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Leveraging Information Sharing to Increase Supply Chain Configurability

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LEVERAGING INFORMATION SHARING TO INCREASE SUPPLY CHAIN CONFIGURABILITY[1]

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Abstract

As supply chains evolve beyond the confines of individual organizations, collaboration has become the Holy Grail in supply chain technology. It plays a key role in achieving flexibility and responsiveness. Information sharing between partners is a key determinant of collaboration. This paper investigates information sharing in four different supply chains—3PL, VMI, CPFR, and supply networks—and compares their information sharing structures, shared data objects, *and* information flow models. *The results show how the various parameters of an information flow model constrain the level of collaboration. Further, the modeling exercise provides insights on how to configure a collaborative supply chain by leveraging information sharing.*

Introduction

In recent years, the competitive business environment, marked by the acceleration of globalization and increasing customer demand for an ever higher level of service, has forced companies to reduce costs while still providing high quality products and services. The pressure of this challenge has compelled companies to improve their supply chains, not only to optimize the internal logistic functions, but also to build real collaborative partnerships across organizations. In addition, the challenging business environment also requires robust supply chains that should respond quickly to a wide variety of changes internally and in the external environment. The flexibility and responsiveness of a supply chain to such changes can be called *supply chain configurability*.

Since collaboration is an important trend in supply chain evolution, and collaborative partnerships will rely heavily on information sharing, this paper will examine in depth the information sharing processes at different levels of supply chain collaboration. Although a formal definition of collaboration does not exist, a measure of collaboration is the extent to which partners make *joint* decisions. We will focus on three important components of information sharing: *information sharing structure, data object,* and *information flow*. We propose a parameterized information flow model and show that information sharing processes can be adjusted "on-the-fly" by modifying parameter setting. Our objective is to try to provide some insight on the relationship between information sharing and the degree of collaboration, and how to achieve collaborative supply chain configurability by leveraging information sharing. A configurable supply chain is one that can be adjusted by modifying certain parameters, thus leading to *responsiveness* and *flexibility*. Researchers have shown empirically that various aspects of supply chain flexibility have considerable impact on business performance (Vickery et al. 1999).

The remainder of the paper is organized as follows. The next section gives an overview of the supply chain evolution and the characteristics of information sharing during different phases. The third section reviews the information sharing structures, data

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objects and modeling of information flows. We then analyze the information sharing in four typical collaborative supply chains, which present different phases in the evolution of a supply chain. Techniques for configuring supply chains are discussed. Finally, the paper concludes with a brief description of our planned future work.

Supply Chain Evolution and Information Sharing

As late as 1969, logistics, the predecessor of supply chain technology, was still in infancy as a modern management science. Since then, enterprises have made increasing efforts to adjust internal functions, reorganize business units, and implement enterprise software in order to optimize their operations. Supply chain technology goes even further in examining how to collaborate with business partners seamlessly and synchronize inter-organizational business processes to produce greater efficiencies and realize more value (Curran and Ladd 2000; Linthicum 2001; Ross 2003). In general, based on the degree of collaboration and the number of participants, supply chains could be classified into three categories: partner collaboration, value chains, and supply networks (Poirier 2002).

Partner collaboration is the first level of supply chain collaboration. At this level, partnership would be bilateral or multilateral, but one partner assumes the leading position in the collaboration. The typical case is that a company seeks external assistance to leverage one or more of several supply chain performance drivers: *inventory, transportation, facility* and *information* (Chopra and Meindl 2001). For example, traditional third-party logistics (3PL) can be used to improve the efficiency of transportation by outsourcing. Vendor managed inventory (VMI) is another type of partner collaboration based on sharing inventory information. Information sharing at this level is usually limited and unidirectional. For instance, Dell shares sales order delivery notes with FedEx, its 3PL provider, to deliver computers to its customers.

A *value chain* results from the vertical alignment of multiple trading partners, such as distributor, retailer, supplier, and manufacturer. At this level, trading partners collaborate on upstream processes or downstream processes, or both. Usually, all trading partners have a peer relationship and are heavily dependent on each other. Through intense collaboration, they leverage the inventory, transportation, facility and information to maximize the total benefit of the supply chain. A value chain is based on intensive information exchange through business documents or, more formally, data objects, such as inventory status, actual demand, and various forecasts.

In contrast to a value chain, a *supply network* is knit by both vertical and horizontal alignments. Figure 1 shows a typical supply network. There are multiple suppliers, manufacturers, distributors, and retailers at different levels in the network. Besides these traditional players, nontraditional intermediaries take an increasingly active part in the networked collaboration. Figure 1 shows two intermediaries, Industry Process Hub and Logistics Net Market. Obviously, the supply network is not a simple aggregate of the relationships discussed above. Although a supply network brings many advantages, such as flexibility and efficiency, its complexity could become the primary barrier to supply chain improvement. A well-known solution for the supply network is to use Internet-based technologies to synchronize and integrate the collaborative processes through multiple trading partners, i.e., e-supply networks. Undoubtedly, information sharing is the enabler of e-supply networks.

Overview of Information Sharing

In recent years, uncertainties have become a greater concern in supply chains. The direct consequences are increased inventories and the distortion of demand forecasts. Moreover, the distortion propagates through the supply chain and is amplified at each stage—the well known *bullwhip effect* (Lee et al. 1997). The bullwhip effect has been identified as one of the biggest causes of inefficiencies in a supply chain. Information sharing is viewed as an effective way to reduce uncertainties and counter this effect. Through information sharing, the demand information flows upstream from the point of sales, while product availability information flows downstream (Lee and Whang 2001; Yu et al. 2001) in a systematic manner. Moreover, information sharing ensures that the right information is available for the right trading partner in the right place and at the right time—*supply chain visibility.* Thus, it offers the potential to prevent, detect, and resolve exceptions spontaneously, and creates unprecedented levels of efficiency in collaborative supply chains.

