

The Effect of Supply Information Sharing in a Supply Chain

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Abstract: Information sharing is a prerequisite for coordinated supply chain operations. The research has long been focused on information sharing from demand side. In this study, a computer simulation program containing mixed-integer programming (MIP) models is built to explore the impact of supply information sharing in the operation of a three-level supply chain. The analysis of simulation output indicates that supply information sharing can reduce total cost and enhance service level of the whole supply chain.

Keywords: supply chain performance, supply information sharing, simulation.

I. Introduction

Information sharing is a prerequisite for coordinated supply chain management. According to [4], information is potentially the most important driver in a supply chain as it directly affects three other important drivers, inventory, transportation and facilities. Mentzer et al. [11, p.8] defined information sharing as “the willingness to make strategic and tactical data available to other members of the supply chain.”

Wide ranges of previous research emphasize the importance of information sharing [5], [7], [8], [9]. However, according to a survey conducted by APICS [1], two-thirds of manufacturers have not successfully coordinated their supply chain operations with those of their partners. 54% of all respondents thought a lack of access of their partners’ information as the major obstacles to supply chain coordination.

Previous literature already made a wide variety of insightful exploration into information sharing of demand-side in supply chain, research efforts have rarely been made into information sharing of supply-side. This research is structured in the following way. We firstly would like to review relevant information sharing research. Secondly, we present the research methodology and supply chain model. Then, we propose our research hypotheses. Finally, we conclude with a discussion on the major research findings and the future research avenues.

II. Review of the Literature

The supply chain concept grew largely out of two-stage

multi-echelon inventory models [2]. Different two-stage supply chain structures have been extensively and thoroughly studied in the literature. Research on demand-side information sharing has been highlighted over time.

In their pioneering attempt, Lee, So, and Tang [10] developed an analytical model of a two-stage supply chain that consists of a retailer and a manufacturer, and analyze the benefit of demand information sharing.

Cachon and Fisher [3] examined the value of sharing demand and inventory information in a model of one supplier and N identical retailers facing stationary stochastic demand. They found that supply chain cost is slightly lower with full information policy than with no information policy. Gavirneni [6] disclosed benefits of cooperation in a two-stage supply chain that contains one capacitated supplier producing and distributing a single product to N retailers who are facing independent and identically distributed (i.i.d.) market demand.

Unlike other studies, Zhao and Xie [15] and Zhao, Xie, and Leung [16] employed two new forms of demand information sharing, one is that the downstream retailers share their forecasted net requirements (demands) in their planning horizon with the upstream supplier (DIS); another is that the downstream partners share its current and planned orders with the upstream supplier (OIS). Both DIS and OIS are developed on the basis of Material Requirements Planning (MRP) approach. These studies assumed that a supply chain faces uncertainty demand with trend and seasonality. These two papers filled the gap which Sahin and Robinson [12, p. 527] claimed in their review “sharing planned order releases and net requirements data are not addressed in the literature”

A supply chain faces uncertain market demands for end products from one side and unstable supply of raw materials or components from another side. However, attention has long been paid to demand side in academia. Demand-side information sharing has driven the studies on information sharing. What information could be shared from supply side and what the impact would be have rarely been considered. Basically, supply-side information indicates current and potential supply capability of a resource unit. In contrast with demand-side information, supply-side information sharing flows from upstream to downstream. According to our review, there is no study treating inventory information as supply information in current literature, but two studies touched issues of capacity information sharing.

The literature review discloses some limitations of the previous research. Meanwhile, these limitations naturally point out the future research avenues. First, two-level supply chain models dominated supply chain information sharing research. More complex supply chain structure needs to be considered. Second, previous literature mainly focus on demand-side information sharing, such as forecasting information sharing, inventory information sharing, demand information sharing, early order commitment. The studies on supply-side information sharing are very limited. Third, what information could be the supply-side information? More efforts have to be made to look for a right indicator of supply-side information. Fourth, MRP system is the main part of enterprise resource planning (ERP) system and has been widely adopted as standard manufacturing planning and control system. A lack of MRP-based research on supply-side information sharing is one gap needs to fill.

In order to fill the gaps in the literature, this research will be conducted on the following issues.

What kind of supply-side information should be shared between supply chain members?

What the impacts of supply information sharing on the performance of a supply chain would be? How does supply information sharing affect decisions of supply chain members?

III. Research Methodology and Supply Chain Model

The methodology of this research is a hybrid approach of computer simulation and mixed-integer programming (MIP). A computer program is built to simulate the operations of a three-stage manufacturing supply chain by using C++ and runs on a Dell PowerEdge 4400 server with Linux operating system.

