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Studying the Value of Information Sharing in E-Business Supply Chain Management

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ABSTRACT

The supply chain management of goods and services involves multiple trading partners such as raw-material suppliers, manufacturers, distributors, and retailers. Every one of these trading partners need to determine their requirements, in terms of merchandise, and match them against availability, pricing, and cost of transportation. At every step of the supply chain economics information retrieval is a crucial and recurring process. In this paper we study information sharing as a strategy for improved decision making that can increase the profitability of the entire supply chain. We describe various different models for information sharing and illustrate the benefits of information sharing using ordering relationships among the trading partners of a simple four-node supply chain. In order to examine the relationship between different variables and the well-known bull-whip effect, we develop a simulation system to quantify the variables and generate different results in different scenarios. These results are analyzed in this paper, and implications are presented.

INTRODUCTION

A supply chain system consists of a number of trading partners that are interconnected through the flow of materials and/or information. As raw material flows downstream from raw material suppliers through the supply chain to the manufacturers, it is transformed into more functional and integrated products with a higher economic value. Further downstream, it flows through distribution channels to retail outlets, and finally reaches the consumer. Information can flow from retail outlets to the trading partners upstream in the form of market forecasts and orders, and also from suppliers/manufacturers to the trading partners downstream in the form of order status and shipment information. In order to meet consumer demand, a large number of suppliers and manufacturers must work together to manage the flow of material and information. Without proper streamlining of information and material flow in this highly complex supply chain, billions of dollars can be lost in the form of stock outs, defects, mark-downs, and inventory costs.

The advent of electronic commerce has created a hyper-competitive marketplace for all supply chain partners. Manufacturers and wholesalers have to be more responsive to the needs of the retailers and consumers. They are being forced to increase their efficiency in order to reduce order cycle times and product costs. New technology has been able to offer means and ways to relieve this pressure by collaborative planning and information sharing, which can help companies avoid carrying costly inventory. This is leading to the fusion of supply chains that can replace inventory with information (Kalakota *et al.* 200; Gottschalk 2002).

In this paper we study information sharing in supply chain management. First we describe a simulation experiment that quantifies the variables affected by the bull-whip effect. We illustrate how information sharing can reduce the adverse effects of bull-whip effect by better management of inventory, reducing backorders, and improving manufacturing planning. Next we discuss about the type of information sharing and discuss the various models for partial information sharing scenarios.

BACKGROUND AND MOTIVATION

It has been found that supply chain collaboration has a significant impact on an organization's ability to meet customer needs and to reduce costs. A key step in this collaboration process is to share information among the supply chain partners. However, sharing information through inter-organizational channels has brought about new concerns for business management. Due to the competitive and adversarial nature of the business itself, managers

tend to overestimate the possible risks without seeing the potential benefits and thus are reluctant to share information with their trading partners. Under this context, evaluating the effectiveness or the value of the information sharing becomes prominent before the managers are willing to push for any IT investment on supply chain collaboration.

Information Sharing Models

The advances in information technologies make information sharing possible, and these advances actually become a key driver of supply chain integration. However, what is the best way to deploy these technologies and to coordinate supply chain-wide activities is still under research.

In terms of architecture for information sharing, literature in Concurrent Engineering (CE) provides generic frameworks for information sharing within an organization. Concurrent engineering is a process of collaboration, coordination and co-decision making within and between cross-functional teams, and targets at sharing information effectively and efficiently to assure engineering and manufacturing conformity with design specifications, and to optimize the use of scarce resources (Davis, 1988; Scheer, 1991; Miao & Haake, 1998). Forgiionne (1994) proposed the architecture for a Concurrent Engineering Decision Technology System (CEDTS), which consists of components for inputs, process, outputs, and feedback loops. It has been proved successfully in the applications in electronics manufacturing (Forgiionne, 1993) and health care (Forgiionne & Kohli, 1993; Kohli & Forgiionne, 1992), and can be possibly extended and applied to the trading partners in a supply chain.