Our analysis focuses on three aspects of information sharing: *information sharing structures, data objects*, and *information flow modeling*. We will further try to study how information sharing is leveraged to increase the effectiveness and efficiency of collaboration.

Figure 1. Supply Networks
(Adapted from C. C. Poirier, "Advanced Supply Chain Management and e-Business," *CRM Today*, July 24, 2002; used by permission.)

Information Sharing Structures

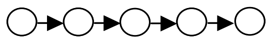
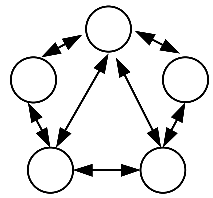
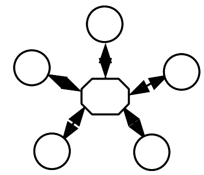
Table 1 (inspired by Hong 2002; Kumar and van Dissel 1996) gives a three-part typology for interorganizational information systems (IOS) based on interorganizational interdependencies: *sequential, reciprocal*, and *hub-and-spoke*. The corresponding structures are as follows (see Table 1):

(1) *Sequential information sharing:* In this structure, the output of one partner's activity will flow into the next trading partner as its input. The information sharing will link the collaborative processes together into a sequential chain. This is the simplest arrangement to implement. Since information flow is sequential, each pair of partners can establish their own protocols for exchange without the need for any universal standard. They could rely on electronic data interchange (EDI) or some other communication mechanisms.

(2) *Reciprocal information sharing:* This is a more complex information sharing structure. Information flow is bidirectional and each partner may communicate with several others. Since there are multiple flows, inconsistencies can arise between the information of different partners. To reduce uncertainty and conflict in the collaboration, the best coordination mechanism for partners is to synchronize and integrate the interactive processes.

(3) *Hub-and-spoke information sharing:* This arrangement is based on a central hub that communicates with all partners. In general, an Internet-based e-hub in this architecture serves a virtual marketplace, thus facilitating a full range of business processes and interactions between trading partners. The hub coordinates, stores, aggregates, and maintains information about each partner, makes decisions, and then communicates them to all partners. A definite advantage of an e-hub-based architecture is its "plug-and-play" capability with few integration points between applications (Hajibashi 2001). Therefore, it is a complex information sharing architecture. Collaborative planning, forecasting, and replenishment (CFPR) is based on the idea of such a centralized hub, as are consortia trading exchanges (CTX) such as Covisint, launched by GM, Ford, and DaimlerChrysler, and private trading exchanges (PTE) such as Carpenterdirect.com (Ross 2003). Standardization plays an important role in such architectures because all partners must use common standards for information description, storage, and exchange. Web services technology can help in implementing this architecture.

Table 1. Information Sharing Structures

Information Sharing	Sequential	Reciprocal	Hub-and-Spoke
Structure			
Level of collaboration	Between neighboring partners only (one-way)	Two-way, multiple partners	Two-way, centralized
Coordination Mechanism	Information flow upstream, goods downstream	Multiple information flows	Intelligent hub
Technologies	EDI	Networking, email, videoconference	Web services
Examples	Traditional supply chain, 3PL	VMI	CPFR, Private Trading Exchanges, Consortia Trading Exchanges

Shared Data Objects

Next, we will try to identify the key data objects shared and their impact on collaboration in a supply chain. The first step is to categorize shared data objects by collaborative process categories. Our categorization of shared data objects is motivated by RosettaNet (2000) clusters and segments. RosettaNet provides excellent partner interface process (PIP) specifications and dictionaries for designing collaborative supply chains. In RosettaNet, a collaborative process group is identified as a cluster and the key interactions between partner types within clusters as segments. Here we categorize the shared data objects based on possible categories of collaboration. The general categories of shared data objects are inventory management, product information, order management, production management, service and support, and supply chain plan/joint business plan.

Information Flow Modeling

An information flow can be described in terms of the following parameters:

- Direction: one-to-one, one-to-many, one-to-hub, hub-to-one, hub-to-many.
- Sender and receiver: the communicating parties.
- Data (Data_Obj): data objects to be shared.
- Template: format of data objects, such as EDIFACT, XML, and other data standards.
- Requested recipient action (Req_Action): actions taken by recipient after flow is received.
- Frequency: daily, weekly or monthly.
- Batch/Real-time: indicates whether information is transferred in batch/real-time mode.
- Level of aggregation: is the information sent at a transactional level (each POS transaction), daily level (total sales of an item), weekly, etc.
- Events and Conditions: information flows can be linked together by means of events and associated conditions. When a flow occurs, it can generate an event prompting the recipient to take action on it, and perhaps generating another flow if the corresponding conditions are satisfied. Events already play an important role in active databases (McCarthy and Dayal 1989) and workflows (Geppert and Tombros 1996).

In the section dealing with configuring the supply chain, we will see how each such flow can be modeled more formally. Before that, we examine the various types of flows that take place in different supply chains.

Information Sharing in Typical Supply Chain Arrangements

To understand and analyze information sharing, we will investigate the following collaborative relationships:

(1) Third-party logistics (3PL)
(2) Vendor managed inventory (VMI)
(3) Two-tier CPFR
(4) Supply network

A UML (unified modeling language) action-object flow diagram (OMG 2003) is used to analyze these relationships. UML is becoming a well-known standard for describing processes. For example, it is a modeling standard for RosettaNet (2000) to illustrate the PIP business process flows. In our formal model of a supply chain process in UML, the shared data is modeled as an object, supply chain activity as action, and information flow as object flow. This modeling matches the semantics of a UML action-object flow diagram. According to the semantics, objects initiate actions, or are used or determined by actions, and object flows connect actions with the input or output objects. We will show how shared data objects initiate the supply chain activities and how information flows make the shared data objects accessible by trading partners. In addition, the swimlanes (OMG 2003) are used to identify the collaborative partners. There are two advantages in this UML model: first, the information sharing structure of supply chain arrangement is clearly sketched by this UML model; second, this model can be shared by multiple partners easily, either as a drawing or after converting it into XML.

