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Effective Inventory Policy for VMI System at Discount Retailers

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대형할인매장의 VMI 시스템을 위한 효율적인 재고관리시스템

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This paper refers to the flow of products from supplier to discount retailers(DRs). Discount retailers prefer frequent delivery of small amount because of limited storage space, while suppliers prefer less frequent delivery of larger amount in order to save transportation cost. In this paper we propose a heuristic algorithm to determine the amount of order and the frequency of delivery which decreases the expected length of stockout. We also evaluate various order policies for Vendor Managed Inventory(VMI) system using simulation with real data.

1. Introduction

In the past, manufacturers had the control of decision on prices and inventories of goods because they had the network of their business agents. But the appearance of large DRs has made the controlling power move from manufacturers to DRs. Manufacturer's loss of control power in supply chain impose more burden of logistics cost to manufacturers.

Many researchers have studied for reducing the logistics cost by maintaining efficient vehicle schedules to minimize total transportation cost. Though having a good transportation and vehicle routing system, a weak inventory system causes the inefficiency of the total system's performance. Bad inventory system often creates urgent order and results in high delivery cost. These kinds of problems bring the need for the integrated system of activities for both of suppliers and retailers, which is important segment of SCM(Supply Chain Management).

Usually, SCM integrates manufacturers, suppliers and customers. Since the manufacturers have lost much of their power, they need to follow DR's policy in their business. Especially, suppliers should keep the delivery policy of DRs, which is VMI system. This system utilizes DR's current inventories coupled with an order point to trigger automatically the replenishment orders for all the items in DR. This supply chain highlights the advantages obtained from the relationship between suppliers and DRs. Recently, the effect of integrated inventory and routing strategies is emphasized by Stalk *et al.*(1992) who review the evolution of the discount retailing industry. This paper refers to the supply chain activities of inventory management of finished goods at DRs. DRs request many kinds of products from suppliers when they order. But increasing the diversity of products leads to growing total inventories, and limiting potential improvement of productivity. So many companies consign some of their functions to TPLC(Third Party Logistics Corporation). Especially, as a result of the increasing need for outsourcing of the logistics functions, suppliers become more conscious about their TPLC selection.

The objective of this paper is to determine the replenishment quantities and reorder point for each item so as to minimize inventory cost and for smooth flow of products into DRs by considering its demands. We consider the EOQ model of multiple items for preventing stockout as much as possible. This problem is similar to a multi-product generalization of distribution system considered by Anily and Federgruen(1990). Mcgavin *et. al.*(1997) examined the optimality of inventory balancing in a one- ware

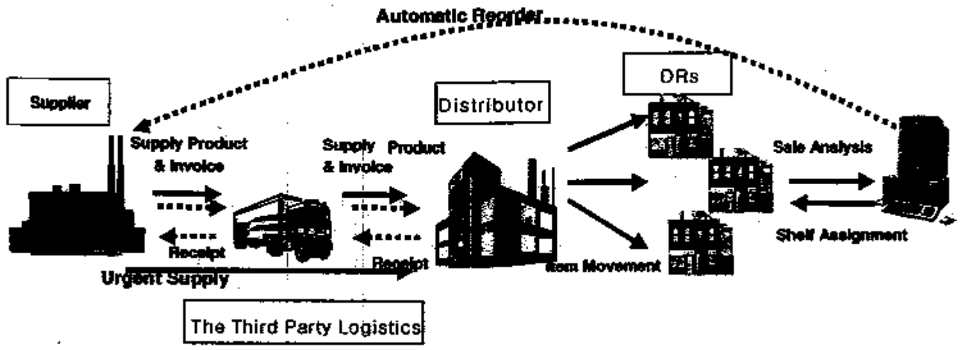


Figure 1. The Flow of Product in Discount Retailier.

house N-retailer distribution system with stochastic demand, but they considered only one item and the predetermined quantity. On the other hand, our model considers an economic order quantity problem, where a tradeoff can be found between stockout cost and delivery cost. We computed the economic order quantity at each fixed period with real data and adjusted the order level continuously by using the proposed learning function with on-line data. We have applied this model to Z, the TPLC, and the results are presented in this paper.

The configuration and the problem of market channel considered in this study are given in section 2. In section 3, heuristic algorithm for order policy is introduced. The results of the application of the proposed algorithm to the real case are given in section 4.

