The Relationship between Demand, Product, and Information Sharing Strategies

Gek-Woo Tan
National University of Singapore

Bei Wang
National University of Singapore

THE RELATIONSHIP BETWEEN DEMAND, PRODUCT, AND INFORMATION SHARING STRATEGIES

Gek Woo Tan
School of Computing
National University of Singapore
tangw@comp.nus.edu.sg

Bei Wang
School of Computing
National University of Singapore
wangbei@comp.nus.edu.sg

Abstract

The hallmarks of today's business environment are volatile demand, shorter product life cycles, and increasing global competition. Advances in information technology allow more and more information to be shared across entities so that the activities can be better coordinated throughout the entire supply chain. For different products and under different demand patterns, sharing information may have quite different results. Our research aims to study the relationship between product nature, demand pattern,and information sharing strategy. As product nature changes at different stages in the production cycle, and over time, demand pattern changes accordingly, thus requiring changes in information sharing strategies employed. We use the multi-agent simulation system to evaluate the effectiveness of the information sharing strategies under different product natures and demand patterns.

Keywords: Information sharing strategy, demand pattern, product nature, simulation.

INTRODUCTION

A supply chain network (SCN) is a network of business units and facilities that procures raw materials, transforms them into intermediate goods and then final products, and delivers the final products to customers through a distribution network. Continuously increasing product variations, shortening the product life cycle, and the requirement of customization intensify the competition. Two goals of supply chain management are (1) to coordinate the activities within each tier and across tiers to facilitate the smooth and efficient flow of products down the value-added chain at the least cost, and (2) to match the supply with the market demand (Bradley and Nolan 1998). Information technologies such as electronic data interchange (EDI) and Web-based EDI enable supply chain partners to work more closely in order to optimize the performance of the entire chain. Information sharing can improve the performance of the supply chain by improving coordination between the supply chain processes and increasing the accuracy of demand forecasts (Lee 1998).

Both industry and academic researchers show great interest in this field. Lee et al. (1997) studied how information sharing improves the supplier's ordering function in a serial system with non-stationary demand. Strader et al. (1998) studied how information sharing improves coordination between the supply chain processes to enable the material flow and reduces inventory costs. Fisher (1997) studied what kind supply chain should be employed with different product nature. Cattani (2000) studied supply chain planning for demand uncertainties.

Despite the use of IT, supply chains often suffer from an excess of some products and a shortage of others because of an inability to forecast demand accurately. As the technical barrier of information sharing is slowly being conquered, the question turns to how information sharing should be employed. Preliminary studies by Tan (1999) and Li et al. (2000) showed that demand patterns and product structures have an impact on the information sharing strategies (ISS) used. This paper delves deeper to discover the relationship between these three factors. We extended and classified the demand patterns along the mix and volume dimensions, and propose that nature of product determines demand pattern, which in turn decides the ISS to be used.

The paper is organized as follows: the next section gives the background on ISS, demand patterns and product natures, and proposes our hypotheses. The simulation model is then described and a summary of our current research status is presented. Finally, conclusions are presented.

THE RELATIONSHIPS BETWEEN PRODUCT NATURE, DEMAND PATTERN, AND INFORMATION SHARING STRATEGIES

Information Sharing Strategies

Information technology enables the information to be shared among trading partners, such as order status, shipment tracking and tracing, sales forecasts, production schedules, inventory levels, product designs and specifications, product descriptions and prices, and sales promotions. Information can flow upstream or downstream. Table 1 shows some common ISS practiced in the industry.

Table 1. Comparison of Information Sharing Strategies

Information Sharing Strategies	Direction of Information Flow	Type of Information Shared	Benefits	Examples
Order-ISS	Lower to upper tiers	No additional information, except order	Cause of bullwhip effect	Beer game (Senge 1994)
Demand-ISS	Lower to upper tiers	Actual sales data such as POS data, orders of direct selling model	Upper tiers can forecast future demand more accurately, reduce safety stock, and anticipate customer needs	Dell's direct selling model (Magretta 1999)
Forecast-ISS	Lower to upper tiers	Forecast of potential sales, trends, customer preferences	Reduce the bullwhip effect by avoiding multiple independent forecasts. Serve as advanced notification for future orders, to help the supplier develop his production plan.	SUN, HP Quantity-Flexible(QF) (Tsay 1999)
InvShip-ISS	Lower to upper tiers	Inventory level, shipment data	The supplier can synchronize its production and delivery schedule	Wal-Mart (Bradley and Foley 1996)
	Upper to lower tiers	Capacity, production and shipment schedule	Sharing shipment data of upper tiers can partially eliminate the shortage gaming.	