The rest of our study will examine in detail

- the relationship between information sharing and collaboration
- the characteristics of information flow: its structure, data objects, and modeling
- the ability of a formal model of information flows to increase supply chain configurability

Based on the results, we will try to construct a basic information sharing system for a collaborative supply chain. The aim of this system is to provide the functionality to meet various requirements for collaborative supply chains (Nøkkentved and Hedaa 2000) such as supply chain visibility; synchronization of activities; responsiveness; exception detection, analysis, and resolution; and process simplification.

Third-Party Logistics (3PL)

Increasingly, companies must concentrate on their core competencies and outsource nonstrategic operations to other parties. Usually, the outsourced elements include transportation, warehouse management, customer order fulfillment, etc. 3PL is one natural outcome of this approach and enables companies to dramatically reduce the burden of physical facilities, lower their cost, improve their responsiveness, and gain logistics agility. Figure 2 shows a typical example of a 3PL arrangement involving two collaborative processes: *inventory transfer* and *customer order fulfillment* in this arrangement. The manufacturer shares its inventory and a part of sales order information (delivery notes) with its 3PL provider, but the 3PL provider does not give any input to the manufacturer's activities.

In Figure 3, 3PL is modeled more formally by a UML action-object flow diagram. The five solid rectangles in the middle show the main data objects shared during the collaboration such as replenishment order (inventory transfer order), sales order (partially), ship notes, and goods receipt. Dotted lines show the information flow. It is clear that information sharing has a sequential structure in this arrangement. Moreover, EDI technology is employed to facilitate the data exchange between trading partners. It should be noted here that as 3PL technology evolves and is subsumed into supply networks, the shared data represented by the dashed rectangle in Figure 3 will become part of a centralized e-hub. In this way, the data can be shared by other partners in the supply chain, leading to increased visibility. Such a trend will also be driven by development of common standards (e.g., XML) for data schemas and for information exchange.

Moreover, our information flow model can be configured to improve responsiveness and logistics agility. First of all, the parameters can be configured for particular warehousing and delivery requirements. For example, the shipper selection usually is based on goods value, customer preference, or other specification in the customer order. Such selection criteria can be stored in *event* and *condition* parameters, which will automatically initiate the information flow to the appropriate shipper specified in the *receiver* parameter. Moreover, the information flow model can be used to enforce different inventory policies, e.g., *continuous*

