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Taeha Kim

The University of Arizona, tkim@bpa.arizona.edu

Byungtae Lee

University of Illinois at Chicago, blee@uic.edu

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Supplier Selection and Allocation Strategy: An Optimal Contract Model of Supply Chain Management Implementation

Taeha Kim, Department of Management Information Systems,
The University of Arizona, tkim@bpa.arizona.edu
Byungtae Lee, Department of Information and Decision Sciences,
The University of Illinois at Chicago, blee@uic.edu

Abstract

We consider the problem of a retailer who implements supply chain management (SCM) to reduce his own and suppliers' costs by innovating purchasing processes. We examine the impact of SCM implementation on the number of suppliers involved over given time periods. To address the problem, this paper presents an optimal contract model that specifies the number of suppliers and their order volumes and provides that in order to offer the contract the retailer must have agreements from a desired number of suppliers to join the supply chain network. This problem is formulated as a noncooperative game between the retailer and suppliers.

We found that the high setup cost to suppliers of joining the SCM decreased the number of suppliers while at the same time suppliers' benefit (cost reduction) increased. To gain bargaining power by having many suppliers, the retailer must choose suppliers who can anticipate high cost reduction. In addition, this paper gives managers an insight into the level of information technology use required to integrate the supply chain.

Keywords: supply chain management, supply chain contract, game theory, constrained optimization.

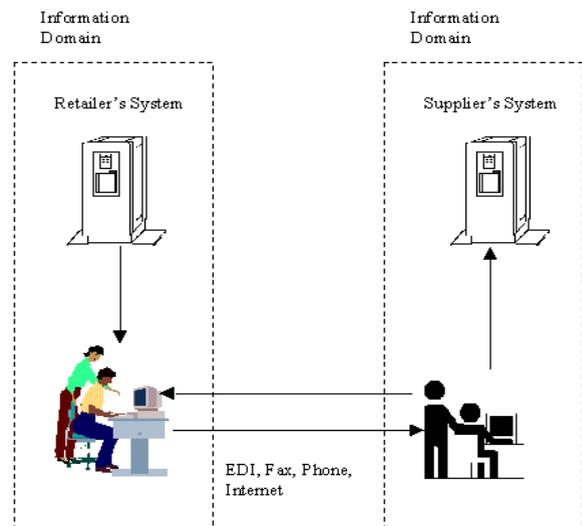
Introduction

Supply chain management (SCM) is an interorganizational information technology that links two or more related agents by a flow of information, funds, and goods. The agents in a supply chain may have conflicting objectives such as profit maximization, better customer relationships, and more bargaining power. SCM implementation obviously cannot ignore the relationships among participating agents (Tsay et al., 1999). We focus on the relationship between a retailer like *Wal-Mart* and its suppliers (manufacturers or wholesalers), where the retailer repeatedly purchases standardized commodities from the suppliers and sell them to consumers in the market.

The retailer implements either a minimum integration system (Figure 1) or a fully integrated SCM system (Figure 2). As shown in Figure 1, the minimum integration system assumes that the supplier can deliver commodities up to a requested level within a requested

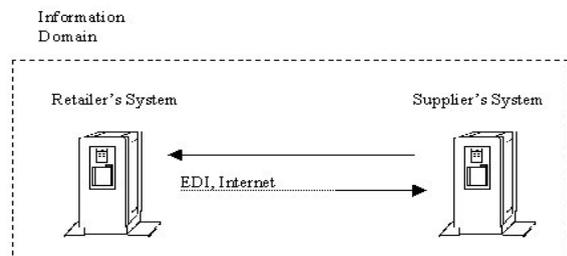
lead-time. It does not check actual available capacity at the suppliers. This form of SCM employs Internet, EDI, fax and phone. For this type of SCM, managers and engineers of the retailer and suppliers should exchange ideas and data to develop the optimum SCM (Langenwaller, 2000).

