In this paper, we reviewed the area of upstream information sharing in supply chain management for the current challenges and future research opportunities for modeling research. Information sharing in supply chain management has become a very much studied area in operations management field. Although downstream information sharing has been widely studied over a decade or so, upstream information sharing has not been studied widely. Therefore, we reviewed the current mathematical modeling or analytical literature in upstream information sharing to identify the relevant issues and potential research ideas.

I. INTRODUCTION

We are living in the “information age”. The availability of information has been increasing at an exponential rate during the last decade. The explosion of information availability has given decision makers of supply chains a lot of possibilities and opportunities for improvements in their supply chain efficiency. As knowledge is power, information is power in supply chains. “It (information) provides the decision maker the power to get ahead of the competition, the power to run a business smoothly and efficiently, and the power to succeed in an ever more complex environment. Information plays a key role in the management of supply chain.” (Nahmias, 2001)

The performance of a supply chain depends critically on how its members coordinate their decisions. Sharing information is the most basic form of coordination in supply chains. There are a number of new emerging technologies available to connect the members of a supply chain to support information sharing. Recent developments in corporate information technology, such as Enterprise Resource Planning (ERP) systems, allow information to be shared seamlessly between members of a supply chain.

However, the benefits of sharing information among supply chain members are not always the same. They depend on the supply chain structure (e.g., serial or distributive systems) and its operational characteristics (e.g., demand patterns and costs involved). Various studies have examined different structures and operational characteristics. In the literature, the members at the supplier’s end are called upstream members, while the members at the manufacturer’s (or buyer’s) end are called downstream members. When supply chain members share information, downstream members can share information with upstream members or upstream members can share information with downstream members – we call the former ‘downstream information sharing’, and the latter, ‘upstream information sharing’. A common example of sharing downstream information can be found in Vendor Managed Inventory (VMI) relationships where grocery retailers (downstream members) share end-customer point of sale (POS) demand data with their suppliers (upstream members).

An example of upstream information sharing can be found in Advanced Shipping Notices (ASNs) which specify how much of the order is being shipped by an upstream member and when the order will arrive at the downstream
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member’s facility. This sharing can be particularly important when the upstream supply chain member has processes with yield losses or output uncertainty. Output uncertainty could be caused by such things as capacity shortages, equipment problems or quality problems. When the upstream member is a wholesaler without production facilities, there is still the chance that insufficient stock is available and only part of an order can be shipped. In this case, if the retailer is not notified in advance, the smaller-than-expected shipment causes problems for the retailer.

There are several review works that have been done in supply chain information sharing, such as Sahin and Robinson (2002), Chen (2003) and Huang et al. (2003). These reviews are very extensive and have broad scopes in terms of supply chain models, methodologies, and types of information being shared so that one could be easily lost in the literature. Therefore, in this paper, we give a compact review that limits its scope to researches on some of the key mathematical modeling papers that are categorized either under downstream information sharing or upstream information sharing. In this way, anyone who wants to conduct modeling research in supply chain information sharing can have a quick overview and grasp the major papers before they can read further other extensive reviews mentioned above. Another important contribution of this paper is that we extensively looked at most current upstream information sharing literature whereas the above three review papers mostly focus on downstream information sharing and have little or none in upstream information sharing literature because this area is even newer than downstream information research. The reason why researchers study downstream and upstream information sharing separately is because there are various types of information that are being shared, and there are different ways that the shared information are used in supply chain decision making process depending on which way the information is shared.

An example of two stage supply chain information sharing with terminology and definitions is illustrated in Figure 1. We present the review on downstream information sharing in Section II followed by Section III on upstream information sharing. Again, we note that we review only analytical or modeling papers in these areas, not empirical studies.

II. DOWNSTREAM INFORMATION SHARING

Although both downstream and upstream information sharing researches are relatively new, downstream information sharing has been more studied than upstream one in the past few decades. Some of the earlier works before the term ‘information sharing’ was used have been

FIGURE 1: AN EXAMPLE OF A TWO-STAGE SUPPLY CHAIN INFORMATION SHARING

A two-stage supply chain

Downstream Information Sharing (e.g., inventory)

Orders

Upstream member (e.g., Supplier)

Upstream Information Sharing (e.g., production output)

Orders

Goods

Downstream member (e.g., retailer)