In *Order-ISS*, lower tiers share their order to upper tiers only, with no additional information gained. In our simulation experiments, we use this strategy to benchmark against other strategies. On the other extreme is the ideal situation, *Demand-ISS,* where end consumer demand is visible to all of the tiers of the supply chain so that upper tiers can better anticipate customer needs and respond more quickly to lower tiers' changing demand. *InvShip-ISS* is more practically feasible since information sharing occurs across adjacent tiers only. Lower tiers share their inventory information with upper tiers to synchronize their production and delivery schedule and maintain a high service level. Upper tiers can also share capacity information with their downstream customers to give them a clearer picture of the conditions of their suppliers, broadening their production planning horizon and minimizing their "gaming" tendencies. In *Forecast-ISS*, lower tiers share their forecast information about the market trend or future purchase number to upper tiers. Forecasts serve as advanced notification for future orders to the supplier, who uses this information to help develop his production plan.

Demand Patterns

Muir (1980) categorized independent demands as statistically predictable and statistically unpredictable. Statistically predictable demand can be either time-dependent or time-independent. Choi et al. (1988) generated stable demands by using normal distribution and uniform distribution respectively, and seasonal demands by adding a sine function with time as the parameter. These two papers focus on variations in demand volume. Our study extends the demand patterns of a single product line along two dimensions: demand volume and demand mix. For example, the cell-phone Nokia 5110 comes in several colors. Demand mix is the ratio of the demand quantity for each color while volume refers to the aggregate demand quantity. Table 2 shows the demand patterns that fall into these two dimensions. Table 2. Dimension pattern classification.

Table 2. Dimension Pattern Classification

<table>
<tr><td colspan="3" rowspan="3">Relationship to be tested</td><td colspan="3">Demand Volume</td></tr>
<tr><td colspan="2">Known</td><td rowspan="2">Unknown</td></tr>
<tr><td>Stable</td><td>Cycle</td></tr>
<tr><td rowspan="3">Demand Mix</td><td rowspan="2">Known</td><td>Uniform</td><td>1.a</td><td>1.b</td><td>2.a</td></tr>
<tr><td>Skew</td><td>1.c</td><td>1.d</td><td>2.b</td></tr>
<tr><td colspan="2">Unknown</td><td>3.a</td><td>3.b</td><td>4.a</td></tr>
</table>

Known demand volume may be *stable* (for example, staple commodities like disposal diapers whose demand fluctuates very little throughout the year) or *cyclic* (following a seasonal cycle, such as Christmas products.) Known demand mix may be *uniform* or *skewed* (for example, blue jeans dominate the market compared to other colored jeans.) For new products into the market and highly customizable products such as agricultural planters, the demand mix and volume are often *unknown*. *Predictable* demand (1.a–1.d) refers to those whose volume and mix are known, *semi-predictable* demand has one known dimension (2.a, 2.b, 3.a and 3.b), while *unpredictable* demand has both dimensions unknown.

Product Natures

Product characteristics such as demand, functionalities, manufacturer concerns, etc., determine the product nature. Tan (1999) and Fisher (1997) classified the products into the following categories: *Functional products* have low product differentiation and demand variation. Their manufacturers are concerned with physical efficiency in production. *Innovative products* attract the fashion conscious and have an extremely short life cycle; hence manufacturers need to be more responsive and flexible toward market demand. *Customizable* products have many features resulting in a large variety of products in a single product line. Manufacturers are concerned with enabling customization at low cost. Demand patterns of customizable products and innovative products overlap because they share some similar characteristics. Although Fisher did not explicitly state the relationship between product nature, demand pattern and ISS, his characterization of product nature suggested that it impacts the other two. Based on the characteristics of the product natures, we map the relationship of products to demand patterns as shown in Table 3.