IPNet (<http://www.ipnetsolutions.com>) identifies three levels of information sharing. The first level information sharing is to expose relevant information via a simple browser to the trading partners who would be affected by the information. The next level is to exchange vital business information in electronic format throughout the supply network. The final level is to automatically negotiate the information. An example of the information sharing at this level could be some business rules that trigger automated corrective actions and/or sophisticated human intervention triggers. For instance, company A's production forecast are automatically updated based on company B's sales forecasts.

Furthermore, Lee & Whang (1998) proposed three system models of information sharing: the Information Transfer Model, the Third Party Model, and the Information Hub Model.

In the Information Transfer Model, a partner transfers information to the other who maintains the database for decision-making. This is a natural evolution from the EDI-based transactional model. The problem with this model is that a company doing business with multiple partners has to provide different interfaces and support multiple standards. The Third Party Model involves a third party whose main function is to collect information and maintain it as a database for the supply chain. The Information Hub Model is similar to the Third Party Model except that the third party is replaced by a system as an information hub.

Challenges of Information Sharing

The existing literature shows that the existence of the bullwhip effect in industry is well documented through case studies and economic data analysis. In addition, its major causes and the counter measures are also well-known. However, the magnitude of its impact is highly dependent upon the specific problem environment including the retailer's ordering pattern (i.e., synchronized versus balanced orders), the demand process (i.e. stationary versus non-stationary), and the inventory policy applied by the channel members, among others. This highlights the need to investigate a wide variety of problem environments and inventory control systems in order to clearly understand industrial dynamics (Sahin & Robinson, 2002)

Furthermore, although information sharing is often considered as a generic cure for the bullwhip effect and it is generally accepted that information sharing can optimize the supply chain-wide performance (Forrester, 1958; Lee et al., 1997a and 1997b; Simchi-Levi et al., 2000; Chen et al., 2000), some literature shows that the value of information sharing varies under different scenario. Baganha and Cohen (1998) find that under certain conditions, the variance of demand faced by a manufacturer is less when filtered through a distribution center than when the retailers submit their orders directly to the manufacture. Bourland et al. (1996) reveal that when the order cycles of

the suppliers and the assembly plant are equal length and each channel member replenishes on the same day, information sharing has no effect on inventories. Lee et al. (2000) indicate that analysis assuming stationary demand may be insufficient to capture the benefits in high-tech, grocery, or other industries, where auto-correlated demand is prevalent. The disparate research findings suggest that it is necessary to expand research scope to consider a wider variety of problem environment with more comprehensive models (Sahin & Robinson, 2002).

Most of existing literature focus on two-stage or multi-stage supply chain model with single player at each level, e.g. two-level supply chain in Lee et al. (2000) and Cachon & Fisher (1999), divisions within the same firm in Chen (1999). How about a multi-stage supply chain with multiple trading partners at each level? How does the competition among these trading partners affect the value of information sharing in terms of reducing the bullwhip effect?

In practice, information sharing is more than a Yes or No choice. The most common cases are partial information sharing. Partial information sharing can be sharing only certain types of information instead of all the necessary information in supply chain decision making process. Or, partial information sharing can be only certain number of trading partners participate in the information sharing efforts. How will partial information sharing affect the industry and individual performance? In the partial information-sharing scenario, who is the critical information resource in the supply chain when considering a two-way information flow? What kind of information contributes the most for the performance enhancement, if any? Does those trading partners, who do not participate in information sharing, gain any benefit from others efforts?

On the other hand, there are major concerns regarding information sharing from an individual partner's perspective from practical perspective.

First of all, although most of the supply chain partners realize the importance and the value of information sharing, some supply chain partners may not willing to share some information due to economical and/or political reasons. Each partner is wary of the confidentiality of information shared and the possibility of other partners abusing information. "What is the minimum set of information to share with my supply chain partners without risking any potential exploitation?" becomes a wide concern. For example, supply chain partners seldom sharing information that relates to sensitive cost data (Lee & Whang, 1998).