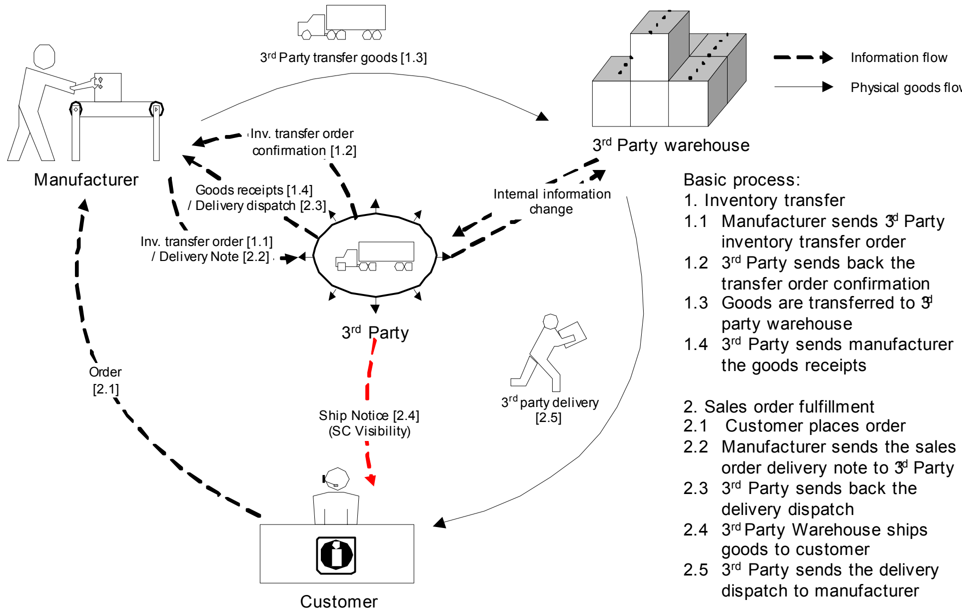


Figure 2. Third-Party Logistics Example

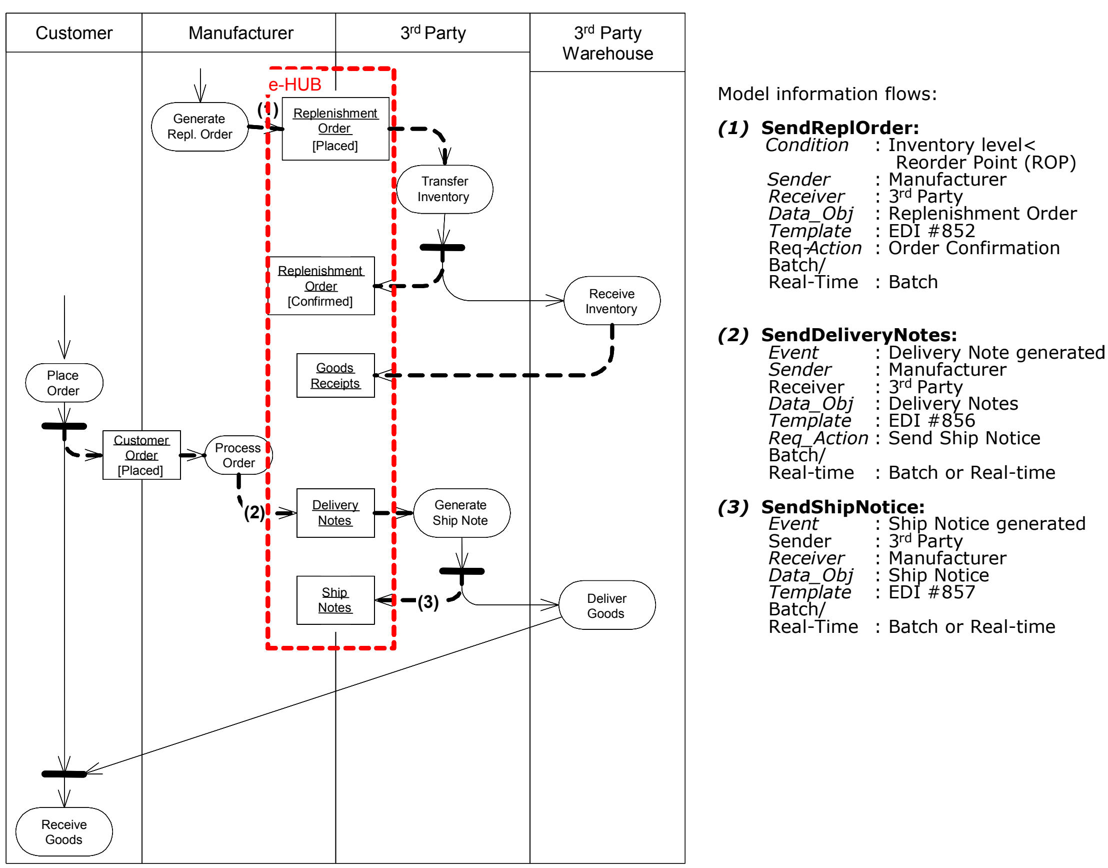


Figure 3. Modeling 3PL with UML Action-Object Flow

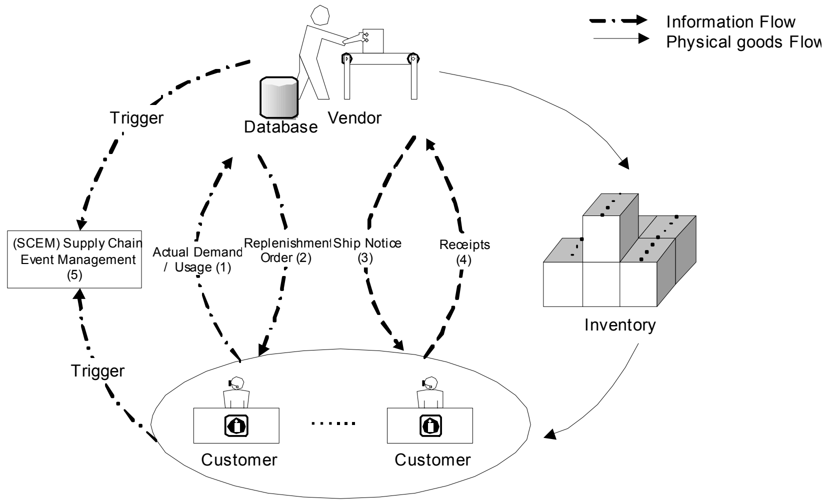


Figure 4. Vendor Managed Inventory

review or *periodic review.* For continuous review policy, the reorder point is a parameter in the condition part of the information flow. When inventory is less than reorder point, information flow "SendReplOrder" will be triggered. For periodic review policy, temporal events are used to trigger "SendReplOrder" to replenish inventory to a predefined level. Second, this model can be used to optimize complex logistics activities such as cross-docking (Chopra and Meindl 2001).

Vendor Managed Inventory (VMI)

In this arrangement, vendors take over the replenishment planning task for their trading partners. The main purpose is to reduce the safety stock as a buffer on the vendor side because of the uncertainty in demand and also reduce the safety stock on the customer side because of uncertainty in supply.

Figure 4 shows that the main processes in VMI are as follows:

(1) Customers share their actual demand or usage with the vendors
(2) Vendors generate the demand forecast and place the replenishment order for customers accordingly
(3) Vendors then send a ship notice and this is followed by physical goods transfer
(4) Customers acknowledge the actual receipts
(5) There may also be need for exception handling through the supply chain event management (SCEM) (Montgomery and Waheed 2001) mechanism

In VMI, trading partners establish some metrics to evaluate the performance of collaboration such as *fill rate, inventory turn rate,* and other criteria. Therefore, it is necessary to trigger a special exception handling process in case the expected performance is not achieved. The term *supply chain event management* (SCEM) is the name of a subsystem for exception handling. Ideally, SCEM must detect and report exception events and analyze them in real-time. However, the exception handling is not a fully automatic process and often manual intervention is necessary. An exception in VMI occurs, for example, when the inventory level at the customer site increases more than expected.

It is apparent from comparing these arrangements that VMI needs more extensive collaboration than 3PL. First, as the UML model (Figure 5) shows, there are more bidirectional information flows between trading partners. Second, the information sharing cannot be simply fitted into a sequential structure. Obviously, the information sharing around the replenishment order is more reciprocal and there is more than one state of replenishment order. However, around the order delivery, the information sharing is still sequential. Third, since exception handling is a necessary collaborative process, information sharing could not be full automatic. For example, in exception resolution, some additional information must be exchanged on a case-by-case basis.