Figure 1. A minimum SCM



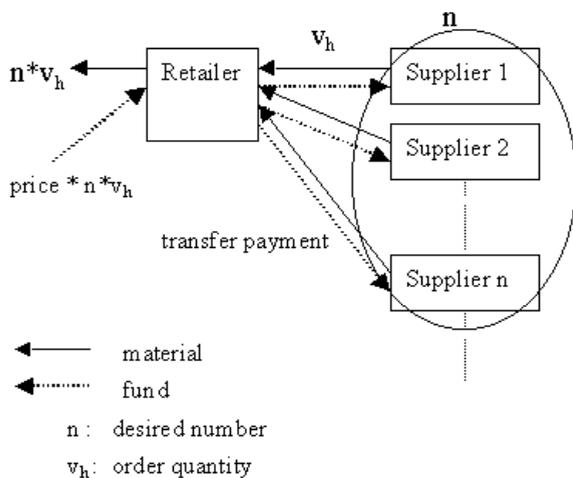
The fully integrated system shown in Figure 2 verifies the capacity information by querying each supplier's computer before computing its own schedule. The system requires cooperation on the part of each party because of the potential failure throughout the information chain based on electronic links between the retailer's and suppliers' systems using some form of Internet, EDI, or private network. (Langenwaller, 2000).

Figure 2. A fully integrated SCM



How does the integration, whether minimum or full, affect the relationship between the retailer and its suppliers? In general, such a SCM implementation benefits both parties by reducing costs by shortening the order cycle, easy coordination, and improved inventory control. By joining the retailer's supply chain, suppliers can defend product market segments, differentiate the firm, and develop stronger business relationship with the retailer. The retailer can maximize its cost reduction by having all desired suppliers timely joining of the SCM. So the supply chain contract provided by the retailer should give incentives for suppliers to join the supply chain. Offering such incentives become constraints for the retailer's profit maximization problem. The supply chain should therefore contract decide the optimal number of suppliers and their volumes for a given time period (Figure 3).

Figure 3. A supply chain management model



Will a fully integrated SCM generate a larger number of suppliers than the minimum SCM? Hypothetically, information technology will increase outsourcing activities of an organization (Malone et al., 1987). Bakos and Brynjolfsson(1993) maintain that reduced coordination costs increase the optimal number of suppliers but the importance of quality decrease the number of suppliers. Our contract model provides a framework to tackle this question. We start from the assumptions that the investment cost for the SCM implementation is fixed and the benefit of SCM is ex-post known to the retailer and suppliers. Given these assumptions, we find that the optimal number of suppliers and optimal volume allocation.

A supply chain contract model

A retailer invests in a supply chain management system and offer n suppliers a contract that specifies a choice between (a) join supply chain and receive at least v_h order volume for T periods, and (b) not-join and get at most v_1 order volume for T periods.

The profit function of a supplier is

$$\Phi_s \begin{cases} \Phi_s^J = \sum_{t=1}^T v_h(u+w)(1-d)^t - k : \text{if join,} \\ \Phi_s^{NJ} = \sum_{t=1}^T v_1 u(1-d)^t : \text{if not join,} \end{cases}$$

where k : SCM setup cost of a supplier,
 u : unit profit(i.e., transfer payment less unit cost),
 w : supplier's cost reduction,
 t : time discount.

We assume setup cost k and unit profit u to be ex-ante public information and supplier's cost reduction w to be ex-post private information of each supplier. A supplier joins in the contract if doing so gives more profit than that resulting from not joining, such that

$$\sum_{t=0}^{T-1} [v_h(u+w)(1-d)^t] - k \geq \sum_{t=0}^{T-1} v_1 u(1-d)^t. \quad \dots(C1)$$

Consider now the profit maximization function of the retailer. We assume market demand is deterministic, downward-sloping, and private information of the retailer. The demand q is always the same with the total order quantity ($v_h n$), so that the retailer does not have an inventory. That is to say, the retailer changes the price to sell all units supplied. The retailer's inverse market demand $p(v_h, n)$ is given as $p(v_h, n) = a - v_h/n$ where a is a market size. The profit function of the retailer is

$$\Pi_R(v_h, n) = \sum_{t=0}^{T-1} (p(v_h, n) - c_L) v_h n (1-d)^t - K,$$

where K : SCM setup cost of the retailer,
 c_L : retailer's unit cost if n suppliers join the supply chain.