Second, implementation of a cross-organizational information system is costly, time-consuming and risky, and not all of the partners have the incentives to invest on information sharing unless they are convinced that such investment is cost/benefit reasonable. Also, an interesting issue is to see how these benefits are shared among the supply chain partners, which can be used to determine the sharing of system implementation costs. Furthermore, each partner is concerned about other partners reaping all the benefits from information sharing. This is because how information sharing benefits each individual trading partner has not been clearly answered. With the answers to the micro level questions, the costs of implementing information sharing systems can be reasonably shared based on the benefits gained. Lack of such analysis may eventually eliminate the potential incentives for the supply chain partners from investing in information sharing system implementation.

In addition, even if each partner is guaranteed a positive gain in return of information sharing, each partner can play a non-cooperative game and haggle over how much. While access to the industry-wide inventory status may be beneficial to the individual manufacturers, there is a concern whether manufacturers will sincerely share their true inventory information (Gal-Or, 1985; Kirby, 1988; Li, 1985; and Whang, 1993). This may potentially lead to a failure to share information.

Before these concerns can be clearly answered, it is hard to expect supply chain management to have enough incentives for implementing an information sharing system.

METHODOLOGY

Integration of supply chain would require improving the communication between various links in the supply chain. These include market forecasters, retailers, manufacturers, and suppliers of raw materials. A quick response turnaround time would be needed to avoid the "bull-whip" effect on the supply chain (Lee et al 1997a; 1997b) in attempting to meet customer demand. A properly designed supply chain should take the following

characteristics into consideration:

1. **Product characteristics:** It has been argued in the literature that different products require a different design for the supply chain. A supply chain system can and should be *configured* to the product characteristics in order to offer maximum speed, efficiency, variety, quality, and accuracy (Fischer 1997; Fischer *et al.* 1994). Product characteristics can be categorized into *functional* and *innovative* products based on the stability of market demands. A functional product has a stable market demand and hence allows longer lead times, which leads to a lower stock out rates. The key to improving the supply chain for a functional product is to lower the cost of production through the increase of equipment use, lowering of inventory levels, and improving the efficiency of the distribution system. An innovative product has a highly variable market demand, which can cause forecast errors, shorter lead times, and higher stock out rates. Thus the key to improving the supply chain for innovative products is to reduce lead time, shorten product life cycle, and respond quickly to changing market demands through flexibility and integration of supply chain members.
2. **Single forecast system:** The goal of a supply chain is to generate an appropriate product flow that meets customer demand. The capacity and availability of manufacturing and logistic processes determines product velocity by suitably adjusting the work-in-process inventory. With the hyper competition being generated by electronic commerce, retailers are often attempting to capitalize on short term differences between the variety of products offered and pricing through discounts and special promotions. This leads to a rapidly changing quantity and mix of stock keeping units (SKUs), products with little market track records, and increase in the uncertainty of market demands.

In the face of these forces that cause a highly oscillating and varying market demand, the supply chain system can reduce loss to a minimum by a number of mechanisms. These include generating a single forecast at the marketing and retail end and propagating it upstream to manufacturers and raw material suppliers, increasing the frequency of product ordering, stabilizing retail pricing to prevent oscillating market demands, and eliminating hedging on orders.

3. **Automation of information services:** Information flow is an important aspect of an efficient supply chain system for process integration. Automation of information services can lead to timely sensing and forecasting of market conditions, rapid communication of critical information among supply-chain partners, considering alternative group strategies among supply chain partners, and expediting execution of plans through production control and information systems. Information flow and processing allows proactive management in the supply chain such as delivering timely products to the marketplace in response to dynamic market demands, supply uncertainty of raw materials, seasonal variations of demand, product quality variations, and range of distribution performance. All these factors determine decisions such as stockpiling of work-in-process materials, adjusting manufacturing capacity, altering batch sizes, and simplifying flow paths.
4. **Synchronization:** The desired outcome of supply chain coordination is the synchronization of activities among the supply chain members so that each member acts in ways that are appropriately timed with respect to that of the others (Fraser 1997). For example, prefabricators and manufacturers should be able to respond quickly to retailers at a short notice, which in turn would require a short turn around time for the raw material suppliers. This has been compared with mid-course correction of direction and real-time feedback of global positioning systems (Fraser 1997). Synchronization can be achieved through data sharing and facilitating communication among supply chain partners, responding proactively to the changes and exceptions taking place in business environments, and activity monitoring throughout the supply chain.

