AN EFFECTIVE COST ALLOCATION STRATEGY FOR THE INFORMATION INFRASTRUCTURE IN SUPPLY CHAIN MANAGEMENT

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ABSTRACT

In order to optimize the supply chain performance, companies need to put in place for information infrastructures to share their production and inventory information with their supply chain partners. But, it is difficult to clearly define who will pay the cost of the information infrastructure. In this paper, we investigate the optimal cost allocation strategy for the information infrastructure in a supply chain: we determine fundamental rules of the cost allocation to optimize the overall supply chain performance, and investigate its dynamics by changing relevant variables (e.g., market characteristics, firm characteristics, etc.) in the model.

KEYWORDS

Supply Chain Management; Cost Allocation, Information Infrastructure, System Dynamics Simulation

1. Introduction

Supply chain management has become an important issue for gaining competitive advantages. One of the most important issues in supply chain management for a manufacturing company is how to satisfy the market demand as much as possible by balancing the stock-out and inventory cost [1, 2]. Fisher and Raman [3] studied the problem of matching supply with demand, and Fisher [4] mentioned that there exists a tradeoff between inventory cost and stock-out cost in supply chain management.

For the problem of matching supply with demand, the bullwhip effect is one of the typical issues: the variance of orders may be larger than that of sales, and the distortion tends to increase as one moves upstream [5]. Perhaps the best illustration of the bullwhip effect is from the well known "beer game". In the game, participants play the roles of customers, retailers, wholesalers, and suppliers of beer. The participants cannot communicate with each other and must make order decisions based only on orders from the next downstream player. The ordering patterns share a common, recurring theme: inventories and backorders of an upstream site are always greater than those of the downstream site. The amplified order variability may be attributed to the participants' irrational decision making. Indeed, the beer game showed that human behavior, such as misperceptions about inventory and demand information, may cause the bullwhip effect.

In contrast, Lee, et al. [6] showed that the bullwhip effect is a consequence of players' rational behavior within the supply chain. This important distinction implies that those companies wanting to control the bullwhip effect have to focus on modifying the chain's infrastructure and related processes rather than the decision makers' behavior. They have identified four major causes of the bullwhip effect: (1) demand forecast updating, (2) order batching, (3) price fluctuation, (4) rationing and shortage gaming. To mitigate this effect, Lee, et al. [6] suggested several alternatives. Among these alternatives, information sharing (regarding sales, capacity and inventory data) and increasing the use of electronic data interchange (EDI) and point-of-sale (POS) data are important. Garvirneni, et al. [7] explored the effect of information sharing between supply chain partners and suggested that as more information is shared, the performance of the entire supply chain is improving.

Nowadays, many companies try to install their information infrastructure like EDI or POS system in their supply chains. Through the information infrastructure, they could better match their supply with market demand, so inventories and backlogs in the supply chain could be reduced, leading to improving the performance of the whole supply chain. This research is motivated by the rapid growth of information technology (infrastructure) and channel partnership in SCM [8]. Examples of such initiatives include EDI, efficient customer response (ECR), continuous product replenishment (CPR), and category management [9].

The investment of this infrastructure costs a great deal. That's why the decision by whom this huge cost will be paid has a great importance. So, our first goal in this paper is to suggest an optimal cost allocation strategy for the information infrastructure in a supply chain.

We examine fundamental rules of a cost allocation to optimize the overall supply chain performance, and investigate its dynamics by changing various contingency variables in this model. In the next section, we develop our research model, using system dynamics. In Section 3, we show the system dynamics simulation results. Finally, we close this paper by discussing key managerial implications.\

2. Model Formulation

Consider a one-product inventory system with one supplier and one manufacturer; this is a two-tier supply chain. In this paper, we intend to examine the relationship between these participants of the supply chain and to find out the dynamics of this system.

