinations of more than one demand models (Zhao et al., 2002c). This study considers three different demand patterns including the steady state uniform distribution, demand with a linear trend, and the autocorrelation (AR(1)).

The lead-time is the time length required for a certain routine operation such as moving, queuing, set-up, and run times (Hopp & Spearman, 2000). In general, the lead-time lessens the certainty of information. Even though the lead-time is known to affect the supply chain performance, many past studies simplify their supply chain models by assuming no lead-time (Robinson et al., 2005). In the simulation model, this study considers two different lead-times. Buyer’s lead-time represents the time duration between the order and arrival of products at buyer's place. Supplier’s lead-time refers the time length between when the production plan schedules a product for manufacturing and when manufacturing the product is complete. In the simulation runs, the lead-time is generated based on the specific probability distribution to allow uncertainty of the lead-time.

The production capacity represents the maximum amount of production throughout, and normally it restricts the flexibility of production process to fulfill unstable demands (Hopp & Spearman, 2000). Since the collaboration programs like VMI are known to lessen the demand uncertainty, they can maintain the limited production capacity and do not require the high inventory level (Wijngaard, 2004).Due to its significant impact on the supply chain performance, many past studies considered the production capacity to be the important condition of collaboration programs (Gavirneni et al., 1999; Waller et al., 1999).

Since the arbitrarily chosen parameters are used in the simulation runs, this study varies the cost parameters to secure generalizability of the simulation outcomes. In particular, the inventory holding, shortage, and ordering costs are chosen among many different cost items, because they are significantly different among distinct industries (Zhao et al., 2002b).By varying the ratio of costs with supplier’sand buyer’s costs, the simulation model maintains the same value of total supply chain cost(Simpson, 2007; Yao et al., 2007).

3.3. Performance Measurement

In the simulation runs, this study accesses the supply chain performance in terms of economic values, customer service levels, and bullwhip effect. Most past studies measured the economic values when they evaluate the supply chain performance due to their practical significance in most businesses (Aviv, 2002; Raghunathan, 1999). This study also uses the economic values including profit as well as cost. In addition, the detailed cost items are calculated to identify the exact causes of overall outcomes.

The customer service level refers the fraction of customer demands fulfilled on time (Hopp & Spearman, 2000).In the past studies, the customer service level has been measured in different scales such as the fill rate (Braglia & Zavanella, 2003; Disney & Towill, 2002) and backorder level (Waller et al., 1999). This study measures the fill rate, which is the fraction of orders fulfilled by available inventory, to indicate both buyer’s and supplier's customer service levels.

The bullwhip effect is the phenomenon that orders to the supplier have higher variance than sales to the buyer (Lee et al., 1997). Many researchers have focused on the bullwhip effect, because its well-known negative effect on the supply chain performance. While many past studies have addressed the issues regarding the bullwhip effect, relatively a small number of them have used it to evaluate the collaboration programs(Chen et al., 2000; Disney & Towill, 2003). This study measures the bullwhip effect in the simulation runs to examine how well the supply chain collaboration programs lessen it. According to the past studies(Chen et al., 2000; Disney & Towill, 2003), the bullwhip effect is measured as the ratio of demand variance at the upstream echelon over one at the downstream echelon.

3.4. Parameter Setting

In the simulation, three different supply chain collaboration programs and three levels of information sharing are considered (Gavirneni et al., 1999), and the experiment is designed to compare total six supply chain systems including the traditional system with no information sharing, traditional system with partial information sharing, consignment with no information sharing, consignment with partial information sharing, VMI with partial information sharing, and VMI with full information sharing. The other three cases from the full factorial design of collaboration programs and information sharing levels are not considered in the experiment, because a certain level of information sharing is not applicable to a particular collaboration program.

The level of information sharing is determined depending on whether the buyer and supplier apply the same parameters to their demand forecasting and estimating market demand (Aviv, 2001; Cachon & Lariviere, 2001). The values of specific parameters used for demand forecasting and market demand in the cases are shown in <Table 1>.

<Table 1> Parameter Setting in Different Levels of Information Sharing

	Same	Different
Forecasting	Buyer: a= 0.3 b= 0.2 t= 10	Buyer: a= 0.3 b= 0.2 t= 10
	Supplier: a= 0.3; b= 0.2; t= 10	Supplier: a= 0.8; b= 0.7; t= 5
Market sensitivity	Actual demand = Max. demand – 3 × retail price	Actual demand = Max. demand – 3 × retail price
	Estimated demand = Max. demand – 3 × retail price	Estimated demand = Max. demand – 2.9 × retail price

Source: Ryu(2006a).