The analysis of the VMI information flow model actually provides more valuable insights into how to improve traditional VMI. First, in batch mode there could be a lag in information sharing and demand fluctuations may not be reflected in the forecasts in a timely manner resulting in forecasting errors and exceptions. Forecast inaccuracy is the main reason for exceptions. To configure a responsive supply chain, information flow should be in real-time mode. In this regard, EDI is inflexible because of its batch nature and will likely be replaced by an XML-based data template (Anderson and Lee 1999). Second, in VMI, information sharing is asymmetric because most information flows are directed from customer to vendor and the vendor's process is relatively opaque. To increase process transparency, the vendor could provide "what if" scenario analysis, e.g., show the effects of modified information flows and simulated order forecasting and replenishment strategies. Later, we will see how such a model can be stored and reconfigured.

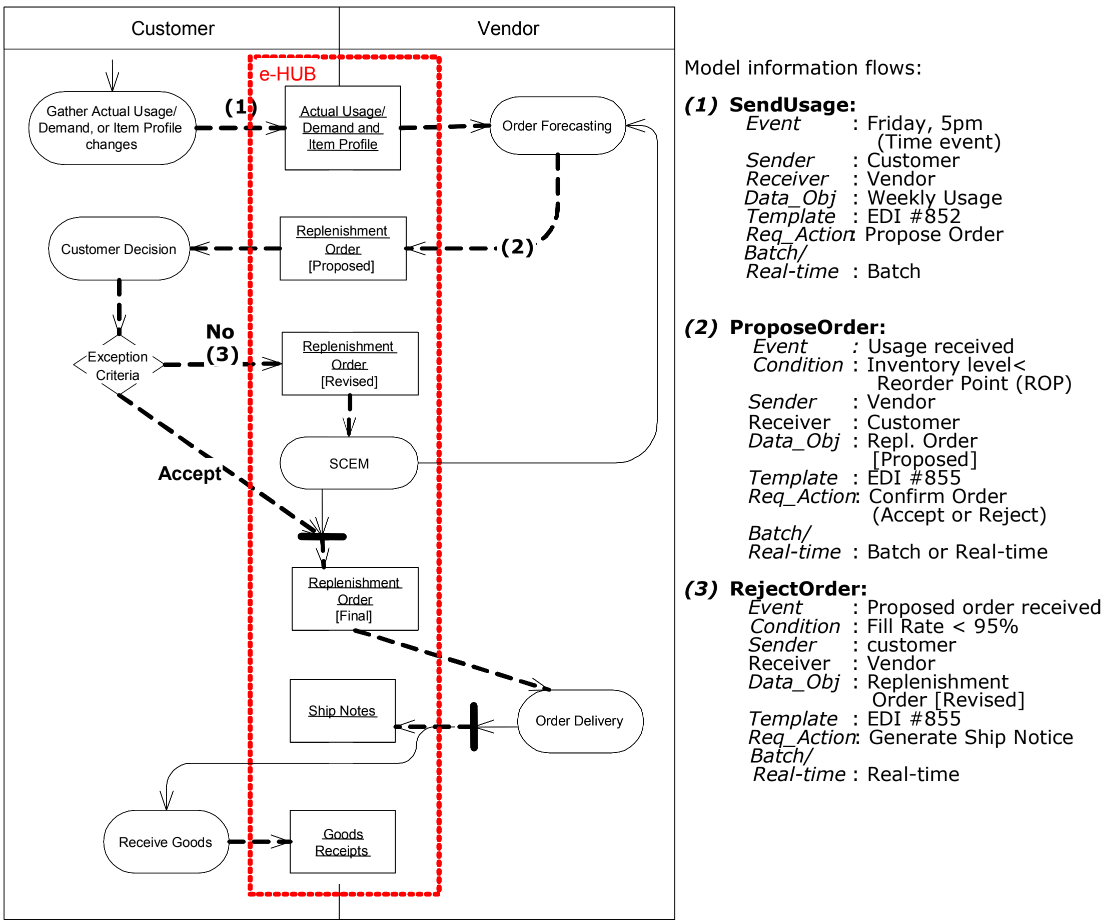


Figure 5. Modeling VMI Process with UML Action-Object Flow

Two-Tier Collaborative Planning, Forecasting, and Replenishment (CPFR)

Collaborative planning, forecasting, and replenishment (CPFR) (VICS 2002) is an effort to streamline every aspect of supply chain management. In general, an *n*-tier CPFR is a collaborative arrangement between *n* trading partners. However, for simplicity, we will focus only on a two-tier CPFR arrangement between a buyer and a seller, or manufacturer and distributor. CPFR aims to produce better alignment of supply and demand through real-time sharing of demand and supply data with trading partners, exception-based management, and structured collaboration to eliminate issues and constraints in fulfilling consumer expectation. Table 2 illustrates the steps of the CPFR processes and the shared data objects produced and consumed in different steps.