In this system, all demand information has a delay. In this paper, we consider two types of information delay. One is the market link (demand chain) delay, and the other is the supply link (supply chain) delay. When market demand arrives to the manufacturer, that immediately results in manufacturer's sales, but information on demand is detected some time after the manufacturer's sales. The situation is the same for supply link. When manufacturer order arrives to the supplier, that immediately results in supplier's sales, but manufacturer's ordering information is detected some time after the supplier's sales. And manufacturer sales are limited by the manufacturer's production amount. In other words, manufacturer's sales cannot exceed the added amount of manufacturer's production and past inventory. On the same reason, supplier's sales are limited by manufacturer's orders, and supplier's production amounts are limited by supplier's sales. Figure 1 illustrates this situation.

Each player follows the same rule about orders and sales. This is the ordering sequence of individual player: (1) some inventory or stock-out exists; (2) a decision is taken to increase the inventory level; and (3) demand arrives.

In this model, all players in this system follow the same rule about ordering amount. The supplier and the manufacturer have the same order-up-to policy. If the demand information (after delay is applied) of downstream entity is lager than the past inventory level, then a manufacturer or a supplier produces as much as he is short of present inventory amount. In case that demand information does not exceed past inventory level, he produces nothing. And the amount of manufacturer's production is constrained by supplier's supplying amount.

Davis [10] postulated that there exists uncertainty at each stage of the supply chain. In this model, we set supply chain profit as supply chain performance, take into account only matching supply with demand. Beamon [11] reviewed various issues (supply chain performance measures, supply chain optimization, supply chain modeling issue and supply chain classification) in supply chain management, and referred to performance measures, decision variables in supply chain. We take into account only matching demand in this paper, and do not consider cost perspective.

In relation to inventory and stock-out cost, in general, the lower the entity (downstream) in a supply chain, the higher the cost of inventory and stock-out. Each period inventory cost and stock-out cost is calculated based on inventory positions (backlog is not permitted).