In the simulation runs, three types of demand patterns including steady state demand, demand with trend, and autocorrelation are considered. The steady state demand indicates the case that the maximum demand is a random number from the uniform probability distribution between 1 and 4 units. The demand with trend is generated by using Holt's linear exponential smoothing method as follows.

$$L_t = \alpha \cdot Z_t + (1-\alpha) \cdot (L_{t-1} + T_{t-1})$$
$$T_t = \beta \cdot (L_t - L_{t-1}) + (1-\beta) \cdot T_{t-1}$$
$$D_{t+m} = L_t + m \cdot T_t$$

where, α = 0.01, β = 0.01, m = 100, $Z_t \sim Uniform$ (1,3), and D_t is the actual demand at time t.

The demand with autocorrelation follows the standard AR(1) model, and it is generated by the following equation.

$D_{t+1} = 2.5 + \rho \times D_t - 2.5 \times Z_{t+1}$ where, $\rho = 0.5$ and $Z_t \sim Uniform$ (-1,1)

<Table 2> shows the values of the specific parameters used for different levels of lead-time, production capacity, and cost structure. The other parameters used in the basic simulation model are shown in <Table 3>.

<Table 2> Parameters Used in Simulation

Parameters		Low	High
Buyer's lead-time		Uniform (2,8) μ= 5; σ^2 = 3	Uniform (7,13) μ = 10; σ^2 = 3
Supplier's lead-time		Uniform (2,8) μ= 5; σ^2 = 3	Uniform (7,13) μ = 10; σ^2 = 3
Production capacity		60 percent of Demand	90 percent of Demand
Inventory holding cost ratio (upstream over downstream)	Buyer's holding cost	16 per unit and a period (10 percent of transfer price)	7.5 per unit and a period (5 percent of transfer price)
	Supplier's holding cost	4 per unit and a period	8 per unit and a period
Set-up cost ratio (upstream over downstream)	Buyer's set-up cost	200 per cycle	150 per cycle
	Supplier's set-up cost	200 per cycle	250 per cycle
Shortage cost ratio (upstream over downstream)	Buyer's shortage cost	150 per unit	100 per unit
	Supplier's shortage cost	150 per unit	200 per unit

Source: Ryu (2006a).

<Table 3> Parameters Used in Base Case

Parameters	Values
Market demand (Max)	Uniform (1,4)
Transportation cost	1 percent of transfer price
Financing cost of inventory holding	5 percent of total inventory holding cost
Profit margin	50 percent of transfer price
Production cost	100 per unit
Capacity expansion cost	50 per unit
Safety stock	40 percent of demand during lead-time

Source: Ryu (2006a).

After all, the number of total cases considered in the simulation are counted as 6 (collaboration programs and information sharing) 3(demand patterns) 2(buyer's lead-time) 2(supplier's lead-time) 2(production capacity) 2(inventory holding cost ratio) 2(ordering cost ratio) 2(shortage cost ratio) = 1,152.The warm-up period is determined after checking how both buyer and supplier's inventory levels change over the time. Since their inventory levels become stabilized after 35 periods, each simulation run has 35 warm-up period.

Total simulation running time is 135 periods including 35 warm-up period. Meanwhile, the simulation performance is recorded during the half-period to keep the rule of i.i.d. (independently and identically distributed) on the simulation outcomes. Accordingly, 50 points of the data in each simulation run are observed for the analyses ((135-35)/2 = 50).

4. Simulation Results

The performances of the individual supply chain systems are obtained from the simulation runs as shown in <Table4>.