End-customer demand

ASN

VMI
done under multi-stage inventory control area. A couple of major ones are as follows: Clark and Scarf (1960) showed that the inventory of a multi-stage system can be managed optimally as long as the central planner has knowledge of the inventory levels of all stages of the system. They came up with *echelon stock* vs. *installation stock* concepts: In a multiple stage supply chain, *echelon stock* is the stock level of the stage of interest plus all stock levels of subsequent downstream stages of the supply chain. *Installation stock*, on the other hand, is the stock level of the stage of interest only. Lee and Whang (1999) showed that even a decentralized multi-stage supply chain system can perform as well as a centralized one when an appropriate transfer-payment contract is in place between the various members of the chain. In these papers, although they did not used the term ‘information sharing’, centralized systems with echelon stock management can be viewed as full information sharing supply chains, whereas the decentralized systems with installation stock information only can be viewed as non-information sharing supply chains in today’s literature.

In a somewhat similar context to Lee and Whang, Cachon and Zipkin (1999) consider a game theoretic approach to the problem consisting of one supplier and one retailer. They show that the equilibrium solutions to the competitive (inventory managed independently) and cooperative (inventory managed as a system) settings are different, but that with the proper transfer payments, a common solution can be found which would be optimal for minimizing system-wide costs.

The term ‘information sharing’ started to be used in late 1990’s. Lee et al. (2000) analytically quantified the benefits of sharing downstream information and identified the drivers of the benefits. They study a similar simple two-stage supply chain with non-stationary end demands, but restricted the demand to be auto-correlated over time. They show that the manufacturer would experience greater savings when (a) the demand correlation over time is high; (b) the demand variance within each time period is high; or (c) the lead times are long.

There are a number of other representative papers, such as Axäter and Rosling (1993), Hariharan and Zipkin (1995), Gullu (1997), Chen (1998), Aviv and Federgruen (1998), Gavirneni et al (1999), Cachon and Fisher (2000), and Aviv (2001), that studied the various different structures of supply chains and types of downstream information being shared. More research is still being done on downstream information sharing.

### III. UPSTREAM INFORMATION SHARING

While most of the recent information sharing research has focused on the value of downstream information as we discussed in Section II, sharing upstream information could improve the supply chain as well. We could only find six papers related to sharing upstream information, and each looked at sharing different types of information with unique supply chain relationships with suppliers although they all look at serial supply chain structures. Most of them are recently published or being worked on except the working paper by Swaminathan et al (1995).

In the first paper and the oldest one, Swaminathan et al. (1995) modeled the impact of suppliers sharing available-to-promise (ATP) information with the manufacturer. They showed that although sharing upstream information is beneficial to the supply chain as a whole, it may be detrimental to individual participants.

Chen and Yu (2001) consider the value of sharing the supplier’s forward capacity information in a model with one retailer and one supplier for a single selling season. It is a two-period problem where the retailer has two opportunities to place orders with the supplier before the season starts. At the first period, the supplier has unlimited capacity, i.e., whatever the retailer orders will be ready for the selling season. At the second period, the supplier’s
capacity is uncertain or limited due to the time constraint and orders from other retailers. There is a benefit for the retailer to postpone the ordering decision to the second period, but the cost of doing this is that the retailer may not get what she orders at the second period due to the supplier’s capacity constraint. In this case, the supplier’s shared information on its forward capacity before the retailer makes the ordering decision can affect the retailer’s optimal ordering quantities. Comparing the costs associated with the different ordering quantities gives the value to the retailer of knowing the supplier’s forward capacity.

Chen and Yu (2005) quantify the value of lead time information in a single location inventory system (single stage problem) where a retailer buys a product from an outside supplier and sells it to her customers. Customer demand is realized periodically, with demands in different periods being independent, identically distributed random variables. If demand exceeds the on-hand inventory in a period, the excess demand is backlogged. On-hand inventories incur holding costs, and customer backorders incur penalty costs. They use a Markov chain to model the randomness in lead times. They compute and compare the retailer’s total long-run average costs when the supplier shares his lead time information and when he does not. Their numerical evidence indicates that the value of lead time information is small for small-volume items, but significant for high-volume items where the percentage cost savings due to lead time information can be quite high depending on the operational parameter settings.