The Relationships between Product Nature, Demand Patterns, and Information Sharing Strategies

Previous research showed that, indeed, under different supply chain scenarios (i.e., product structure and demand pattern), the ISS impacted SCN performance differently (Tan 1999; Li et al. 2000). We hypothesize that product nature determines demand pattern, which in turn decides the ISS to be used (see Figure 1.)

Table 3. Demand Patterns of Different Product Natures

Product	Characteristics	Demand Pattern
Functional	Staple commodities satisfy basic needs, which do not change much over time	1.a, 1.b 1.c, 1.d
Innovative	Innovations in fashion or in technology attract customers to buy the new product, and have high profit margins.	2.a, 2.b 3.a, 3.b, 4.a
Customizable	Customizable products are tailored to satisfy the individual needs.	2.a, 2.b 3.a, 3.b, 4.a

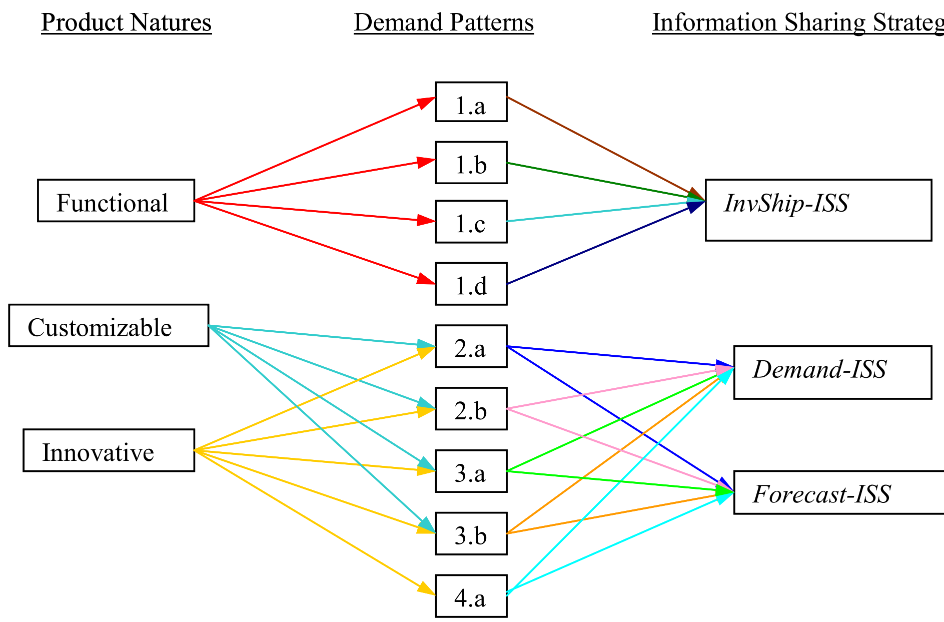

Figure 1. The Mappings Between Product Nature, Demand Pattern, and Information Sharing Strategy

The left side of Figure 1 shows the mappings between product nature and demand patterns, based on Table 2. The right side of Figure 1 hypothesizes the most suitable ISS for each demand pattern. For predictable demand (1.a–1.d), the volume and mix are both known and we hypothesize that *InvShip-ISS* will result in lower cost. Sharing shipment and inventory data downstream reduces shortage gaming, while sharing shipment data upstream reduces demand variability distortion. For unpredictable demand (4.a) and semi-predictable demand (2.a–3.b), we hypothesize that *Forecast-ISS* and *Demand-ISS* will improve the whole chain's performance under uncertainties.

Discussion

Product nature changes over time in two ways: it may change along its life cycle and it may take on different natures at different stages in its development cycle. The changes are discussed below:

(1) *Product nature changes along its life cycle*. Fast product introduction helps companies be the first to market, acquire additional market share, and establish industry leadership. As innovative products mature and gain market share, they transform to customizable products or just quit the market after a very short period, like three to six months. They no longer go through the traditional life stages of introduction, growth, maturity and decline. Functional products may also increase market share

by increasing product variety, moving toward customizable products. Hence, demand pattern changes as product nature changes, requiring a change in ISS.