<Table 4> Average Performances of Supply Chain Systems

	Traditional System without Information Sharing	Consignment without Information Sharing	VMI with Partial Information Sharing	Traditional System with Partial Information Sharing	Consignment with Partial Information Sharing	VMI with Full Information Sharing
Demand	217.71	217.42	219.72	222.65	222.71	231.52
Buyer's Revenue	50,219.41	50,173.60	50,513.88	50,991.75	51,000.92	51,315.68
Buyer's Set-up Cost	394.17	402.58	350.00	422.25	402.50	350.00
Buyer's Holding Cost	635.44	725.15	9,667.17	689.90	710.38	765.91
Buyer's Shortage cost	2.13	2.27	0.00	2.45	2.36	2.91
Buyer's Payment	29,737.39	28,052.56	30,293.58	28,734.53	28,072.28	29,319.49
Buyer's Total Cost	30,769.13	29,146.31	30,293.58	29,849.13	29,152.00	29,319.49
Buyer's Profit	19,450.28	21,027.29	20,220.31	21,142.61	21,848.92	21,996.19
Supplier's Revenue	29,737.39	28,052.56	30,293.58	28,734.53	28,072.28	29,319.49
Supplier's Set-up Cost	274.17	274.00	450.00	268.50	268.50	450.00
Supplier's Holding Cost	3,816.43	4,096.60	300.23	1,248.10	1,201.38	269.31
Supplier's Shortage Cost	14.61	14.19	23.37	16.26	16.45	23.23
Production Cost	17,354.09	17,348.28	17,108.50	16,771.37	16,764.88	16,507.44
Transportation Cost	297.37	280.53	302.94	287.35	280.72	293.19
Capacity Cost	302.88	303.03	378.10	303.10	303.26	370.30
Supplier's Total Cost	22,059.55	22,352.88	28,580.30	18,894.67	18,870.72	19,032.29
Supplier's Profit	7,677.84	5,699.68	1,713.28	9,839.86	9,201.57	10,287.19
Supply Chain Profit	27,128.12	26,726.97	21,933.58	30,982.47	31,050.49	32,283.39
Supply Chain Cost	52,828.68	51,499.19	58,873.88	48,743.80	48,022.71	48,351.78
Buyer's Service Level	0.97	0.97	1.00	0.97	0.97	0.96
Supplier's Service Level	0.84	0.84	0.75	0.82	0.81	0.75
Bullwhip Effect	29.54	29.51	25.58	30.28	30.29	26.37
Buyer's Inventory	20,998.67	18,935.31	247,932.83	18,461.58	18,963.87	20,153.11
Supplier's Inventory	249,969.12	261,588.43	17,378.81	84,316.51	81,147.47	16,455.49
Retail Price	231.52	231.62	230.98	229.88	229.86	229.21
Transfer Price	156.17	156.18	157.21	152.69	152.71	153.67
Buyer's Order Quantity	86.21	77.72	96.78	77.57	79.55	95.50
Supplier's Production Rate	117.83	117.81	76.66	116.36	116.33	74.82

According to the simulation outcomes, the supply chain system achieves higher supply chain profit than the others in the order of VMI with full information sharing, consignment with partial information sharing, traditional system with partial information sharing, traditional system without information sharing, consignment without information sharing, and VMI with partial information sharing. Under the assumption that the supply chain system applies more advanced collaboration programs than the others in the order of VMI, consignment, and traditional system, this result supports that more advanced collaboration programs result in greater supply chain profit than less advanced ones.

In addition, the simulation results indicate that higher level of information sharing leads to greater supply chain profit regardless of the collaboration program applied to the system. In particular, without high level of information sharing, more advanced collaboration systems such as VMI and consignment achieve lower supply chain profit than less advanced ones. This result implies that the collaboration program can be successful only if the proper amount of information is shared among supply chain members.

The main cause of the simulation results can be figured out by observing the demand and order quantity. Overall, the collaboration programs enable the members to increase their revenues by increasing the total through put in the entire supply chain system and they can reduce the cost by controlling the order quantity efficiently. In particular, under VMI, the supplier has the full authority over ordering products and is able to reduce the cost significantly by properly balancing his production rate and buyer's order.

Information sharing allows the supply chain members to figure out the exact market sensitivity and obtain correct forecasted demands. With accurate information, they tend to lower their prices to increase the total demand, and it leads to the increased supply chain revenue.

In general, the buyer obtains greater profit when more advanced collaboration program is applied to the system and the level of information sharing is higher. On the other hand, the supplier’s profit is lower under more advanced collaboration systems. This result implies that the buyer receives most of the benefits from the supply chain collaboration program. With the consideration of the key nature of the supply chain collaboration, which requires every member’s participation, the proper program to compensate supplier’s loss must be prepared to ensure successful application of the collaboration program. In one exceptional case of VMI with full information sharing, both buyer and supplier improve their performances, and again, it implies the importance of information sharing in applying the collaboration program.

The buyer’s and supplier’s service levels appeared in <Table 4> show no significant difference under the distinct collaboration programs or with different levels of information sharing. Meanwhile, supplier’s service level is less under VMI compared with the other systems.

The bullwhip effect, which is another indicator of the supply chain performance, is not significantly different between the traditional system and consignment. VMI, however, results in less bullwhip effect than the other systems. VMI enables the supplier to determine ordering and prevents the excessive changes of order quantity over time.