2. Configuration

The market of DRs, such as Wal-mart, Carrefour, and E-mart, appeared a few years ago in Korea. As the market grow bigger, many businesses have strived to meet the new trend. One of the concerns of this paper is the market channel consisting of DRs, TPLCs and suppliers. The flow of products and the participants of the market channel are given in <figure 1>. The company Z delivers products from suppliers to a distributor of DRs. This distribution channel is simpler and different from other existing channels. Generally, in this channel, suppliers cannot deliver their products to DRs directly and must do via a distributor of DRs. The order policy in this channel uses VMI system integrated with POS system of DRs. VMI system utilizes DRs current inventory coupled with an order point of an item to trigger automatically the replenishment orders for items within a DR. But there may be some problems in the channel. Let's see those problems in DRs and suppliers.

(1) The Dilemma of Supplier and the TPLC

Suppliers usually ask DRs to order more goods at one time to reduce the number of delivery. In initiative trade, suppliers make a contract with the head office of DRs on the service level of logistics(the number of delivery per week, quantity per delivery, the shelf position, fee, etc). Namely, the quantity of replenishment and the period between orders are determined. When the timing of the replenishment order is subject to uncertainty, an inefficient inventory policy gives rise to stockout or overstock. If any one of DRs runs short of products, urgent orders come to a supplier, whereupon he should replenish goods. But suppliers cannot know when an urgent order occurs. Besides, if any one of products is not replenished during the specific number of consecutive times of reorder, the product would be deleted from the order list of products in VMI. Thus suppliers have a burden of increasing delivery frequency.

(2) The Dilemma of Discount Retailers

DRs want to keep a rich assortment of goods, and small-amount and high-frequency deliveries are favorable to the DRs because of limited storage space. But, DRs should be careful not to make a stockout to happen. If any shelf in a DR is empty, sales volume decreases and MD(Manager of Division) should take the responsibility. Hence MD must manage items on shelves in DR carefully watching out for stockout. MD's competency runs counter to the supplier's needs. So it is necessary for supplier and TPLC to determine the appropriate logistics service level; the number of delivery per week and

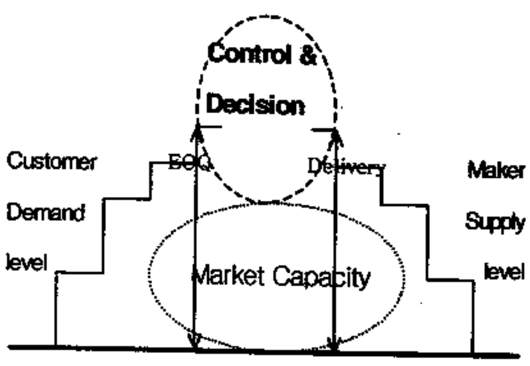


Figure 2. Decision Logistics Service Level.

the economic order quantity. For deciding the logistics service level, suppliers or TPLC and DRs would have the mutual goal of performance improvement which is greater than what could be achieved through each company's separate efforts. In addition, EOQ and the number of delivery should be controlled according to the state of market, customer demand level and maker supply level, as shown in <figure 2>.

3. The Proposed Algorithm

(1) Cost Factors

It is very hard to estimate exactly the inventory cost due to the inadequate and insufficient demand history. This paper considers inventory holding cost, ordering cost (including delivery cost), and stockout cost. Holding cost in our configuration occurs only at DRs since the finished goods are sent and stored at DRs. Hence we can estimate the value regarding this cost as rental fee for DRs and distributor. Ordering cost is subject to the TPLC. Whenever a vehicle is sent out to replenish inventory, it incurs a fixed cost plus a cost proportional to the total traveled distance of the vehicle from the supplier's warehouse to the distributor. We classified orders into regular order that happens regularly, and urgent order that happens unpredictably. The cost of urgent order depends on the order quantity and the order points. We computed ordering cost by using operational expenses of TPLC. Lastly, we dealt with stockout cost too. The identification of the stockout cost is very difficult because many qualitative parameters must be converted into quantitative unit. In inventory systems, stockout cost is very important because stockout often means a lost customer as well as a lost sale. From Okumura F. and Nomura S(1997), there are several reasons why suppliers hold inventories: urgent order(32.1%), limited capacity of production(32.1%), short lead time(21.4%), etc. In other words, suppliers have inventories for preventing stockouts. Petsinis *et al.*(1999) proposed the expected stockout cost as follows:

$$C_q = q_u C_u + g q_d C_d$$

$$SO_{it} = (a_i y_i + b_i y_i \beta) \times \max\left[0, \frac{q_{it}}{|t'|}|t| - q_{it}\right] + \alpha\left(\frac{q_{it}}{|t'|}|t| - q_{it}\right) \quad (1)$$

$$O_{it} = [pRO + (1-p)\,UO + \gamma] \quad (2)$$

$$H_{it} = \left[\sum_{i=1}^{m}\sum_{t=1}^{n_i}(x_{it} \times pr_i) \Big/ \sum_{i=1}^{m}\sum_{t=1}^{n_i} x_{it}\right] \times \lambda \times q_{it} \quad (3)$$

$$\min \quad \sum_{t=1}^{n_i} TC_{it} = SO_{it} + O_{it} + H_{it} \quad (4)$$

$$q_{it+1} = q^{*}_{it} + \theta \quad (5)$$

RO = Fee of TPLC / (# DRs #Days) —(6) UO = RO + (Fee of Delivery Van/#DRs) —(7)

H = Fee of DRs and DC / #Sales of Items per month —(8) = Salary of MD / (#Days # Items) —(9)

RO : Regular ordering UO : Urgent ordering SO_{it} : Stockout cost O_{it}: Ordering cost H_{it} : Holding cost

TC_{it} : The total cost of item i at period t a_i : The rate of lost sale of item i b_i : The rate of lost customer of item i

y_i : The profit of item i α : The coefficient of MDs dissatisfaction β : Lost customers recurring lost sales

γ : Cost including depreciation and insurance λ : The fee of DC and DRs

$|t|$: Length of period t $|t'|$: Length from the starting of period t to the stockout

q_{it} : Order quantities of item i during period t p : The probability of occurring regular ordering m : The kind of items

pr_i: Price of item i x_{it}: The sales quantity of item I in period t n_i: Delivery times within a month

θ : If stock happens, this value is '1'. And if retaining inventory is 7 times more than expected demand per day, this value is '-1'. Otherwise, the value is zero

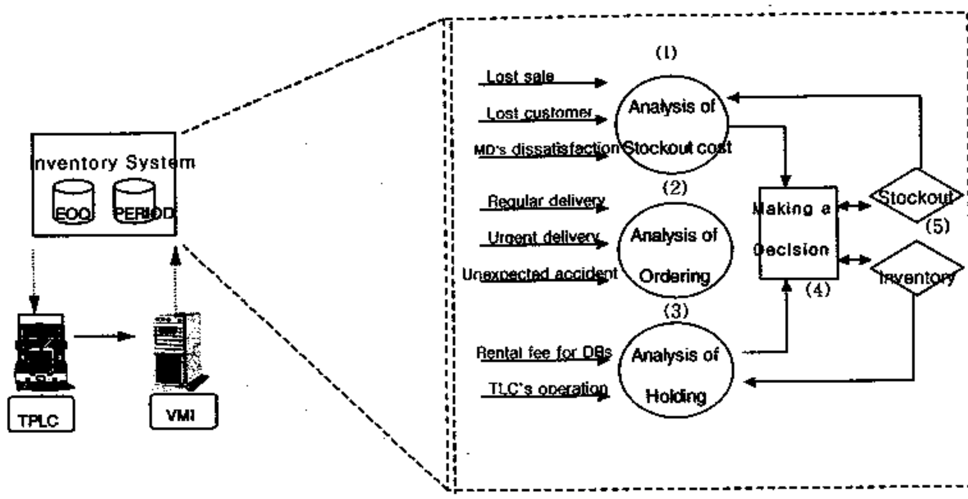


Figure 3. The flow of algorithm.

q_d : Coefficient representing the resentfulness of the destination.

C_q : The expected stockout cost.

C_u : The urgent order cost.

C_d : The cost due to the delivery delay.

q_u : Coefficient representing the criticality of the spare parts.

g: The probability of belated delivery to the destination.

Besides those factors, we also consider the factor of MD's dissatisfaction in our system. If there is a stockout in DR, a manager of DR imposed a penalty on MD due to neglecting of duty. This term of MD's dissatisfaction became the seeds of discord between MD and supplier.