Chen (2007) considers the value of disclosing suppliers’ production costs information to a buyer when there are multiple suppliers bidding for a buyer’s business and the buyer’s net profit depends on the supplier’s inputs and costs. In the Chen’s procurement problem, the buyer’s profit is an increasing and concave function of the input quantity from the supplier. Each supplier has a different unit cost to produce the input quantity to the buyer and bids for the supply to the buyer. The buyer’s optimal procurement solution is to announce a quantity-payment schedule which is a buyer’s commitment to pay a different dollar amount for a quantity supplied. A supplier, if chosen by the buyer, is free to choose any quantity to deliver to the buyer and be paid according to the pre-announced plan. In this way, the buyer is effectively proposing a business proposition to the potential suppliers. Chen derives a mathematical expression for the supply chain profit difference between knowing the lowest cost among the bidders and not knowing it. The profit difference decrease as the number of suppliers bidding increases.

More recently, Choi et al. (2008) studies the value of sharing supplier’s production yield information with retailer. They look a simple serial two stage supply chain where the supplier has multiple internal production processes that suffer random yield problems. The retailer faces independent and identically-distributed end customer demand. In the case the retailer is the dominant player and decides the order quantity based on her demand and the past history of the supplier’s yields. The retailer is also responsible for the system inventory costs since it is controlling the system inventory. In these settings, they compare the long run average system inventory costs of three scenarios: no information sharing, partial information sharing, and full information sharing. The controlled factors are the demand distributions, the degree of demand variability, and the degree of penalty-to-holding cost ratio. Using simulations, they come up with pseudo-optimal order-up-to levels for each run of the experimental design for the periodic review system. They find that the value of sharing the supplier’s production yield output information ahead of time increases as the demand variability increases for any type of demand patterns and as the p/h ratio increases.

The last paper in upstream information sharing, Choi (2008) considers the impact of errors in sharing in a similar supply chain setting as in Choi et al. (2008). The nature of
information errors they discuss can be data entry errors or information transmission errors. They referred more detailed examples on types of errors that are possible in supply chains to Raman et al (2001). A simple two stage serial supply chain is studied where the supplier has a single internal process with a random yield problem. They compare three scenarios: no information sharing, information sharing, and information sharing with errors. Mathematical order quantities are formulated and compared to identify where the cost savings are coming from. An optimal order-up-to-level was searched for each simulation run using a search algorithm. After comparing long run time average system costs are compared, they find that costs improved from no information sharing to information sharing. However, the benefits of sharing production yield information decrease as the information contains more errors. As the error variations become larger, at some point sharing erroneous information wipes the benefits of sharing. The impact of errors in the shared information is greater as the demand variation is small, and is always high over any penalty-to-holding costs ratio variation levels.

We were not able to find any other work in upstream information sharing in supply chain management in terms of mathematical modeling research leaving a lot of potential in conducting modeling research in this area as well as possible empirical researches. The next section summarizes what we have reviewed and discusses future research suggestions.

IV. SUMMARY AND DISCUSSIONS

In this paper, we have presented a compact review on information sharing in supply chain management in general. We have summarized the area of downstream information sharing by reviewing a few key representative works for the area in order to make a comparison with the other way of sharing information, upstream information sharing. We have reviewed as many papers as possible in upstream information sharing and presented a half dozen of papers which implies that there is a large potential for further research in the area. We have restricted our review in the key mathematical modeling research. Table 1 show the summary of

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<th>TABLE 1: SUMMARY TABLE FOR DOWNSTREAM AND UPSTREAM INFORMATION SHARING LITERATURE</th>
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<tr>
<td><strong>Downstream Information Sharing Literature</strong></td>
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<tr>
<td>Clark and Scarf (1960): Multi-echelon stock policy,</td>
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<tr>
<td>Axåter and Rosling (1993): Multi-echelon stock policy,</td>
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<tr>
<td>Hariharan and Zipkin (1995): Customer order information,</td>
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<td>Gullu (1997): Sharing correlated demand forecast information,</td>
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<td><strong>Upstream Information Sharing Literature</strong></td>
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<td>Chen and Yu (2001): Supplier’s forward capacity information,</td>
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<tr>
<td>Choi (2008): Supplier’s output information with errors</td>
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</table>
literature we reviewed in downstream information sharing and upstream information sharing.

Since we reviewed only mathematical research papers, certainly challenges would lie in coming up with closed form solutions for very complex models where information flow is involved in multi-state supply chain structures. As in many modeling research, information sharing research often have to rely on simulations to prove optimality, which requires writing extensive programs to carry out specific information sharing scenarios.

The future research potential would be upstream information sharing in a different supply chain structure other than serial supply chains with which all the reviewed papers looked at. Certainly various different types of upstream member’s information other than the ones we reviewed above can be investigated in improving supply chain performance.

V. REFERENCES


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