<Table 5> Average Performances of Supply Chain Systems in Individual Cases

Systems		Traditional System without Information Sharing		Consignment with Partial Information Sharing		VMI with Full Information Sharing	
Levels		Low	High	Low	High	Low	High
Buyer’s Lead-time	Buyer’s Profit	19,574.95	19,325.61	21,979.11	21,718.73	21,996.19	21,996.19
	Supplier’s Profit	8,018.23	7,337.45	9,447.18	8,955.96	10,287.19	10,287.19
	Supply Chain Profit	27,593.18	26,663.06	31,426.28	30,674.69	32,283.39	32,283.39
Supplier’s Lead-time	Buyer’s Profit	19,450.28	19,450.28	21,848.92	21,848.92	21,996.19	21,996.19
	Supplier’s Profit	7,271.14	8,084.54	8,954.71	9,448.43	10,251.83	10,322.56
	Supply Chain Profit	26,721.41	27,534.82	30,803.63	31,297.34	32,248.02	32,318.75
Production Capacity	Buyer’s Profit	19,450.28	19,450.28	21,848.92	21,848.92	21,996.19	21,996.19
	Supplier’s Profit	12,995.44	2,360.24	13,173.17	5,229.96	13,722.99	6,851.39
	Supply Chain Profit	32,445.72	21,810.52	35,022.09	27,078.88	35,719.19	28,847.59
Inventory Holding Cost Ratio	Buyer’s Profit	19,765.34	19,135.22	21,243.60	22,454.23	21,660.15	22,332.24
	Supplier’s Profit	7,609.57	7,746.11	9,765.14	8,638.00	10,611.08	9,963.30
	Supply Chain Profit	27,374.90	26,881.33	31,008.74	31,092.23	32,271.23	32,295.54
Ordering Cost Ratio	Buyer’s Profit	19,807.66	19,092.89	23,547.79	20,150.04	21,996.19	21,996.19
	Supplier’s Profit	9,192.61	6,163.07	7,861.03	10,542.10	10,287.19	10,287.19
	Supply Chain Profit	29,000.27	25,255.96	31,408.83	30,692.14	32,283.39	32,283.39
Shortage Cost Ratio	Buyer’s Profit	19,449.85	19,450.70	21,848.45	21,849.39	21,996.19	21,996.19
	Supplier’s Profit	7,652.03	7,703.65	9,212.10	9,191.03	10,289.93	10,284.46
	Supply Chain Profit	27,101.88	27,154.36	31,060.55	31,040.42	32,286.12	32,280.65

<Table 5> shows buyer's, supplier's, and supply chain profit under different levels of the operational and environmental factors. The simulation outcomes indicate that the traditional system and consignment make greater profit when buyer's lead-time is shorter, but it shows a marginal difference from when buyer's lead-time is longer. Meanwhile, VMI's performances are not significantly affected by buyer's lead-time.

When supplier's lead-time becomes longer, buyer's profit does not change, but both supplier's profit and supply chain profit increase. This outcome is commonly observed regardless of supply chain collaboration programs.

Supplier's production capacity has no significant impact on buyer's profit. However, greater production capacity significantly decreases supplier's profit. This outcome is also shared by every collaboration system. This result happens due to the increased cost caused by unnecessarily high supply with excessive production capacity and the consequent increase in the order quantity.

When the inventory holding cost ratio is high, buyer's profit is lower and supplier's profit is higher in the traditional system. With higher inventory holding cost ratio, buyer's profit is greater and supplier's profit is less under the consignment and VMI. When the ratio is high, the traditional system obtains less profit, and the consignment and VMI have greater profit.

With high ordering cost ratio, both buyer and supplier's profits are lower in the traditional system. Under the consignment, buyer's profit is lower and supplier's profit is higher when the ratio is high. Meanwhile, the ordering cost ratio has no significant impact on buyer's and supplier's profits under VMI. Except for VMI, the supply chain profit is greater with high ordering cost ratio.

The shortage cost ratio has the marginal impact on buyer's profit in every collaboration system. With the high ratio, supplier's profit is higher in the traditional system but it is less under the consignment and VMI. However, they show just marginal differences. Consequently, the shortage cost ratio has an insignificant impact on the supply chain profit regardless of collaboration programs.

In general, the traditional system generates higher supply chain profit with shorter buyer's lead-time, longer supplier's lead-time, lower production capacity, lower inventory holding cost ratio, lower ordering cost ratio, and higher shortage cost ratio. Compared with the traditional system, however, the consignment system's profit is greater with higher inventory cost ratio and higher shortage cost ratio. Meanwhile, VMI achieves higher profit with longer supplier's lead-time, higher inventory cost ratio, and lower shortage cost ratio.

5. Conclusion

Since the supply chain management became one of the key issues in the business, both researchers and practitioners have been searching for the specific programs that bring efficient collaboration among supply chain members and consequently improve the supply chain performance. This study examines the consignment and VMI as well-known supply chain collaboration programs. By evaluating their performances under various circumstances, this study intends to find out how these collaboration programs perform under different conditions.