Figure 1: Research Context – Demand and Delay

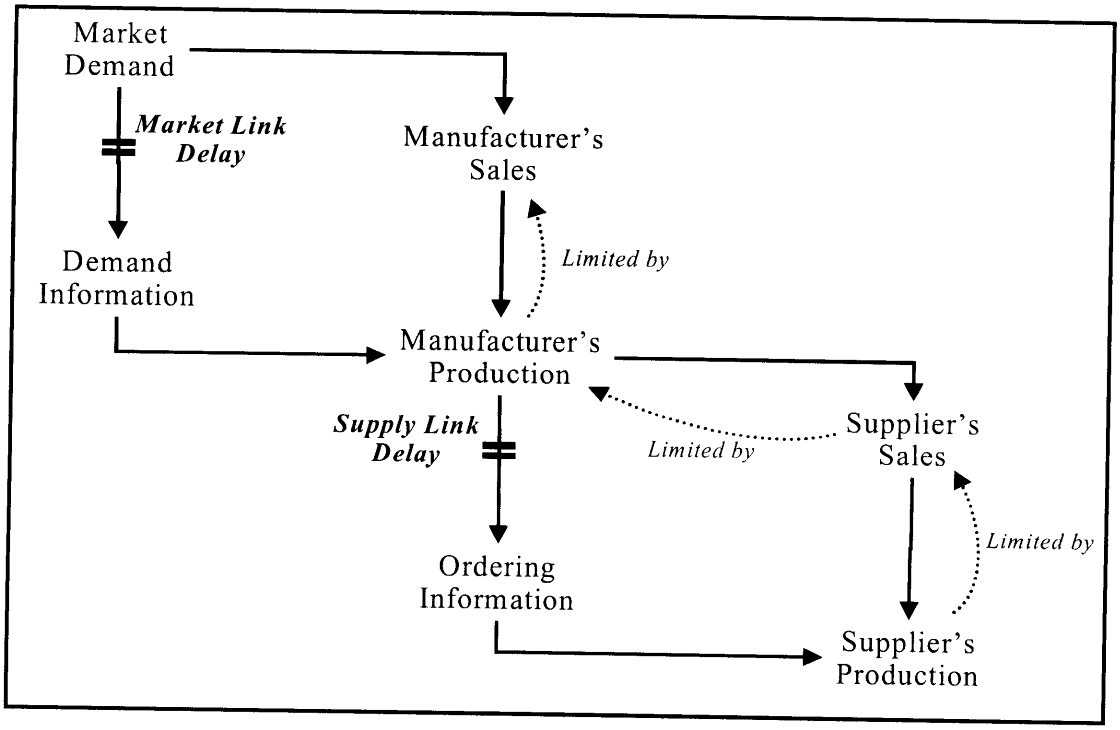
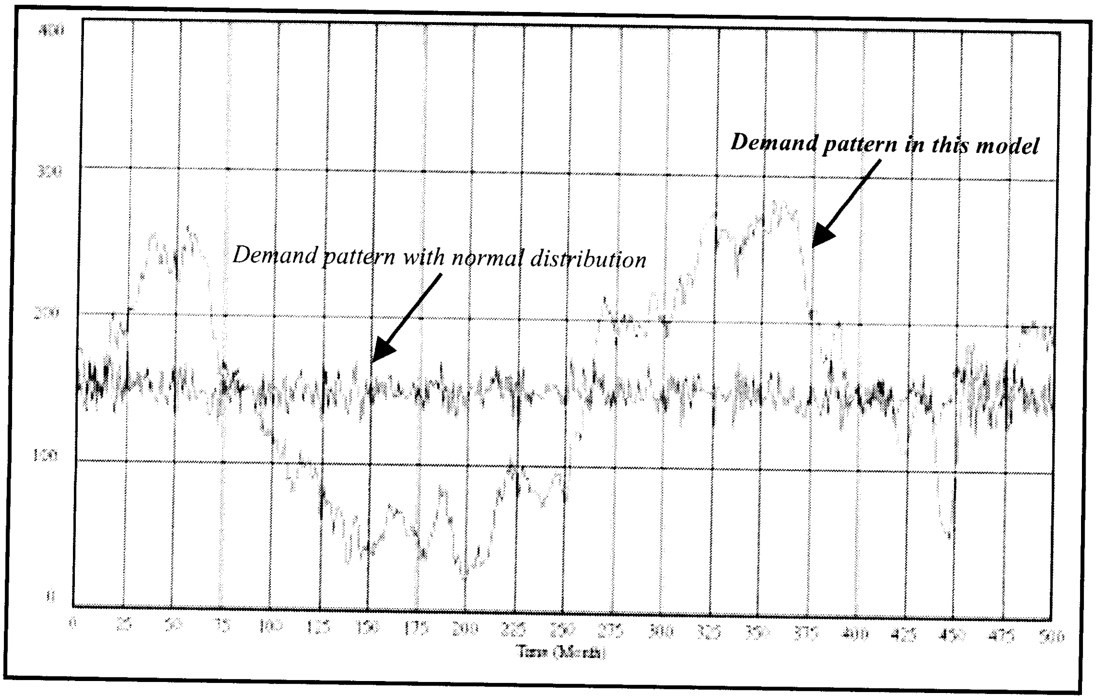


Figure 2: Demand Pattern in This Model



In relation to the market demand, a random generator of simulation package randomly generates market demand as normal distribution. A general demand characteristics of this model is a random walk. It means that an expected demand of current period is a real demand of the past and its variance is represented as the same value (market uncertainty). It can be represented as follows.