Table 2. CFPR Data Flow Summary

Process Step	Data Consumed	Data Produced
Develop collaboration arrangement	Point-of-sales (POS), historical shipments	Exception criteria
Create joint business plan	Trading partners' corporate plans and strategies	Joint business plans, item management profile
Create sales forecast	Joint business plan, POS data, exception criteria, events	Sales forecast, identified exception items
Create order forecast	POS data, inventory, sales forecast, events, historical demands and shipments, product availability data, item management profile	Order forecast, identified exception items
Generate order	Order forecast, item management profile	Order

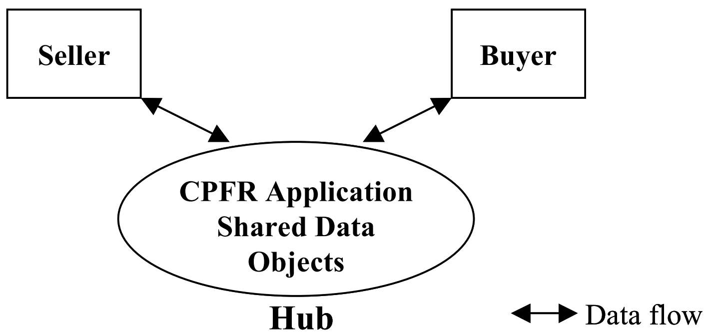


Figure 6. Shared Deployment

Although the CPFR guidelines have identified two types of deployment scenarios, shared deployment and peer-to-peer deployment (VICS 2002), shared deployment is the easier way. Figure 6 shows a typical shared deployment scenario similar to the hub-and-spoke model of Table 1. In this model, two partners rely on the same application for specific CPFR functionality. Table 3 shows two examples of information flows in this shared deployment scenario. On the other hand, in a peer-to-peer deployment scenario, the partners have individual CPFR applications and they are designed to inter-operate with one another. This scenario can fit into the reciprocal information sharing framework. Although this scenario can provide flexibility for each partner to select its appropriate CPFR application, synchronization of exchanged data is a big challenge. Every change made to the data schema or new added data object would involve complex data consolidation across CPFR applications. In particular, as Table 2 shows, CPFR involves a large number of shared data objects and the accuracy of data like sales forecast is critical to success. On the contrary, in the hub-and-spoke model, trading partners use the same database for shared data objects, so data synchronization is not required. In view of the flexibility of information sharing that it permits, the hub-and-spoke structure is more appropriate.

Table 3. Example of Information Flows in a Hub-and-Spoke Model

1. SendSalesForecast		**2. ConfirmSalesForecast**	
Event:	Sales forecast generated	***Event:***	Sale order received
Sender:	Hub	***Condition:***	No exception (Exception resolved)
Receiver:	Buyer	***Sender:***	Buyer/Seller
	Seller	***Receiver:***	Hub
Data_Obj:	Sales Forecast	***Data_Obj:***	Sales Forecast
Template:	XML Sales Forecast data schema	***Template:***	XML Sales Forecast data schema
Req_Action:	Confirm sales forecast	***Req_Action:***	Generate Repl. Order
Batch/Real-time:	Real-time	***Batch/Real-time:***	Real-time

Based on Tables 2 and 3, several inferences may be drawn. Clearly, CPFR needs even more intensive collaboration than VMI for each activity of the supply chain from forecasting to order generation. First of all, a *joint business plan* is established to guide supply chain activities. Second, processes are fully integrated, i.e., trading partners have the same sales forecast and cooperate on key processes of supply chain, thus reducing the conflicts because of reciprocal interdependency. Third, there are more shared data objects, ranging from structured data like orders and item management profile (e.g., lead times, order intervals, order minimums, etc.) to unstructured data like *ad hoc* item design. Fourth, the number of information flows in CPFR is obviously more than in VMI, and exception handling becomes an integral part of the key processes, sales and order forecasting. Because of the diversity of data objects, XML messaging standards are preferred to the inflexible EDI standards. Finally, as the examples show, although batch and real-time modes of information exchange are possible, real-time exchange is preferable.

Since CPFR focuses on supply chain synchronization, our information sharing model can be used to solve two core problems in this arrangement: forecast inaccuracies and capture of exceptions as a result of impending fluctuations in supply and demand. To improve the forecast inaccuracy, demand, supply, and other relative data are shared in real time. Since data and the corresponding data templates are parameters in our model, it gives flexibility to gather and share any relative data, but also brings workload for an e-hub to consolidate data. Based on real-time information sharing, instant exception capture can be easily achieved. The *condition* parameter can be set for any exception criteria such as mismatch between demand and supply, fluctuation in demand or supply, unsatisfactory performance metrics like forecast errors, service level, fill rate, or inventory turns. The condition will trigger exception messages to affected partners. The destinations are predefined by the receiver parameter. At the same time, the expected exception handling action to be taken by the recipient is specified by the requested action parameter.

Supply Networks

Supply networks can also be modeled in a somewhat similar way to CPFR, except that the collaborative processes involved are more complex and information flows more *ad hoc*. For brevity, we omit a concrete example of information flows in such networks. Nevertheless, it is evident that the information flow model must be richer in several ways in supply networks than in other arrangements discussed earlier. First, information flows could have multiple recipients and may need to be structured in an *ad hoc* way. Second, there are many more shared data objects such as customer information and order, product profile and design, inventory and product availability, manufacturing information, and other source documents. Correspondingly, there are many new data standards such as RosettaNet, BizTalk, and exchange-centered REA models (resource-event-agent) (Haugen and McCarthy 2001). But in general, all of these data standards are XML-based. Third, more complex events must be considered besides the primitive events like temporal events and standard requests. Composite events are composed of primitive events by unary or binary logical operations. For example, only after *all* bids have been received and evaluated will a reply occur. In this case, it is necessary to combine multiple events.

Currently, there are multiple types of supply networks such as auction houses, private trading exchanges, supply hubs, and other business-to-business trade exchanges, but, in general, trading partners are likely to collaborate on the following key processes:

- *Strategic sourcing*: As multiple suppliers participate in a supply network, sourcing becomes a complex match-making process (Hoffner 1999). This collaborative process varies in its structure from sequential sharing (e.g., subcontracting) and reciprocal sharing (e.g., auctioning) to centralized information sharing (e.g., catalog sharing). Thus, the data objects shared range from quotes to catalogs to complex product designs.