(2) *Product nature changes at different development stages.* In practice, many companies mass-customized their products to meet the requirements of different markets. A product is made from components, which are assembled at different stages in SCN. A customizable product generally has specific components (the color casing in the Nokia 5110 example) and generic components (the motherboard of the phone). Thus, generic components exhibit the characteristics of a functional product, while specific components provide the customizable portion of customizable products.

THE SIMULATION MODEL AND PRELIMINARY RESULTS

We used the multi-agent simulation approach to test our hypotheses in Figure 1. We chose this methodology because it encompasses all of the major components of a real-world supply chain and enables a detailed review of the inner-workings in real time that is not seen in high level analytical models (Shannon et al. 1975). We developed a multi-agent simulation system based on the Swarm toolkit (developed by the Sante Fe Institute) to study the relationships described in the previous section. Since agent simulation allows us to specify individual agent behavior and observe the interactions of agents, it is a particularly suitable tool for studying relationships in a dynamic environment. In our simulation model, each entity in the SCN is modeled as an agent. The SCN is thus a swarm of agents. The combination of individual agent behaviors determines the collective performance of the whole chain. The performance measurements used to evaluate our experiments are inventory cost, backorder cost, total cost, and fill-rate.

Current Project Status

Currently we have completed the first phase of our simulation experiments involving the SCN scenario of a single product line without manufacturing. We tested the demand patterns on *Demand-ISS* and *InvShip-ISS* strategies, benchmarked against *Order-ISS*. Table 4(a)-(d) tabulates the simulation results. In Table 4(a)-(c), we show the ratios (in percentage) of *Demand-ISS* (in regular and black font) to *Order-ISS* and *InvShip-ISS* (in italic and blue font) to *Order-ISS.* Table 4(d) shows the actual fill-rates (in percentage) of *Order-ISS* (in underline and red font), *Demand-ISS* (in regular and black font) and *InvShip-ISS* (in italic and blue font.) We compare the results of different ISS within the same demand pattern. We cannot compare across demand patterns because they are not equitable.

We observed that no ISS gives superior performance for all demand patterns. Overall, *Demand-ISS* have the lowest inventory cost except for demand 1.a. The more unpredictable the demand, the higher the cost savings as a result of visibility of end consumer demand by all tiers in the SCN. *InvShip-ISS* saves on inventory cost when demand mix is uniform or unknown but badly skew on demand mix. The backorder cost of both *Demand-ISS* and *InvShip-ISS* is generally higher, correlated by the lower fill-rates. This is because *Order-ISS* keeps a higher stock-level and hence is able to better buffer against unstable and non-uniform demand. Since the study is partially completed, we cannot conclude whether our hypotheses are supported. In our next phase, we will refine *InvShip-ISS* strategy and conduct experiments on the *Forecast-ISS* strategy. Phase three will be the identification of demand patterns and the adoption of the appropriate ISS in real time.

Although we cannot compare results across different demand patterns, we observe the absolute cost figures of uniform demand mix are fairly small, while those of unknown demand mix are fairly large. Cyclical demand volume generally has higher cost than both stable and unknown demand volume. During the peak season, when a product goes out-of-stock, it is harder to fill the backlog as demand remains high during that period. Similarly, it is harder to reduce excess stock during low demand season. For unknown demand patterns, the high and low demand fluctuations have a better chance of evening out over a short period compared to the cyclical demand.

CONCLUSION

This paper explores the relationships between product nature, demand pattern, and information sharing strategies. As product nature changes over time, it becomes important to better understand how they relate to each other in order to maximize supply chain network performance. Using a multi-agent simulation system, we conducted experiments to study the relationship and evaluate the performance of the information sharing strategies under different demand patterns. To date, we tested and observed some insights on the behavior of *Order-ISS, Demand-ISS,* and *InvShip-ISS* on the demand patterns. We will continue our experiments on *Forecast-ISS* and the identification of demand patterns and adoption of the strategies in real time.