INFORMATION ASYMMETRY

Information asymmetry refers to the difference in information available to different supply-chain partners. Potentially valuable information includes those about resources such as capacity, operations such as sales, and strategy such as market data (Simatupang *et al.* 2001). It has been demonstrated that information sharing improves supply chain performance such as cost reduction, improved cycle time, and improved customer service (Foster 1993, Schonfeld 1998). However, there are some obvious challenges in sharing private information with other trading

partners because of issues related to trust and the perceived economic value of information shared. Hence, it is conceivable that the type and amount of information shared among the supply chain partners may vary to a large extent. We divide the possible alternative scenarios in information sharing into the type of information shared and the amount of information-based integration in a supply chain.

Type of Information Shared

In general the more information available to an inventory manager, the better the quality of inventory decision he/she can make. In general there are three types of information sharing scenarios: no information sharing, partial information sharing, and full information sharing.

Generally, the degree of information sharing can be defined from two perspectives: the type of information shared (horizontal perspective) and the number of trading partners involved in information sharing (vertical perspective). This section discusses the information sharing scenarios from the horizontal perspective, and next section covers the information sharing scenarios from the vertical perspective. The types of information that can be shared among the supply chain partners include:

- Product information
- Inventory level and consumer transaction information
- Decision models

This research assumes that all the trading partners have access to the correct product information, thus the degree of information sharing can be divided into the following three categories:

No information sharing scenario: In this scenario, there is no communication between trading partners. The inventory manager has access to only the order information from its direct downstream partner(s). According to (Marquez *et al.* 2000), this is a very common situation in real life, where for example, there may be two or three manufacturers, twenty or thirty distributors, two and three thousand wholesalers, and twenty or thirty thousand retailers. Each node produces their own forecast and places its orders according to its own forecasting system based on the previous orders placed by its downstream partners.

Partial information sharing scenario: In this scenario, the inventory level maintained by each supply chain partner as well as the customer transaction information is shared among the trading partners. A specific partner has access to its partners' inventory level and the real customer demand. The forecasting, however, is done locally.

Full information-sharing scenario: In this scenario, all information related to inventory management and demand forecasting is shared among the trading partners. The information here includes inventory levels, customer transaction information, and the decision models that are used for demand forecasting. In this case, a single forecast system is used across the entire supply chain, and no local forecast is needed. In practice, this is where VMI (Vendor Managed Inventory) and CFAR (Collaborative Forecasting and Replenishment) fit in. These three scenarios are summarized in Table 1.

Table 1. Models of Information Sharing

	No information sharing	Partial information sharing	Full information sharing
Demand forecast	Local	Local	Shared
Inventory level and customer demand	Local	Shared	Shared
Product information	Assembly available to all the trading partners.		
Scenario ID	S1	S2	S3

Amount of Integration

We can also define the degree of information sharing by looking at the number of trading partners that are sharing their information with. This can be further divided into the following two different possibilities.

The first possibility is that only certain levels of the whole supply chain share information among each other while others do not. Given the importance of customer demand information, we assume that the integration always starts from the downstream supply chain partner. For example, in a 7-node supply chain (n1, n2, ..., n7), this is illustrated in Table 2.

Table 2. Partial Information Sharing

Scenario ID	Trading partners who share information	Trading partners who do not share information	Degree of information sharing
S4	None	n1, n2, n3, n4, n5, n6, n7	No information sharing
S5	n1, n2	n3, n4, n5, n6, n7	Partial information sharing 1
S7	n1, n2, n3	n4, n5, n6, n7	Partial information sharing 2
S8	n1, n2, n3, n4	n5, n6, n7	Partial information sharing 3
S9	n1, n2, n3, n4, n5	n6, n7	Partial information sharing 4
S10	n1, n2, n3, n4, n5, n6	n7	Partial information sharing 5
S11	n1, n2, n3, n4, n5, n6, n7	None	Full information sharing

Another possibility is that at a specific level only some of the trading partners share information and others do not. From this perspective, three degrees of information sharing can be defined: no information sharing, partial information sharing, and full information sharing.