$$E(d_{t+1}) = d_t, \qquad Var(d_{t+1}) = \delta^2,$$

$$d_{t+1} \sim Normal\ Distribution(d_t, \delta^2)$$

Figure 3: Supply Chain Dynamics : Investment and Delay

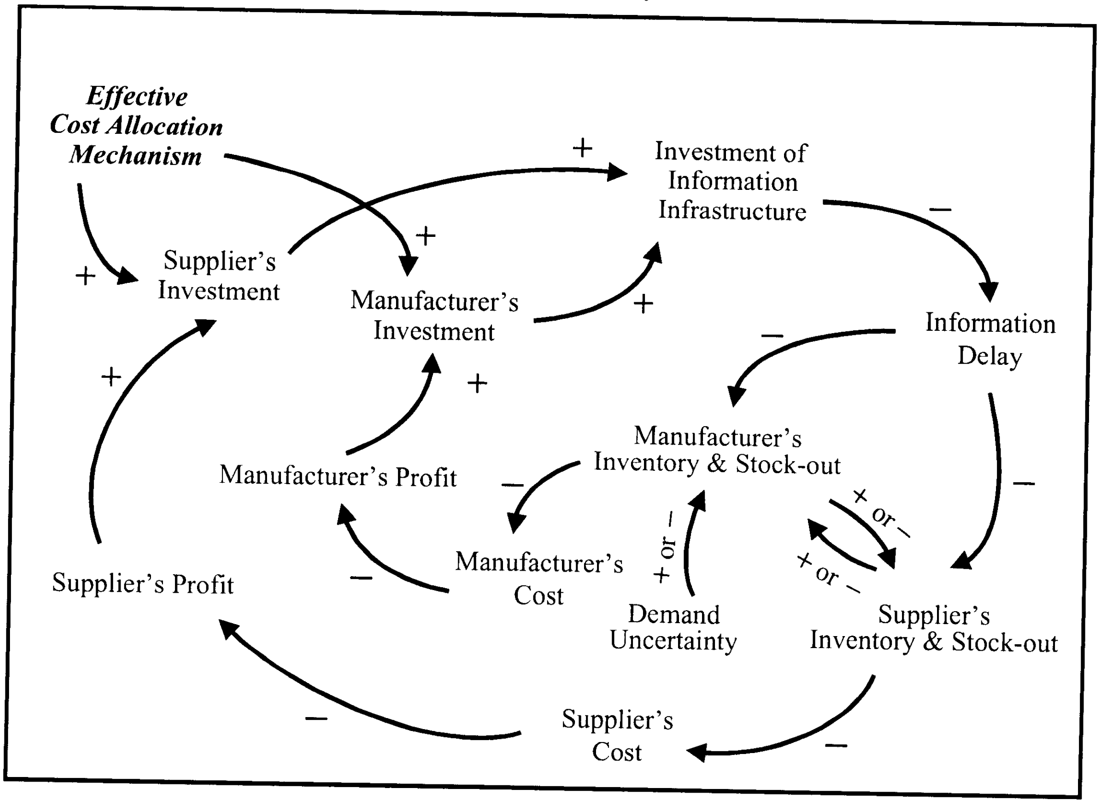


Figure 3 describes the effect of information infrastructure dynamics in an influence diagram. In the dynamics, we can see that the investment of information infrastructure can lead to reduced information delay, can reduce each entity's inventory and stock-out and eventually increase their profit. And effective cost allocation mechanism leads to supplier's and manufacturer's investment that would benefit their profit.

And we need results from system dynamics to find out whether the market demand uncertainty affects each entity's investment decision.

Desiraju and Moorthy [12] suggest a pay-for-performance scheme in supply chain management. By applying this scheme we suggest the fundamental rules of the cost allocation to optimize the overall supply chain performances. This is the rule of cost allocation method that we suggest;

Rule 1: [Favorability of Information Infrastructure Investment] *All the entities in supply chain must have a increased benefit by introducing an information infrastructure, and the cost of introducing an information infrastructure is smaller than the increased benefits of total supply chain.*

Rule 2: [Fairness of Information Infrastructure Investment] *Each entity pays for a supply chain's information infrastructure cost in proportion to its increased benefit over increased benefit of total supply chain.*

This is the mathematical illustration of rule 1 and rule 2.