For the analysis of the distinct supply chain systems, this study applies simulation modeling with time-phased operations. The simulation model represents the multiple steps of supply chain operations in a two-stage supply chain system where a supplier manufactures and sells a single product item to one buyer. In the simulation runs, six operational and environmental factors are considered and different collaboration programs are evaluated in terms of profits, service levels, and bullwhip effects. Based on the analysis on the simulation outcome, two supply chain collaboration programs are compared with the traditional non-collaborated system, and their performances are further examined to figure out the impacts of operational and environmental factors.

The simulation outcomes lead to the following main findings and managerial implications. First, in general, the simulation results support that more advanced supply chain collaboration programs result in better performance than less advanced ones. More advanced collaboration program holds stronger collaboration among supply chain members and wider scope of their participation on the operations enables the supply chain system to achieve better performance. This result implies the potentials to develop new collaboration program that can lead to better performance than the existing ones such as VMI and consignment. The companies need to keep looking for additional collaborative features to design new collaboration programs.

Second, the increased total throughput in the entire system is the main reason that the supply chain collaboration system outperforms the traditional system. The enlarged throughput is mainly caused by joint decision making based on cooperation between supply chain members. This result indicates that the companies should count the revenue as well as cost to identify the true value of supply chain collaboration.

Third, the simulation results indicate that there are specific conditions that the particular collaboration programs perform better. By implication, full knowledge about the specific operational and environmental conditions is quite required to obtain maximum outcomes from the collaboration program.

Fourth, the supply chain system achieves greater performances as its members share more information. This result supports that information sharing brings a significant value to the supply chain system (Cachon & Fisher, 2000; Lee et al., 2000). In particular, the simulation outcomes indicate that information sharing is essential for successful supply chain collaboration.

Finally, the buyer receives most benefits from the supply chain collaboration (Yao et al., 2007). This result can be the major obstacle for practical application of the supply chain collaboration programs. The proper program that compensates supplier's loss is required to apply the collaboration programs in practices.

The key contributions of this research are threefold. First, this study directly compares two distinct collaboration programs. Most past studies show the advantages of individual collaboration systems over the traditional non-collaborated system (Mateen & Chatterjee, 2015; Rad et al., 2014). There have been only a few studies that directly compare different collaboration programs (Cachon, 2001; Gumus et al., 2008). By analyzing two different collaboration systems at the same time, this study attempts to validate that more advanced collaboration program outperforms less advanced one.

Second, this study figures out the circumstances that the specific collaboration program performs well. By evaluating the performances of two collaboration programs under different levels of operational and environmental factors in the simulation, this study identifies the particular conditions that the collaboration programs can fully exploit their advantages.

Finally, the outcome of this study can answer the important question of whether the supply chain members should share information with others at their expense. By examining more than one collaboration programs having different levels of information sharing, this study evaluates the value of information sharing under distinct collaboration forms.

This study has some limitations that may become potential research issues. Since the simulation runs in this study rely on the arbitrarily chosen parameters, the simulation outcomes may not be applicable to every case. The future study can acquire generalizable results by using the data obtained from the empirical study on real cases.

This study shows how operational and environmental factors affect the performances of two collaboration programs, but it does not provide the comprehensible reasons of their impacts. The thorough experiment with extensive ranges of parameter setting is required to identify the exact causes of the simulation outcomes, and it can lead to the reasonable guideline on which collaboration program to select under the specific condition. This issue is rendered to the future study.

References

Angulo, A., Nachtmann, H., & Waller, M. A. (2004). Supply Chain Information Sharing in a Vendor Managed Inventory Partnership. *Journal of Business Logistics,* 25(1), 101-120.

Aviv, Y. (2001). The Effect of Collaborative Forecasting on Supply Chain Performance. *Management Science,* 47(10), 1326-1343.

Aviv, Y. (2002). Gaining Benefits from Joint Forecasting and Replenishment Processes: The Case of Auto-Correlated Demand. *Manufacturing & Service Operations* Manage ment, 4(1), 55-74.

Battini, D., Gunasekaran, A., Faccio, M., Persona, A., & Sgarbossa, F. (2010). Consignment Stock Inventory Model in an Integrated Supply Chain. *International Journal of Production Research,* 48(2), 477-500.

Braglia, M., & Zavanella, L. (2003). Modeling an Industrial Strategy for Inventory Management in Supply Chains: The 'Consignment Stock' Case. *International Journal of Production Research,* 41(16), 3793-3808.

Cachon, G. P. (2001). Stock Wars: Inventory Competition in a Two-Echelon Supply Chain with Multiple Retailers. *Operations Research*, 49(5), 658-674.

Cachon, G. P., & Fisher, M. (2000). Supply Chain Inventory Management and the Value of Shared Information. *Management Science,* 46(8), 1032-1048.

Cachon, G. P., & Lariviere, M. A. (2001). Contracting to Assure Supply: How to Share Demand Forecasts in a Supply Chain. *Management Science,* 47(5), 629-646.