In the scenario of no information sharing, none of the trading partners at each level are involved in informatino sharing. The second scenario is partial information-sharing. In this scenario, only some of the trading partners at each stage are involved in information sharing. For example, in a supply chain with two or three factories, twenty or thirty distributors, two and three thousand wholesalers, and twenty or thirty thousand retailers, only one factory, 10 distributors, one thousand wholesalers, and ten thousand retailers are integrated to share information with each other while others do not, but still do business in a traditional way. The third degree of information sharing is full information-sharing. Obviously, in this scenario, all the trading partners are integrated all together for the information sharing purpose.

The asymmetry in information sharing may lead to differences in benefits and costs shared. Inequitable distribution of the benefits and costs may lead to distortion of information shared, which may in turn adversely affect performance. In order to solve this problem, one has to study the outcome of information sharing. Examples of positive outcomes include reduced inventory and cost and increased profit. Examples of negative outcomes include increase in technology investment and transfer price.

A SIMULATION BASED ON INFORMATION SHARING

In this section we describe a simulation study of the effect of information sharing on inventory level and order stability. In this research we have developed a Discrete Event Dynamic Systems (DEDS) simulation model (Viswanadham & Raghavan, 2002). The DEDS simulation is already part of the MRP/ERP toolbox for quantifying the costs and benefits of strategic and operational policies (Vollmann et al 1997).

For simplicity, we use the "beer game" to examine the relationships between the "bull-whip effect" and the possible variables. In a typical scenario of the beer game, four partners--retailer, distributor, wholesaler, and manufacturer--form a beer-selling supply chain. As we can see, the retailer sells beers to consumers, and fills his inventory by ordering beers from a distributor. Similarly, the distributor ships the order to the retailer, and fills his

inventory by ordering beers from the wholesaler; the wholesaler sells to the distributor and orders from the manufacturer; and the manufacturer produces the product—in this case, beer.

In order to maximize profits and minimize costs, one of the issues that each partner in the supply chain has to consider is to balance their inventory at such a level that the inventory level is optimum. However, in most real life situations, each partner tends to over-stock to a degree, in order to avoid being stocked out. The optimal level can be estimated based on the cost function of possible profit loss in stock out situations and the inventory cost. We assume that the retailer keeps his inventory at 1.5 times of his daily sale, the distributor keeps 2 times of his daily sale (which comes from retailer's order) and the wholesaler keeps 3 times of his daily sale.

When the whole supply chain reaches some balance point, everything becomes stable. That is, each partner has a stable sale and orders stable amount of products from its upstream partner. However, this balance point, if any, cannot last for long if consumer needs change frequently. As the result, all the partners in the supply chain have to adjust their orders according to the new demands.

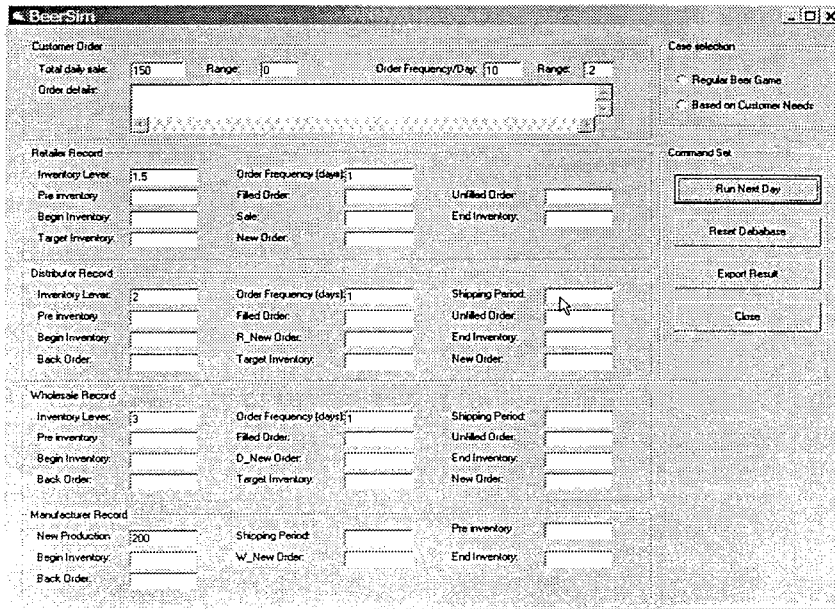
Among the four reasons of bull-whip effect discussed in (Lee *et al* 1997), duplicated forecast directly or indirectly amplifies the order fluctuation. There are two solutions to avoid duplicated forecast. One is to eliminate the intermediary, the other is to do all the forecast based on the same raw data. Since eliminating intermediary cannot be applied to all cases (Bailey & Bakos 1997), we will discuss the second solution in this paper.