Rule 1: *Increased Benefit of Each Entity* $\geq$ 0

Cost of Infrastructure < *Increased Benefit of Total Supply Chain*

$$\textbf{Rule 2}: \ MFG's\ Investment\ Ratio = \frac{Increased\ Benefit\ of\ Manufacturer}{Increased\ Benefit\ of\ Supply\ Chain\ (= MFG's + Supplier's)}$$

$$Supplier's\ Investment\ Ratio = \frac{Increased\ Benefit\ of\ Supplier}{Increased\ Benefit\ of\ Supply\ Chain\ (= MFG's + Supplier's)}$$

$$(Supplier's\ Investment\ Ratio + MFG's\ Investment\ Ratio = 1)$$

For instance, if manufacturer's increased profit after introducing information infrastructure is \$30 and supplier's increased profit is \$20, then the manufacturer would charge 60% ($\approx \frac{30}{30+20}$) of total information infrastructure cost and the supplier would charge 40% ($\approx \frac{20}{30+20}$) of total investment.

3. System Dynamics Simulation

Based on the system dynamics simulation, we can present our simulation result. Here we state the basic characteristics of the dynamics and defer interpretation and implications of the outcomes to the final section of this paper.

Figure 4 outlines the manufacturer's investment ratio in relation to the total information infrastructure cost as the market link (between market and manufacturer) delay and the supply link (between supplier and manufacturer) delay vary.

From Figure 4, we can infer that the manufacturer's relative investment amount increases as (i) the market link delay before installing information infrastructure increases, although with a much less regularity, and (ii) the supply link delay decreases. This means that each firm in a supply chain must invest more extensively if the information delay of closer site before introducing information infrastructure is relatively large.

Figure 5 outlines the total increased profit of the entire supply chain in relation to the total information infrastructure cost as the market link (between market and manufacturer) delay and the supply link (between supplier and manufacturer) delay vary.

In Figure 5, we can see that as the market link delay before installing information infrastructure becomes longer, the total increased profit of supply chain goes up. Also as the supply link delay at the first time becomes longer, the total profit of supply chain increases.

In connection with market uncertainty, as varying the market demand variance, the investment ratio of each player is the same, without regard to any combination of market and supply link delay. Even if the market demand uncertainty is changed, the ratio of investment of each entity in supply chain maintains the status quo in same delay situation. And the increased profit of each player increases as the market demand uncertainty increases.