- *Collaborative planning and execution* (Anderson and Lee 1999): Besides demand planning and order fulfillment analyzed above, joint capacity planning is a key part of the three-pronged effort. In general, information sharing will penetrate in every process from demand forecast to order fulfillment.

- *Customer management*: While strategic sourcing, planning, and execution are the processes in the back office, order management is a front office activity. Outsourcing customer support has become a widely accepted practice. Information sharing could occur in outbound marketing, channel management, customer service, and other fields of customer relationship management.

Summary

Information Sharing Structure

As the information sharing arrangement gets more complex, more sophisticated solutions are required. 3PL and VMI rely mainly on sequential sharing because the needs are well structured and well defined. Information is exchanged in the batch mode and thus centralized sharing is not required. However, both CPFR and supply networks need a hub-and-spoke arrangement to increase visibility and improve coordination. Since both of these arrangements are subject to uncertainties and the trading partners are knit together more tightly, it is necessary for each trading partner to share information rapidly and to check the status of the entire supply chain, detect exception events in real time, and propagate the effect of such events. In general, to configure a supply chain, the first step is to select a proper information sharing structure. Earlier, we identified three architectures. It is also possible to develop hybrid architectures from these basic ones.

Shared Data Objects

Table 4 summarizes shared data objects introduced earlier and shows with an "x" the objects needed in various arrangements. Some observations are as follows:

(1) **Inventory and product availability**: Whatever the level of collaboration, inventory is shared by trading partners since it is the starting point of collaboration. Moreover, at higher levels of collaboration, product availability including product substitution, product design and production capacity should be shared as production shifts toward a make-to-order mode.

(2) **Sales forecast and plan**: A shared sales forecast developed jointly by all trading partners will definitely result in more intensive collaboration as in CPFR. In contrast, trading partners of VMI may not commit to a common sales forecast.

(3) **Joint Business Plan**: In CPFR, the joint business plan will guide all collaborative processes in order to achieve the optimization in the whole supply chain, as opposed to a particular trading partner.

Table 4. Shared Data Objects in Collaborative Supply Chains

Category	3pl	Vmi	Cpfr	Supply network
Inventory Management				
Replenishment order forecast		X	X	X
Inventory	X	X	X	X
Replenishment order	X	X	X	X
Goods receipts	X	X	X	X
Product Information				
Product management profile	X	X	X	X
Product design				X
Order Management				
Sales forecast			X	X
Catalog/quotation				X
Sales order/actual usage, pos		X	X	X
Order delivery notes, ship notice	X			X
Production Management				
Master production plan, capacity plan				X
Production order				X
Bill of material (BNOM)				X
Service and Support				
Technical service and support data, feedback, etc.				X
Supply Chain Plan/Joint Business Plan			X	x

Table 4 shows that as supply chains evolve, more data objects, and from additional categories, must be shared. One challenge for configurable supply chains is how to integrate these varied data objects seamlessly. A possible solution is to exchange the data schema along with the actual data. In our model, data schema (or template) is shared by the sender and receiver as a parameter of information flow. Consequently, standards to support exchangeable data schemas should be further developed in order to simplify the process of data consolidation. For instance, at a minimum data schemas under the same category in Table 4 should be compatible because the data objects within a category are more closely related.

Supply Chain Evolution, Information Sharing and Level of Collaboration

Through the above analysis and comparison, we can see two trends in supply chain evolution. First, as supply chains evolve toward supply networks, a variety of shared data objects, complex information sharing structures, and considerably greater information flows reflect more extensive information sharing between partners. Second, the stages of supply chain evolution can fit well into Prahalad and Ramaswamy's (2001) taxonomy of collaboration: arms-length relationship, shared process (3PL), shared process and codevelopment (VMI), shared goals, and joint marketplace development (CPFR, supply networks). Hence, we see a continuum of collaboration of varying intensity from low to high in supply chain evolution. Clearly, there is strong correlation between information sharing and the level of collaboration.

Configuring the Supply Chain

In this section we discuss how the supply chains described above can be configured dynamically in response to external or internal events. Our strategy for configuration is shown in Figure 7. As events occur, three strategies can be applied: modify existing flow (i.e., change a parameter value), add a new flow, or delete an existing flow. Before the change can be applied, it must be checked to make sure that the modified flow or new flow resulting from the change is correct. This involves making sure that the new parameter values are valid and also that no interdependencies between flows are violated. For example, in Table 5, flow "ShipNotice" is preceded by "AcceptOrder" and followed by "GoodsReceipt." Each activity generates an event through its "Req_Action" parameter, thus creating a chain of events. It is important that a modification should not inadvertently destroy this chain. The specific techniques for correctness checking need to be further developed and are beyond the scope of this paper. As Figure 7 shows, only after the correctness check is passed can the change be applied. Otherwise, the request is either rejected or revised, and in the latter case a new round for reconfiguration begins. We will use VMI as an illustrative example although the same method can be applied to other arrangements.

We first describe a database schema to capture the information flows. A simple schema is as follows:

Flows(Flow_id,Event,Condition, Sender, Receiver,Data_obj,Template,Req_Action,Mode)
Partner(Trading Partner, ID, Name, Address, URL)
Template(Template_Id, Description, Template_ Location)

In order to make the supply chain configurable, we need to represent each information flow suitably. The six flows for the VMI arrangement (of Figure 5) are described formally in Table 5. (Similar *partner* and *template* tables may also be constructed.) The information flow is initiated by an event, and takes place upon checking an associated condition. If the condition is true, then the flow takes place. The information flow involves a sender, receiver(s), data object(s), and a requested action from the receiving party. The event may also be a temporal one that takes place at a certain time. A temporal event may be a one-time or a periodic event.