We compare two different scenarios in this paper. The first scenario (SCENARIO 1) is when all supply chain members forecast future demand using the order information received from their immediate downstream partner. This is almost the same as the case described in Section 1, except that manager experiences are not used to adjust target inventory. That is, we assume that all the orders are taken care by the computer systems using certain predefined models/rules. One of the concerns about this simplification could be that ignoring management experiences might enhance the bull-whip effect. This might be true, but we also notice that not all managers make correct decisions based on their experience. Actually, research shows that human behavior, such as misconceptions about inventory and demand information, may also cause the bull-whip effect (Sterman & Senge, 1989).

The second scenario (SCENARIO 2) is when all supply chain members forecast future demand using the same input data—end consumer demand. As in the first scenario, manager experiences are ignored in order to avoid biases.

In order to compare these two scenarios, we developed a simulation to quantify the changes in different scenarios. The simulation system is built using Microsoft Visual Basic 6.0, and the data is collected in Microsoft SQL Server for further analysis. Figure 2 is a screenshot of the simulation system.

Figure 2. A Screen Shot of the Simulation System



ANALYSIS OF RESULTS

We compare the following parameters between these two scenarios: order quantity, individual inventory, backorder and order losses, and overall supply-chain inventory. In Figures 3-5, we represent the time periods in the x-axis and the quantities in the y-axis.

Order quantity: As shown in Figure 3, the largest order quantity, order fluctuations, and order differences are much more amplified in scenario 1 than in scenario 2. This shows that the bull-whip effect is much worse in scenario 1 than in scenario 2.