Chakraborty, A., Chatterjee, A. K., & Mateen, A. (2015). A Vendor-Managed Inventory Scheme as a Supply Chain Coordination Mechanism. *International Journal of Production Research*, 53(1), 13-24.

Chen, F. (1998). Echelon Reorder Points, Installation Reorder Points, and the Value of Centralized Demand Information. *Management Science,* 44(12), S221-S234.

Chen, F., Drezner, Z., Ryan, J. K., & Simchi-Levi, D. (2000). Quantifying the Bullwhip Effect in a Simple Supply Chain: The Impact of Forecasting, Lead Times, and Information. *Management Science,* 46(3), 436-443.

Chen, F., Federgruen, A., & Zheng, Y. (2001). Coordination Mechanisms for a Distribution System with One Supplier and Multiple Retailers. *Management Science,* 47(5), 693-708.

Chen, L.T. (2013). Dynamic Supply Chain Coordination under Consignment and Vendor-Managed Inventory in Retailer-Centric B2b Electronic Markets. *Industrial Marketing Management,* 42(4), 518-531.

Danese, P. (2006). The Extended VMI for Coordinating the Whole Supply Network. *Journal of Manufacturing Technology Management,* 17(7), 888-907.

Derrouiche, R., Neubert, G., & Bouras, A. (2008). Supply Chain Management: A Framework to Characterize the Colla borative Strategies. *International Journal of Com puter Integrated Manufacturing,* 21(4), 426-439.

Disney, S. M., & Towill, D. R. (2002). A Procedure for the Optimization of the Dynamic Response of a Vendor Managed Inventory. *Computers & Industrial Engineering,* 43(1-2), 27-58.

Disney, S. M., & Towill, D. R. (2003). Vendor-Managed Inventory and Bullwhip Reduction in a Two-Level Supply Chain. *International Journal of Operations & Production,* 23(5/6), 625-651.

Egri, P., & Vancza, J. (2013). A Distributed Coordination Mechanism for Supply Networks with Asymmetric Information. *European Journal of Operational Research,* 226(3), 452-460.

Fenton, R. D., & Sanborn, B. A. (1987). Consignment Purchasing: From Industry to Health Care. *Hospital Materiel Management Quarterly,* 8(4), 1-7.

Gavirneni, S., Kapuscinski, R., & Tayur, S. (1999). Value of Information of Capacitated Supply Chains. *Management Science,* 45(1), 16-24.

Gerber, N. (1987). Consignment in Health Care: When and

Why. *Hospital Materiel Management Quarterly,* 8(4), 8-12.

Gerber, N. (1991). Objective Comparisons of Consignment, Just-in-Time, and Stockless. *Hospital Materiel Management Quarterly,* 13(1), 10-17.

Guan, R., & Zhao, X. (2010). On Contracts for VMI Program with Continuous Review (R, Q) Policy. *European Journal of Operational Research,* 207(2), 656-667.

Gumus, M., Jewkes, E. M., & Bookbinder, J. H. (2008). Impact of Consignment Inventory and Vendor-Managed Inventory for a Two-Party Supply Chain. *International Journal of Production Economics,* 113(2), 502-517.

Harding, M. L. (1999). Designing Automatic Resupply Systems. *Hospital Materiel Management Quarterly,* 20(3), 37-41.

Holt, C. C. (2004). Forecasting Seasonals and Trends by Exponentially Weighted Moving Averages. *Journal of Economic & Social Measurement,* 29(1), 123-125.

Hopp, W. J., & Spearman, L. (2000). *Factory Physics* (2nd ed.). New York: Irwin/Mc Graw-Hill.

Kiesmuller, G. P., & Broekmeulen, R. A. C. M. (2010). The Benefit of VMI Strategies in a Stochastic Multi-Product Serial Two Echelon System. *Computers & Operations Research,* 37(2), 406-416.

Kim, D. H., Kim, S. S., Jung, M. H., & Youn, M. K. (2014). A Comparative Analysis of Teukyakmeip and Consignment. *Journal of Distribution Science,* 12(4), 5-9.

Kim, T. H., Oh, M. S., & Kim, L. S. (2011). A Study on Suitability of Demand Characteristics and Supply Chain Collaboration Types. *Logistics Study,* 19(1), 97-115.

Kim, T. R., & Song, J. G. (2013). The Effect of Asset Specificity, Information Sharing, and a Collaborative Environment on Supply Chain Management (SCM): An Integrated SCM Performance Formation Model. *Journal of Distribution Science,* 11(4), 51-60.

Lee, H. L., Padmanabhan, V., & Whang, S. (1997). Information Distortion in a Supply Chain: The Bullwhip Effect. *Management Science,* 43(4), 546-558.