(2) Algorithm

We have proposed 5 functions and 4 indices for estimating costs; stockout cost function (1), ordering cost function (2), and holding cost function (3). If a stockout happens, the value of function (1) accrues. Function (2) considers urgent order index (7) and regular order index (6), and the holding cost within DRs is estimated by function (3) and index (8). Function (4) is a total cost function, and function (5) is learning function which reflects variant of demand. These functions are established for minimizing total cost as given in <figure 3>. We compute the q_i (economic order quantity) from this algorithm and the obtained q_i is controlled by the online record of sales. Then, changing the delivery points(from Tuesday to Saturday) under the determined delivery times, we find the economic order points for minimizing total cost.

In this system, order quantities can be flexible changed by last function (5) automatically according to the rate of demand and the quantities of holding items. We have computed the value for order up to levels at each fixed period with real data, and adjusted the values with the proposed function using on-line data continuously. The assumptions of this model are: an order cannot be delivered separately, shortages are permitted, fixed quantity can be delivered at any time, and insurance fee γ is not considered. Actual data was used for the purpose of drawing specific values of parameters, and this paper also utilized Attwood *et al.*(1992)'s results except for the value of delayed sale, because there is no delaying in our case. They had shown that a lost sale occurred in 67% of stockout, a lost customer in 23% of stockout and a delayed sale in 10% of them. A lost customer means a recurring loss(β) of sales, and it would be assumed in this case that each customer who is lost would have made two more purchases. Here, the outline of algorithm is shown in <figure 3>.

4. Case Study

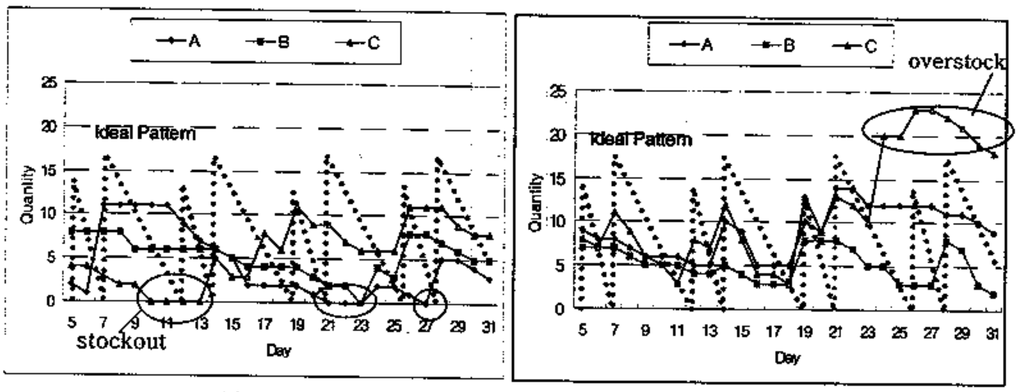
The company Z is a TPLC for managing items only at DRs. Main operations of Z are management and delivery of items which are at DRs. In case study, Z handles 24 items of metal goods at every DR. The flow of products and the participants are given in <figure 1>. The logistics service level of Z−2 deliveries (Wednesday and Friday) per week - was made in a contract with DRs. The activities related

Table 1. The sales and orders of records

DR K's sales	1	2	3	4		6		8	9	10	11		13		15	16	17	18		20		22	23	24	25		27		29	30		SUM
A	2	3				1						2	2	1	1	3				1	1			3		1	1			1	1	24
B		2	1		1				2						1	1				1	1		2	1	1			1	1	1		17
C	2	1		1	2		1	1		2					2			2		2		2	1						2	1		22
DR K's orders																																SUM
A	7						10																	5				5				27
B	12																							5		5						22
C	10													5			5		5							5						30
DR H's sales	1	2	3	4		6		8	9	10	11		13		15	16	17	18		20		22	23	24	25		27		29	30		SUM
A		5			1	1		1	1			1			1	4				1			2					1		1	1	22
B	3	2			3			1	1			1		1	1	1						1			2				1	4		20
C	1	2	1	1	2	1	1	2	3	1	2		1		4	4		1		4	1	1	2					3	1	2		41
DR H's orders																																SUM
A	5				10									5					5		5											27
B	5				10														6									5				22
C	5				10		5					5		5					10		5			10								30