Figure 4: Investment Ratio as Varying Supply Link Delay and Market Link Delay

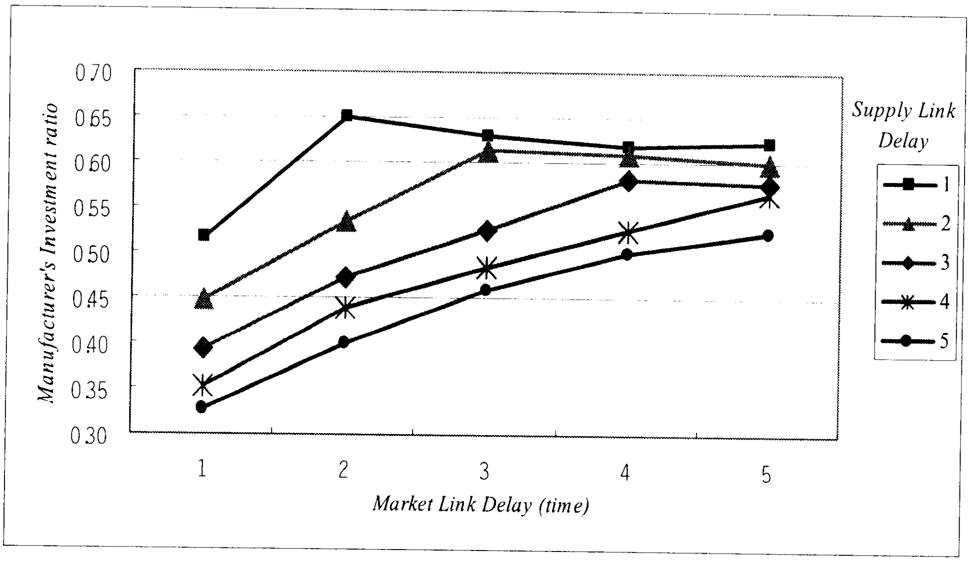
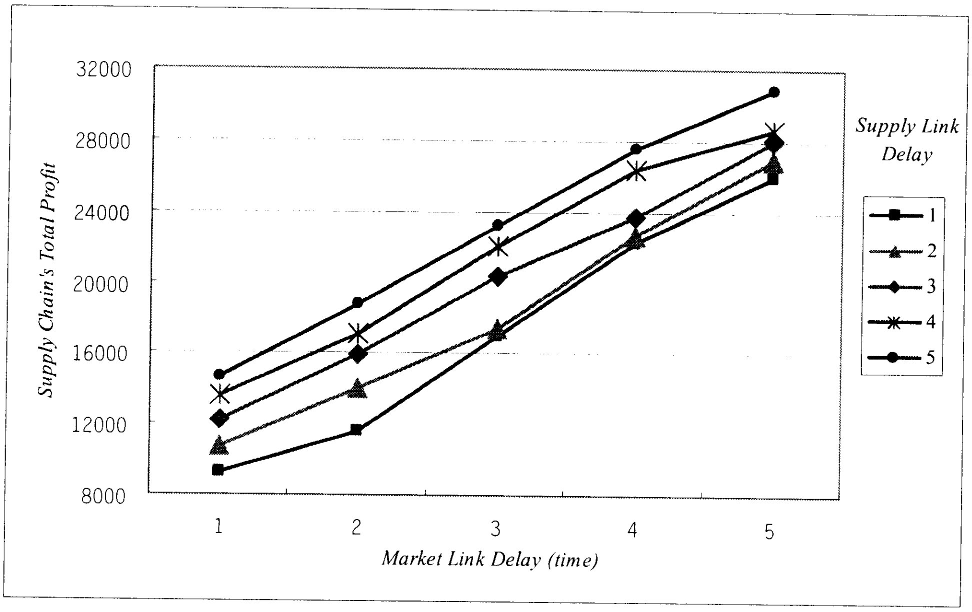


Figure 5: Supply Chain's Increased Benefit as Varying Supply Link Delay and Market Link Delay



5. Conclusions and Management Implications

In this paper, we suggest some guidelines of cost allocation for the IT infrastructure in a supply chain, and from the simulation analysis, we can infer a few managerial implications.

As can be easily guessed, by reducing the information delay, that each firm in the supply chain gains profits: we can see the need of information infrastructure. As the market link delay before installing the information infrastructure increases or as the supply link delay decreases, the manufacturer's relative investment amount increases. This means that each firm in a supply chain must invest more extensively if the information delay of closer site before installing the information infrastructure is relatively large. Those who will benefit have to bear the cost of information infrastructure.

As varying the market demand variance, the investment ratio of each player remains the same. Even if the market demand uncertainty is changed, the investment ratio of each entity in supply chain is the same as in situation of the same delay. Generally, we can imagine different investment ratios as varying the market demand uncertainty, but there is no capacity restriction of supplier and manufacturer in this model, so the result of simulation may change if a capacity restriction is included.

There are some limitations to our research. For instance, we don't consider the manufacturing capacity of each entity in the supply chain. By the limitation of simulation package, randomly generated number in this package is not a perfect random number. And the order-up-to policy in this model may not be an optimal policy under certain situations. Finally, no alternative pricing strategy is considered.

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