The requested action can generate an event at the receiving end causing the receiving party to act on it. The data in row 1 of Table 5 corresponds to the *sendUsage* information flow. This flow occurs at 5:00 p.m. every Friday (temporal event) and there is no associated condition. Thus, the usage information is sent in a weekly usage form (in a standard template) from the customer to the vendor. The second row describes the action taken by the vendor on receiving the usage. If the inventory value is below the reorder point, then a new information flow called *proposeOrder* is sent from the vendor to the customer. The customer either accepts the proposed replenishment order as is (row 3) or rejects it and sends a modified order to the vendor (row 4). The vendor then processes the order and generates a ship notice (row 5) according to the shipping instructions. Finally, upon receipt of the product, the customer checks the quality and sends an acknowledgment.

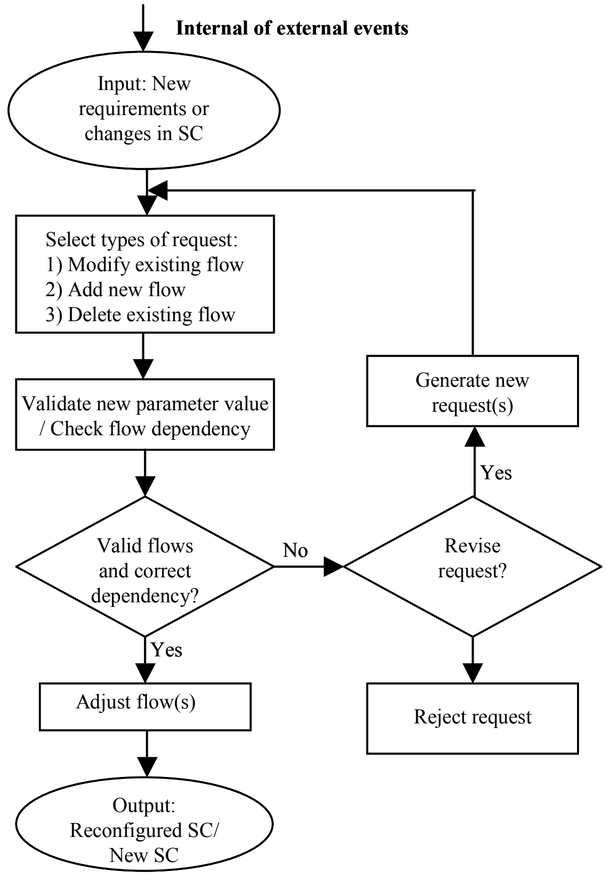


Figure 7. Strategy for Configuring a Supply Chain

Table 5. Sample Data in Flows Table for the VMI Supply Chain Arrangement

Information Flow	Event/ time	Condition	Action (Send Information Flow)				Requested Recipient Action	Batch/ Real-time
			Sender	Receiver	Data Objects	Template		
SendUsage	Friday, 5pm		Customer	Vendor	Weekly Usage	EDI #852	Propose Order	Batch
ProposeOrder	Usage Received	Inventory < 100 (Reorder Point)	Vendor	Customer	Repl. Order [Proposed]	EDI #855	Confirm Order (Accept or Reject)	Batch
AcceptOrder	Proposed order received	No exception (e.g., fill rate ≥ 95%)	Customer	Vendor	Repl. Order [No change]	EDI #855	Generate Ship Notice	Real-time
RejectOrder	Proposed order received	Exception (e.g., fill rate < 95%)	Customer	Vendor/ SCEM	Repl. Order [Revised]	EDI #855	Generate Ship Notice	Real-time
ShipNotice	Confirmed Order received	If shipday = Sat, Ship_grnd else ship_air	Vendor	Customer	Ship Notice	EDI #857	Receive goods	Real-time
GoodsReceipt	Goods received	Quality_val > 90	Customer	Vendor	Goods Receipts ACK	EDI #861	NONE	Real-time

In this framework, there are several avenues for configuration. First, many adjustments may be made in the condition column. The reorder point (row 2) or the target level for the fill rate (row 3) may be changed to a different value by the customer. The condition in row 5 allows the customer to specify that the shipment mode depends on the ship day, and this condition can be configured as well. Finally, in row 6, a quality threshold can be specified and varied. All of the above changes can be made on-the-fly, while other flows remain unchanged. The second aspect of configuration relates to the sender and receiver of an information flow. Existing flows may be modified and new ones may be added. For example, suppose the vendor wished to implement 3PL with a third-party shipping company for delivery of goods from the vendor to the customer. In this case, an additional flow, say, *sendDeliveryNotes*, from the vendor to the shipping company may be inserted above row 5 to inform the shipping company about the anticipated delivery for a new order. To add such a flow, the dependencies between the existing flows must be suitably modified and verified as per the procedure of Figure 7. Finally, the formats of documents can also be easily changed by specifying a new template name, if, say, one partner modifies its documents.

The **flows** table is stored either at one partner's location or centrally in a hub. It may also be replicated across multiple sites; however, this would incur synchronization overhead.

Conclusions and Future Work

Information sharing plays a key role in various supply chain functions such as demand generation and planning, order execution, capacity planning, purchasing, etc. In this paper, we showed that a formal analysis of various supply chain arrangements (3PL, VMI, CPFR, and supply network) provided helpful insights that led to a methodology for the design of reconfigurable supply chains. It is quite clear that, at all levels of collaboration, three enablers of supply chain flexibility must be fully developed: an architecture for information sharing; an exchangeable schema for shared data; and an information flow model. These mechanisms allow us to leverage the collaborative processes to realize supply chain configurability. Clearly, standardization of supply chain technologies must play a key role in this effort. We expect our future work to focus on architectures for an e-hub, standards to support diversity of shared data objects, more formal rule language to coordinate information sharing processes, and exception handling issues.

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