■ Regular Delivery

Stockout



(a) DR K (b) DR H

Figure 4. The trend of inventories.

to the replenishment for lots of items are carried out periodically. But unexpected demands and bad inventory policy result in inconstant service level, which is an irregular order quantity as shown in <figure 5>. So high operating cost happened to Z and stockouts happened to DRs. <Table 1> and <figure 4> show the sales and replenishment records for a month at DR K and DR H. There is a strong contrast between DR K and DR H. At DR K, there are 9 regular orders(5, 7, 12, 14, 19, 21, 26, 28, 31), 2 urgent orders(17, 24), and 3 stockouts(for 9 days) in a month. On the contrary, oversupply happens to DR H. Item C at DR H is piled up high as shown in figure 4(b). The record of DR H has 9 regular orders(5, 7, 12, 14, 19, 21, 26, 28, 31), 1 urgent orders(24), and no stockout in a month. Order quantity of each item at all DRs are extremely variable as shown in <figure 5>. We can recognize that the accumulated inventories become high with the lapse of time as shown in <figure 4>. So the

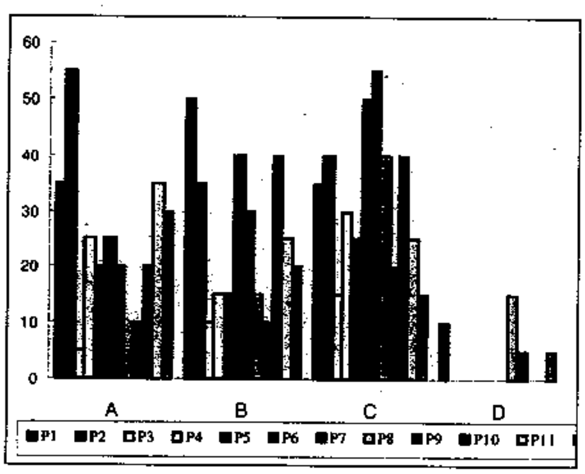


Figure 5. Fluctuating Demands of items.

existing inventory policy has some problems. While some DRs have a pile of item B, there may be a DR which does not have item B at all. Although all DRs except one DR have item B, an order is sent to supplier automatically by VMI system, and supplier

Table 2. The value of parameters

	A	B	C	Parameters
H	7.55	7.15	9.91	$\alpha=167$, $\beta=2$, $\gamma=0$, $\lambda=0.15$, a=0.67, b=0.23,
y_i	795	720	735	$RO=847.5$, $UO=1076.19$

should replenish item B. We need efficient inventory system reflecting inconstant demand. This simulation considers only 3 homogeneous items out of 24 items. We seek to maintain a proper balance between too much stock and too little, and these difficulties have been solved with the proposed algorithm.

This algorithm has proposed the proper order quantity of each item through on-line sales information. The system is coded with Visual Basic 6.0 and Access for database. The parameter's values used in the system are given in <tables 2>. We have estimated these values by analyzing operating costs and applying indices. In case of item A, B, and C, several stockouts occurred at DR K in spite of holding enough stocks.

On the contrary, items overflow at DR H. Especially item C, whose average inventory is about 12 per day, is oversupplied. Generally, total inventory of item A, B, and C is growing up with the lapse of time, but stockouts frequently happen at DR K. At DR K, the results of this simulation have shown that the proper order quantity of item A is about 3 units, item B is 2 units, and item C is 3 units as shown in <table 3>. If the order quantity is changed, we can reduce inventory cost up to 40% and the quantities of inventory 7.9 into 4.1. <Table 4> and <figure 6> have shown the inventory costs according to various order points. The existing order points are wednesday and friday, but they(DRs, supplier, and TPLC) had better change the order points into wednesday-saturday or thursday-saturday for mutual benefit. The results of DR H are summarized at <table 3> and 4 too. In case of DR H, we can reduce inventory as well as cost: inventory of items at DR H can be reduced 8.65 into 4.0, the cost can be decreased about 42%. Especially, order quantities of item C are changed by learning function (5): (5, 8) on 1st order point, (4, 8) on 2nd, (4, 7) on 3rd, (3, 7) on 4th, and (3, 6) the last. The current order points are good. From <table 4>, we can recognize that order points will make a great difference in term of cost.