Figure 3. New Order Differences

New Order in Regular BeerGame

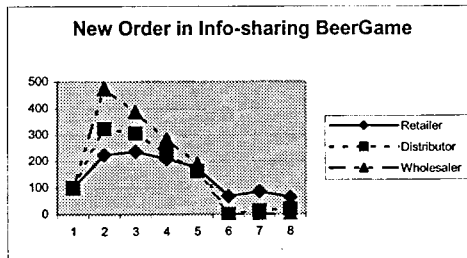
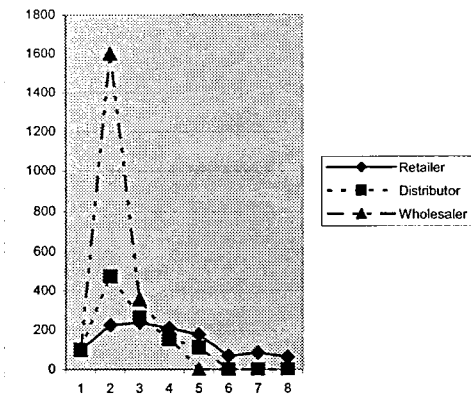
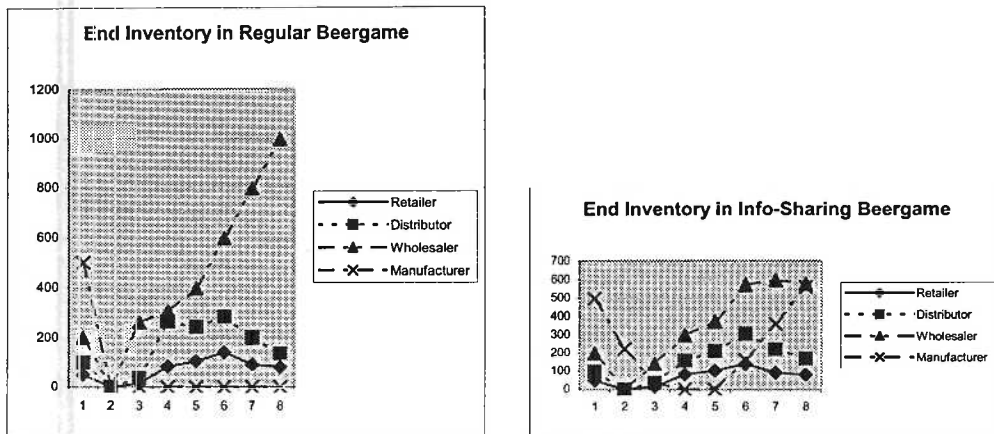
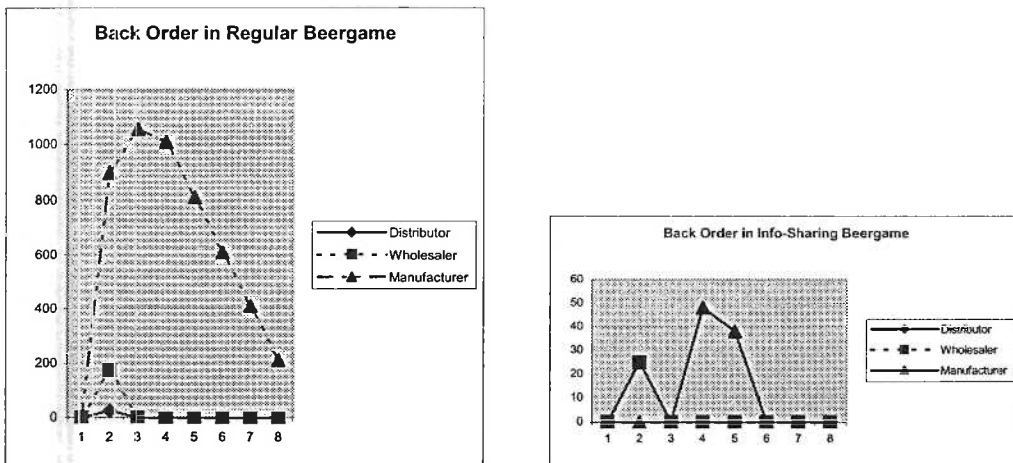


Figure 4. Individual Inventory Differences



1. **Individual inventory:** As shown in Figure 4, the individual inventory levels in scenario 2 are much more stable than that in scenario 1, especially for Wholesaler and manufacturer. Furthermore, for the wholesaler, the inventory level in scenario 2 is much lower than that in scenario 1, which means much less inventory costs. Also, the manufacturer inventory level is zero in many scenarios, which indicates back orders and order losses.

Figure 5. Backorder Differences



3. **Backorders and order losses:** Backorder and order losses affect the quality of customer service. Too many backorders may not only result in loss of business, but more serious results such as losing customer confidence. To prevent backorders, supply chain partners always maintain some safety inventory based on their experience. As shown in Figure 5, the backorder amounts for the wholesaler are much large in scenario 1 than in scenario 2.

CONCLUSION

In this paper we have discussed the value of information sharing in supply chain management and described various models of information sharing. We report a simulation study that shows the effect of single-point forecasting using retail sales data on supply chain management. We used five parameters to quantify these effects:

order quantity, individual inventory, backorder and order losses, and overall supply-chain inventory. We have used two scenarios in the simulation study. In the first scenario the demand forecasting is done on the basis of the order of the immediate downstream partner. In the second scenario the demand forecasting is done on the basis of the retail sales data. We illustrate that single-point demand forecasting using retail sales data can lead to significant gain in the overall supply chain management. The study is limited to the simple scenario of a four-level supply chain with one partner at each level. Future research issues include determining the gain of each channel partner, developing alternative models for integrating supply chain data, and studying the effect of competition on information sharing in supply chain management.

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