Table 4. Tabulation of the Simulation Results (in Percentage)

(a) Inventory Cost			Demand Volume: Known, Stable		Demand Volume: Known, Cycle		Demand Volume: Unknown	
Demand Mix	Known	Uniform	1.a	115.39 *92.7*	1.b	62.35 *99.98*	2.a	66.6 *70.64*
		Skew	1.c	81.22 *187.78*	1.d	49.91 *98.8*	2.b	60.62 *135.49*
	Unknown		3.a	50.97 *55.13*	3.b	40.83 *45.3*	4.a	43.17 *51.16*

(b) Backorder Cost			Demand Volume: Known, Stable		Demand Volume: Known, Cycle		Demand Volume: Unknown	
Demand Mix	Known	Uniform	1.a	11.39 *53.02*	1.b	127.95 *132.79*	2.a	87.87 *99.66*
		Skew	1.c	94.34 *172.55*	1.d	119.57 *141.32*	2.b	102.47 *160.52*
	Unknown		3.a	154.13 *151.23*	3.b	152.48 *161.23*	4.a	157.46 *150.98*

(c) Total Cost			Demand Volume: Known, Stable		Demand Volume: Known, Cycle		Demand Volume: Unknown	
Demand Mix	Known	Uniform	1.a	82.69 *80.23*	1.b	82.85 *110.21*	2.a	71.67 *77.51*
		Skew	1.c	85.83 *182.42*	1.d	63.47 *107.1*	2.b	71.89 *142.23*
	Unknown		3.a	66.85 *69.92*	3.b	51.59 *55.85*	4.a	62.06 *64.92*

(d) Fill Rate			Demand Volume: Known, Stable		Demand Volume: Known, Cycle		Demand Volume: Unknown	
Demand Mix	Known	Uniform	1.a	76.38 95.23 *83.23*	1.b	84.98 81.8 *77.02*	2.a	80.58 77.31 *76.55*
		Skew	1.c	90.83 91.74 *87.61*	1.d	89.89 88.02 *86.07*	2.b	90.15 87.93 *86.35*
	Unknown		3.a	87.83 80.39 *79.6*	3.b	90.97 85.6 *84.55*	4.a	88.59 80.72 *80.24*

References

Bradley, S. P., and Foley, S. "Wal*Mart Store, Inc.," Harvard Business School Case Study 9-794-024, Cambridge, MA. August 1996.

Bradley, S., and Nolan, R. *Sense and Respond: Capturing Value in the Network Era*, Harvard Business School Press, Boston, 1998.

Cattani, K. D. "Supply Chain Planning for Demand Uncertainties," *Supply Chain Management Review*, Winter 2000, pp. 25-28.

Choi, R. H., Malstrom, P. E., and Tsai, R. D. "Evaluating Lot-Sizing Methods In Multilevel Inventory System by Simulation," *Production And Inventory Management Journal* (29:4), 1988,pp. 4-11.

Fisher, M. L. "What Is the Right Supply Chain for Your Product?," *Harvard Business Review*, March-April, 1997, pp. 105-116.

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

Lee, H. L., and Whang, S. "Information sharing in a Supply Chain," Stanford University Working Paper, July 1998.

Li, J., Shaw, M. J., and Tan, G. W. "Evaluating Information Sharing Strategies in Supply Chains," in *Proceedings of the Eighth European Conference on Information Systems* (Volume 1), Vienna, Austria, 2000, pp. 437-444.

Magretta, J. "The Power of Virtual Integration: An Interview with Dell Computer's Michael Dell," *Harvard Business Review*, March-April, 1998, pp. 73-84.

Muir, J. W. "Forecasting Items with Irregular Demand," *American Production and Inventory Society Conference Proceedings*, 23rd Annual International Conference, 1980, pp. 143-145.

Shannon, R. E., Long, S. S., and Buckles, B .P. "Operations Research Methodologies in Industrial Engineering," *AIIE Transaction* (12), 1980, pp. 364-367.

Senge, P. M. "Prisoners of the System, or Prisoners of Our Own Thinking," Part 1 in *The Fifth Discipline: The Art And Practice of the Learning Organization*, Doubleday Books, New York, 1994.

Strader, T. J., Lin, F., and Shaw, M. J. "Information Infrastructure for Electronic Virtual Organization Management," *Decision Support Systems* (23), 1998, pp. 75-94.

Tan, G. W. *The Impact of Demand Information Sharing on Supply Chain Network*, Unpublished Ph.D. Thesis, University of Illinois at Urbana-Champaign, 1999.

Tsay, A. "The Quantity Flexibility Contract and Supplier-Customer Incentives," *Management Science* (45:10), October 1999, pp. 1339-1358.