The Basic Assumptions

- 1) The supply chain consists of three capacitated suppliers, one capacitated manufacturer, and four retailers, which is a combination of divergent structure and convergent structure.
- 2) The manufacturer produces two functional products in a make-to-stock process, which consume the same key resource and can substitute each other to some extent. Production lead time assumes to be zero. Capacity absorption rate for both products is equal to one, that is, one unit of product needs one unit of resource to produce.
- 3) Each product needs two components (raw materials), and one of the two components is a common component. The usage rate of any raw materials for two products is one.
- 4) The retailers confront with uncertain, time-varying customer demands for both products. The average demands for both products are both

1000 units at each period. In turn, the manufacturer faces demands from the retailers for replenishing their inventories, so the retailers' average demands for both products are both 4000 units at each period. Sufficient initial inventories are provided for each retailer and the manufacturer to avoid no enough inventories to satisfy demands at the beginning of the simulation. The manufacturer needs to place orders for raw materials to its suppliers when inventories of raw materials are not enough to produce the two products.

- 5) The lead times of placing orders from retailers to manufacturer and from manufacturer to raw material suppliers are assumed to be zero.
- 6) The suppliers are end suppliers; that is to say, they do not need to order raw materials from other suppliers to make their own products.
- 7) The manufacturer employs MRP system to organize its production activities.
- 8) Each supplier is the only supplier for the manufacturer for specific raw material, but each supplier does not just supply this manufacturer.
- 9) Transportation lead times from suppliers to manufacturer and from manufacturer to retailers are assumed to be one period. Transportation capacity of a vehicle is assumed to be large enough for any large orders.
- 10) Downstream partners pay for the regular transportation cost and upstream partners pay for backorder transportation cost.
- 11) The determination of cost structures: All cost figures are from a real case of a local beverage plant whose supply chain structure is similar to the one we studied. The transportation costs from manufacturer to retailers are \$450, \$255, \$331 and \$553 per vehicle respectively because of different transportation distances; The transportation costs from suppliers to manufacturer are \$520 per vehicle. The order processing costs of the manufacturer for raw materials procurement is \$100 per order and the order processing costs of the retailers for end products procurement is \$100 per order also. The production setup cost of the manufacturer is \$1000 per setup. The unit inventory holding costs at each period for manufacturer and retailers are designed in the way that their natural order cycles cover 4 periods. This approach has been used in previous studies, such as Zhao and Lee [14]. Both products of the manufacturer and the raw materials purchased have the same unit inventory holding cost. The unit inventory holding cost for suppliers is estimated to be \$0.02. The estimation of backorder cost is a little difficult. It stands for possible loss of goodwill and the potential profit

loss due to customer dissatisfaction caused by backorder. After consulted with the plant's supply chain manager, the unit backorder costs paid from suppliers to manufacturer and from manufacturer to retailers were estimated to be \$2.50 and \$5.00, respectively. Manufacturer's production cost is \$34 each unit for both products, respectively. And manufacturer's raw materials procurement cost is \$17, which is the same for all suppliers.

Independent Variables of the Experimental Design

Information Sharing from Supply Side (ISS): ISS is the information sharing arrangement that downstream supply chain members have access to product availability information of upstream supply chain members. In this study, ISS was implemented between the suppliers and the manufacturer, and between the manufacturer and the retailers. Two levels, no supply information sharing (NIS) and supply information sharing (SIS), will be examined. NIS means upstream members do not share products availability information with downstream members. SIS means upstream members share products availability information with downstream members.

Demand Pattern (DP): Three demand patterns representing different combinations of trends and seasonality will be examined. SEA produces demand with seasonality without trend. SIT generates demand with seasonality and increasing trend. SDT generates demand with seasonality and decreasing trend. These demand patterns are generated for four retailers by the following formula.

$$\text{Demand}_{it} = \text{Base} + \text{Slope} \bullet t + \text{Season} \bullet \sin\left(\frac{2\pi}{\text{SeasonCycle}} \bullet t\right) + \text{Noise} \bullet \text{snormal}_i() \quad (1)$$

where Demand_{it} is the demand at period t for retailer i ($i=1,2,3,4$; $t=0,1,2,\dots, 299$); Base is the initial demand which is selected to ensure that the average demand for each product during all simulation period is 1000; Slope describes the increasing or decreasing trend of demand; Season represents the magnitude of seasonal variation of demand; SeasonCycle is the cycle of the seasonal variation of demand, and its value is 7 in this study to represent a weekly fluctuation; Noise is the magnitude of random disturbance; $\text{snormal}()$ is a standard random function. To avoid the possibility of generating negative demand, we restricted the standard normal random variable to values from the range of -3.0 to $+3.0$ only.

Capacity Tightness (CT): CT reflects how tight production capacity of the manufacturer comparing with the demand it faces. It is defined to be the ratio of the total available capacity to the total capacity needed. It is the reciprocal of capacity utilization. Because we assume the capacity absorption rate is one, that is, one unit of product needs one unit of resource to produce, the total demand to be satisfied is an equivalent to the total capacity needed. Therefore, the total available capacity equals the total demand to be

satisfied times CT. We assume that available capacity is evenly distributed over all simulation periods. Three levels of capacity tightness, Low (1.33), High (1.18), and Middle (1.05), are set in the simulation. These CT values correspond to capacity utilization of 75%, 85% and 95% respectively.