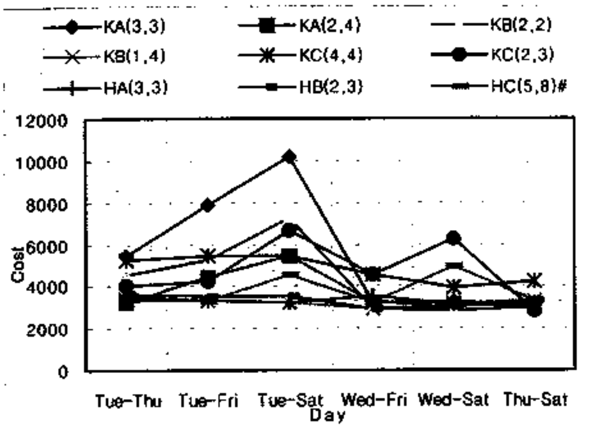


Figure 6. Chart of costs at order points.

Table 4. Costs according to various order points

Item	Quant	Tue-Thu	Tue-Fri	Tue-Sat	Wed-Fri	Wed-Sat	Thu-Sat	Max/Min
KA	3,3	5488	7858	10229	3276	3186	3095	3.37
	2,4	3178	4453	5397	3216	3095	3035	
KB	2,2	4574	5224	7294	2891	2861	3004	2.55
	1,4	3669	3578	3488	2912	2997	3344	
KC	4,4	5246	5480	5740	4580	3926	4212	2.31
	2,3	4043	4219	6627	4538	6236	2869	
HA	3,3	3374	3284	3193	3517	3101	3216	1.13
HB	2,3	3669	3578	3488	2912	2997	3344	1.26
HC	'5,8	3556	3359	4558	3254	4985	3359	1.53

Table 3. Simulation Results

DR K			A					B					C		
# Order	Present	4	3	2, 4	2, 3	Present	3	2	2 & 3	1 & 4	Present	4	3	2 & 3	2
₩ Cost	7953	4212	3276	3216	12679	4497	3777	2891	3305	2969	8672	4580	5502	4538	20813
Percent	100	55	42.8	42	165.7	100	84	64.3	73.5	66	100	52.8	63.4	53.3	240
#Stockout	2	0	0	0	3	1	0	0	0	0	1	0	1	1	4
(Day)Inventory	4.88	10.33	5.17	4.83	2.41	10.71	11.94	4.53	7.47	5.18	8.1	10.27	4.64	3	1.41

DR H		A				B				C			
#Order	Origial	3, 3	2, 4	4, 2	Original	3, 3	2, 3	3, 2	Original	5,8	6, 6	5, 8->	7, 7
(₩) Cost	4167	3351.7	5762	3412	3326.7	3191	2912	6378.3	5491.4	4129	5680	3253.6	5412.1
Precent	100	80.4	138.3	81.9	100	95.9	87.5	191.7	100	0.75	103	59.2	98.6
# Stockout	0	0	1	0	0	0	0	2	0	0	0	0	0
(Day)Inventory	8.96	4.96	4.67	5.26	5.22	3.63	2.96	2.26	11.78	8.67	6.93	4.37	11.48

In this system, order quantity can be changed by learning function (5) automatically according to the rate of demand and the quantities of holding items. So, this system can propose the adequate number of delivery and determine the rate of occupancy of shelves among homogeneous items. In conclusion, we can reduce inventory cost and resolve the dilemma between DRs and suppliers through the suggested system.

5. Conclusion

We suggest an algorithm not for optimality but for balancing of DR's and supplier's inventory policy. We have shown that order points make a great difference with respect to cost and economic order quantity is necessary to reduce inventory cost. Order quantity of this paper is not fixed but flexible according to fluctuation of sales. Namely, this is the market-oriented system. Although various quantities of replenishment in every period improve performance of the system, complicated inventory policy may increase the difficulty of management and heavy burden of employees.

As businesses continue to face new distribution structures such as B2B, P2P, e-commerce, and outsourcing, it is imperative for suppliers, TPLC, and DRs that costs be restricted, profits enhanced for high competitive power, and they need an agent of market-oriented system more and more. In the future, the key to effective management may lie in closer partnership relations. These companies would have the mutual goal of achieving performance improvements which is greater than what could be achieved through each company's separate efforts. Further works will make effort to establish systems for win-win strategy.

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