Lee, H. L., So, K. C., & Tang, C. S. (2000). The Value of Information Sharing in a Two-Level Supply Chain. *Management Science,* 46(5), 626-643.

Mateen, A., & Chatterjee, A. K. (2015). Vendor Managed Inventory for Single-Vendor Multi-Retailer Supply Chains. *Decision Support Systems,* 70, 31-41.

McCarthy, T. M., & Golicic, S. L. (2002). Implementing Collaborative Forecasting to Improve Supply Chain Performance. *International Journal of Physical Distribution & Logistics Management,* 32(6), 431-454.

Mishra, B. K., & Raghunathan, S. (2004). Retailer- Vs. Vendor-Managed Inventory and Brand Competition. *Management Science*, 50(4), 445-457.

Moon, S. A., & Kim, D. Y. (2007). A Dynamic Analysis of VMI Effect on the Supply Chain of Combat Uniform for Army Training Center. *Logistics Study,* 15(2), 1-21.

Ng, C. T., Li, L. Y. O., & Chakhlevitch, K. (2001). Coordinated Replenishments with Alternative Supply Sources in Two-Level Supply Chains. *International Journal of Production Economics,* 73(3), 227-240.

Rad, R. H., Razmi, J., Sangari, M. S., & Ebrahimi, Z. F. (2014). Optimizing an Integrated Vendor-Managed Inventory System for a Single-Vendor Two-Buyer Supply Chain with Determining Weighting Factor for Vendor's Ordering Cost. *International Journal of Production Economics,* 153, 295-308.

Raghunathan, S. (1999). Interorganizational Collaborative Fore casting and Replenishment Systems and Supply Chain Implications. *Decision Sciences,* 30(4), 1053-1071.

Raghunathan, S. (2001). Information Sharing in a Supply Chain: A Note on Its Value When Demand Is Nonstationary. *Management Science,* 47(4), 605-610.

Raghunathan, S., & Yeh, A. B. (2001). Beyond EDI: Impact of Continuous Replenishment Program (Crp) between a Manufacturer and Its Retailers. *Information Systems Research,* 12(4), 406-419.

Robinson, E. P., Sahin, F., & Gao, L.L. (2005). The Impact of E-Replenishment Strategy on Make-to-Order Supply Chain Performance. *Decision Sciences,* 36(1), 33-64.

Ryu, C. S. (2015). How VMI and Consignment Jointly Affect Supply Chain Performance. *Journal of Distribution Science,* 13(3), 31-39.

Ryu, C. S. (2006a). An Investigation of Impacts of Advanced Coordination Mechanisms on Supply Chain Performance: Consignment, VMI I, VMIII, and CPFR. Buffalo, NY U.S.A.: Thesis for Doctorate in the State University of New York at Buffalo.

Ryu, C. S. (2006b). An Investigation of the Impact of VMI on Supply Chain Performance. *Journal of the Korean Production and Operations Management Society,* 17(4), 47-73.

Ryu, C. S. (2007a). Examination of Consignment as the Supply Chain Coordination Program. *Journal of the Korean Production and Operations Management Society*, 18(2), 3-31.

Ryu, C. S. (2007b). Review of Supply Chain Coordination: Information Sharing, Cost Payment, and Decision Authority. J*ournal of the Korean Society of Supply Chain Management,* 7(1), 25-35.

Ryu, C. S. (2012). An Investigation of the Impact of Two VMI Variants on Supply Chain Performance. *Korean Corporation Management Review,* 19(4), 1-26.

Ryu, C. S. (2013a). An Investigation of the Impacts of Market Demand, Forecast Error, and Profit Margin on VMI's Benefit. *Korean Corporation Management Review,* 20(3), 201-222.

Ryu, C. S. (2013b). Investigation on the Performances of Two Supply Chain Collaboration Programs - Consignment and VMI. *Korean journal of Business Administration,* 26(11), 2979-3001.

Sadeghi, J., Sadeghi, S., & Niaki, S. T. A. (2014a). A Hybrid Vendor Managed Inventory and Redundancy Allocation Optimization Problem in Supply Chain Management: An Nsga-Ii with Tuned Parameters. *Computers & Operations Research*, 41, 53-64.

Sadeghi, J., Sadeghi, S., & Niaki, S. T. A. (2014b). Optimizing a Hybrid Vendor-Managed Inventory and Transportation Problem with Fuzzy Demand: An Improved Particle Swarm Optimization Algorithm. I*nformation Sciences,* 272, 126-144.

Sari, K. (2007). Exploring the Benefits of Vendor Managed Inventory. *International Journal of Physical Distribution & Logistics Management,* 37(7), 529-545.