The retailer's maximization problem is

$$\text{Max}_{v_h, n} \Pi_R(v_h, n) = \sum_{t=0}^{T-1} (a - v_h/n - c_L) v_h n (1-d)^t - K$$

subject to

$$\sum_{t=0}^{T-1} v_h(u+w)(1-d)^t - k \geq \sum_{t=0}^{T-1} v_1 u(1-d)^t : \text{join constraint}$$

$$a - v_h/n - c_L > 0 : \text{non-negative profit constraint}$$

$$\text{and } n, v_1, v_h > 0.$$

We solve the nonlinear programming problem using Kuhn-Tucker (K-T) conditions, which yield a solution only if the join constraint and non-negative profit constraint do not bind. The optimal solution (v_h^*, n^*) satisfies

$$v_h^* n^* = \frac{a - c_L}{2}, v_h^* \geq \frac{v_1 u D + k d}{(u+w)D}, n^* \leq \frac{1}{2} \frac{D(u+w)(a - c_L)}{v_1 u D + k d},$$

$$\text{where } D = 1 - (1-d)^T.$$

There are many choices that satisfy above conditions, all of which are optimal. If we assume the retailer prefer maximum number of suppliers, then the optimal solution is

$$v_h^* = \frac{v_h u D + k d}{(u + w) D}, n^* = \frac{D(a - c_L)(u + w)}{2(v_h u D + k d)}.$$

The optimized profit, price, and demand with any optimal choice are

$$\Pi_R(v_h^*, n^*) = \frac{D(a - c_L)^2}{4d} - K_s, p^* = \frac{a + c_L}{2}, q^* = \frac{a - c_L}{2}.$$

From the static analysis of (v_h^*, n^*) , we found

$$\begin{aligned} k \uparrow &\Rightarrow v_h^* \uparrow, n^* \downarrow, \\ w \uparrow &\Rightarrow v_h^* \downarrow, n^* \uparrow, \\ c_L \downarrow &\Rightarrow n^* \uparrow, p^* \downarrow, q^* \uparrow. \end{aligned}$$

The SCM setup costs that suppliers must pay to join decrease the number of suppliers and the retailer has to allocate to the suppliers volume proportional to their setup costs.

It should be noted that suppliers' cost reduction (w) is ex-post private information. While w decreases volume and increases the number of suppliers, it does not affect the profit of the retailer. The profit maximizing retailer need not consider the cost reduction of each supplier. However, when the retailer prefers to contract with more suppliers to reduce the high dependency risk of having only a few, the retailer may choose suppliers having potentially high cost-reduction suppliers when seeking to increase the number of suppliers.

Retailer's cost reduction from utilizing SCM results in lower price, more demand, and more profit. The cost reduction is positively related to the amount of SCM investment in most cases. So the retailer should compare possible profit outcomes when considering different SCM options. For example, when choosing between different types of supply chain such as full integration or minimum integration, a retailer compares profits of each case. For example, the retailer will choose full supplier integration only if it yields better profit than the manual integration ,

$$\text{i.e., } \frac{D(c_m - c_f)(2a - c_f - c_m)}{4d} > K_f - K_m, \text{ where } f \text{ denote "full" and } m \text{ denote "minimum" integration.}$$

Conclusions

We considered the optimization problem of a retailer who implements SCM. We set up a contract model on which all suppliers agree. Our analysis explains the effects of parameters (setup cost and cost reduction). The cost reductions of suppliers and retailer increase the optimal number of suppliers while the SCM setup costs to suppliers reduce that number. For his own profit maximization, the retailer should be concerned only with its process innovation available from SCM. However, the

retailer is also concerned with the supplier's cost reduction because it affects the optimal number of suppliers. The retailer may choose suppliers having high cost-reduction potential if they try to avoid high dependency on a few number of suppliers.

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