Dependent Variables of the Experimental Design

Two categories of criteria, cost and service level, have been used as the dependent variables of the experimental design to measure performance of the supply chain:

- Total cost of the supply chain (TC): the sum of ordering cost, transportation cost, inventory carrying cost and the backorder cost for all supply chain members.
- The customer service level of the retailers (SL): the percentage of customer demand satisfied by the supply chain.

The Simulation Procedure

The simulation program is composed of two parts. The first part is the simulation program developed by Zhao, Xie, and Leung [16] and Zhao and Xie [15] that was modified to adapt to the new supply chain structure and setting. This part is to simulate forecasting, ordering, and supplying activities in the supply chain. The second part is Genetic algorithm for general capacitated lot-sizing problem (GCLSP) developed by Xie and Dong [13] that was modified to solve MIP model for the manufacturer's lot-sizing issue. An interface was built to link these two parts so that simulation parameters could be transferred interactively between them.

In the scenario of no supply information sharing, demand forecasting data, the manufacturer's production capacity constraint data, and inventory data of the two products were imported into the MIP model from the simulation program. Then, the production level and inventory level of the two products at each period were exported to the simulation program from the MIP model.

In the scenario of supply information sharing, demand forecasting data, manufacturer's production capacity constraint data, raw materials availability data, and inventory data of the two products and three raw materials were imported into the MIP model from the simulation program. Then, the production level of the two products and the procurement level of the three raw materials at each period, and inventory level of products and raw materials at each period were exported to the simulation program from the MIP model.

VI. Research Hypotheses

Hypothesis 1

H_0 : The supply information sharing (SIS) will not significantly improve the performance of supply chain members and the whole supply chain.

H_1 : The supply information sharing (SIS) will significantly improve the performance of supply chain members and the whole supply chain.

If supply information were visible to customers, it would provide them with accurate information about their suppliers' supply capability so that customers can improve their own production plan and procurement plan. Basically, we estimate that the benefits of supply information sharing have twofold. First, supply information sharing allows manufacturer to generate feasible MPS to avoid frequent schedule adjustment and to reduce the possibility of loss of sales. Second, it also gives retailers additional flexibility to revise their purchasing plan to avoid possible stockout to customers. We expect that when there is supply information sharing between suppliers and manufacturer, and between manufacturer and retailers, the total cost of the supply chain will reduce and service level of the supply chain will rise.

Hypothesis 2

H_0 : The supply information sharing (SIS) will not be useful in reducing order variance of the retailers.

H_1 : The supply information sharing (SIS) will be useful reduce order variance of the retailers.

Mounting order variation from downstream to upstream is a major characteristic of bullwhip effect. According to Lee et al. [9], one of the reasons of bullwhip effect is rationing and shortage gaming. When product demand exceeds supply, a manufacturer usually allocates its product proportionally to retailers according to the amount they ordered. In an attempt to get original amount, retailers tend to exaggerate their orders to manufacturer. In another paper, Lee and Whang [8] suggested that sharing planned capacity information with downstream partners can help alleviate their potential rationing and shortage gaming behavior, because partners can adjust their procurement plan to prepare against possible shortages. Therefore, we expect that supply information sharing can help reduce downstream members' order variance.

V. Discussions and Conclusions

The results show that supply information sharing can reduce total cost and enhance service level of the whole supply chain. In addition, supply information sharing can also alleviate order variance of downstream partners. It is worth noting that the role of supply information sharing in reducing order variance depends on demand patterns faced by retailers and the degree of manufacturer's production

capacity sufficiency.

Because capacity is evenly distributed and demand pattern of SEA does not have monotonous increasing or decreasing trend, retailers has plenty of room to adjust order plans by moving orders beyond capacity limit to the preceding periods in which slack capacity exists if they know supply information. Therefore, sharing supply information can make peaks and valleys of volatile orders straight. As we have already seen, the more stringent capacity it is, the less volatile order pattern would be.

When demand pattern has increasing (SIT) or decreasing trend (SDT), the situation are quite different. Under SIT, although retailers can move orders at the later periods to earlier periods, they cannot do this without limit if capacity becomes tighter and holding cost is too huge. Under SDT, tight capacity has more severe impact because orders at early periods cannot be moved to the periods even earlier. In comparison with the case of DP=SIT, retailers do not have incentive to move part of orders backward during the later periods when DP=SDT. Basically, when demand pattern is SIT or SDT, supply information sharing can help reduce order variance without compromising service level under low capacity tightness. If capacity becomes tighter, supply information sharing can only reduce order variance at the expense of increased backorders. Another observation is that order variance under SDT is the largest among all demand patterns across all capacity tightness levels.

Because this is only a preliminary study of supply information sharing in a supply chain, further research should examine the interaction effects among capacity tightness, demand patterns and the value of supply information sharing. In addition, there are a wide variety of other pertinent operational factors influencing a supply chain, such as forecasting errors, suppliers' capability, and product substitution. What are the impacts of these influencing factors on the supply chain performance? What are the interaction effects between these influencing factors and the value of supply information sharing? The answers of these questions can help us to know the conditions for better achieving the benefit of supply information sharing.

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