Sari, K. (2008a). Inventory Inaccuracy and Performance of Collaborative Supply Chain Practices. *Industrial Management & Data Systems,* 108(3/4), 495-509.

Sari, K. (2008b). On the Benefits of CPFR and VMI: A Comparative Simulation Study. *International Journal of Production Economics,* 113(2), 575-586.

Seifbarghy, M., & Gilkalayeh, A. P. (2012). Supply Chain Integration under Vendor Managed Inventory Mode of Operation Considering Stock out. *Economic Computation & Economic Cybernetics Studies & Research,* 46(1), 197-218.

Simchi-Levi, D., Kaminsky, P., & Simchi-Levi, E. (2000). *Designing and Managing the Supply Chain; Concepts, Strategies, and Case Studies.* Boston: Mc Graw-Hill Higher Education.

Simpson, N. C. (2007). Central Versus Local Multiple Stage Inventory Planning: An Analysis of Solutions. *European Journal of Operational Research*, 181(1), 127-138.

Song, D. P., & Dinwoodie, J. (2008). Quantifying the Effectiveness of VMIand Integrated Inventory Manage ment in a Supply Chain with Uncertain Lead-Times and Uncertain Demands. *Production Planning & Control,* 19(6), 590-600.

Valentini, G., & Zavanella, L. (2003). The Consignment Stock of Inventories: Industrial Case and Performance Analysis. *International Journal of Production Economics,* 81/82(1), 215-224.

Vigtil, A. (2007). Information Exchange in Vendor Managed Inventory. *International Journal of Physical Distribution & Logistics Management,* 37(2), 131-147.

Waller, M., Johnson, M. E., & Davis, T. (1999). Vendor-Managed Inventory in the Retail Supply Chain. *Journal of Business Logistics,* 20(1), 183-203.

Wang, C. X. (2009). Random Yield and Uncertain Demand in Decentralised Supply Chains under the Traditional and VMI Arrangements. *International Journal of Production Research,* 47(7), 1955-1968.

Weng, Z. K. (1995). Channel Coordination and Quantity Discounts. *Management Science,* 41(9), 1509-1522.

Weng, Z. K. (1997). Pricing and Ordering Strategies in Manufacturing and Distribution Alliances. *IIE Transac tions,* 29(8), 681-692.

Wijngaard, J. (2004). The Effect of Foreknowledge of Demand in Case of a Restricted Capacity: The Single-Stage, Single-Product Case. *European Journal of Operational Research,* 159(1), 95-109.

Wong, W. K., Qi, J., & Leung, S. Y. S. (2009). Coordinating Supply Chains with Sales Rebate Contracts and Vendor-Managed Inventory. *International Journal of Production Economics,* 120(1), 151-161.

Xu, K., & Leung, M. T. (2009). Stocking Policy in a Two-Party Vendor Managed Channel with Space Restrictions. *International Journal of Production Economics,* 117(2), 271-285.

Yao, Y., Evers, P. T., & Dresner, M. E. (2007). Supply Chain Integration in Vendor-Managed Inventory. *Decision Support Systems,* 43(2), 663-674.

Yu, H., Zeng, A. Z., & Zhao, L. (2009a). Analyzing the Evolutionary Stability of the Vendor-Managed Inventory Supply Chains. *Computers & Industrial Engineering,* 56(1), 274-282.

Yu, Y., Huang, G. Q., & Liang, L. (2009b). Stackelberg Game-Theoretic Model for Optimizing Advertising, Pricing and Inventory Policies in Vendor Managed Inventory (VMI) Production Supply Chains. *Computers & Industrial Engineering,* 57(1), 368-382.

Zhao, X., & Xie, J. (2002). Forecasting Errors and the Value of Information Sharing in a Supply Chain. *International Journal of Production Research,* 40(2), 311-335.

Zhao, X., Xie, J., & Leung, J. (2002a). The Impact of Forecasting Model Selection on the Value of Information Sharing in a Supply Chain. *European Journal of Opera tional Research,* 142(2), 321-344.

Zhao, X., Xie, J., & Wei, J. C. (2002b). The Impact of Forecast Errors on Early Order Commitment in a Supply Chain. *Decision Sciences,* 33(2), 251-279.

Zhao, X., Xie, J., & Zhang, W. J. (2002c). The Impact of Information Sharing and Ordering Co-Ordination on Supply Chain Performance. *Supply Chain Management,* 7(1), 24-40.

Zheng, K. W., Tsai, C. H., Li, R. K., Chen, C. P., & Tsai, S. C. (2009). Development of the Distribution/VMI Game Based on Theory of Constraints. *The Asian Journal of Quality,* 10(1), 53-76.