Internet-Enabled Supply Chains

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INTRODUCTION

In today's global economic setting, it is clear that an individual organization alone can no longer prosper in business. Instead, it is the *entire network* of firms that are involved in the delivery of goods and services to end customers that form the nexus of marketplace success (Boone and Ganeshan 2007; Lancioni et al. 2003). Supply chain management (SCM) is an approach whereby this entire network is analyzed and managed in order to produce and distribute merchandise in the right quantities, to the right locations, and at the right time.

Information is *critical* to effectively coordinate and integrate business partners in a supply chain. However, before the advent of the Internet, linking information systems across supply chains was expensive and technically challenging. As a result, the development of supply chains has been slow and, for small and medium-size organizations, the cost has been prohibitive. The proliferation of the Internet over the past decade has had a dramatic impact on the way supply chains are managed, planned, and controlled.

Merging SCM and the Internet—hence, *Internet-enabled supply chain management*—is a key area of concern for contemporary managers and researchers (Lancioni et al. 2003; Rahman 2003). Internet-enabled SCM enables optimization of the overall behaviors of supply chains through maximizing the information sharing across the Internet, thereby offering significant opportunities for cost reduction and service improvements. For instance, many companies have implemented point-of-sales scanners that read what is being sold in real time. These companies not only collect information to make the decision on what to order or how to replenish their stores, but send this information, via the Internet, to their suppliers for *synchronization* of their production to actual sales.

While the Internet offers promising opportunities for SCM, some significant challenges need to be overcome before these opportunities can be fully realized. An important challenge is *information management*. This has been a central concern because of highly volatile and heterogeneous information systems among supply chain partners (e.g., incompatibility of data), which imposes unique challenges in terms of scalability, performance, manageability, and legacy systems (Lancioni et al. 2003). Moving crucial management decisions and processes onto the Internet also presents serious security and privacy issues. Last but not least, Internet-enabled SCM raises not only technical challenges, but also social and economic issues. For example, constant education is needed for staff to keep up with the rapid changes in Internet technologies.

Internet-enabled SCM is a natural evolution of the traditional SCM in the new millennium. In the past few years, it has been an active area in both research and development. In this chapter, we provide an overview of the current status of this area and introduce the major enabling technologies, both existing and emerging, for realizing Internet-enabled SCM. We also highlight some challenging issues that could be future directions for research and development.

The chapter is valuable to readers looking for a general overview of the topic of Internet-enabled SCM. It is also useful to professional SCM users seeking guidance in the development of Internet-based SCM applications.

CURRENT STATUS OF THE INTERNET-ENABLED SUPPLY CHAIN

In this section, we focus on discussing the essential processes of SCM where Internet technologies have been used and applied successfully in industry. The impact of Internet-enabled SCM is also briefly discussed.

Key Supply Chain Processes and the Internet

Purchasing/Procurement over the Internet

As one of the key processes of SCM, purchasing of the desired product with lowest price and high quality is one of the factors critical to a company's success. During the past decade, many Internet-based purchasing/procurement systems have been developed and used throughout the world, such as electronic catalogs, price search engines, recommendation agents, and comparison matrices. Internet technologies have also been increasingly utilized in other aspects of purchasing activities such as customer need recognition and its technical specification, supplier search, and evaluation of purchase alternatives (Garrido et al. 2008).

For example, Dell, a U.S. computer company, has enhanced its procurement process resulting in almost 90 percent of the company's procurement being done online (Chou 2004). To summarize, Internet-based purchasing is widely used to:

- Purchase goods and services online. Through the Internet, an e-procurement system can provide a customized catalog that provides a fast response to a customer's search request. Applications that support e-reverse auctions can enable a company to buy goods or services over the Internet at the lowest price or a combination of the lowest price and other conditions.
- Implement global procurement strategy. Through Internet catalogs, a company can check vendors' price quotations online. This gives the company a wide spectrum of choices to get the best quote on the products. Moreover, the company can also purchase from a vendor's web site at any time and transcend the geographical limitations encountered by traditional procurement methods.
- Manage and handle product-damage, return, and warranty issues. Internet-based purchasing can reduce the costs of handling returned or damaged goods by using the fast-tracking and notification mechanism before damaged goods are shipped (Lancioni et al. 2003).

Inventory Management

Inventory management is one of the critical activities of SCM. Research has shown that the lack of efficient flow of information is the major reason for the high cost of inventory management and inefficiencies in SCM. Internet technologies are able to provide exact solutions to facilitate the information flow.

Research by Mahar et al. (2008) shows that many companies use the Internet to successfully manage their inventory, since an Internet-enabled inventory management system is able to provide *real-time* stock information at all levels in the supply chain, from customer stocks to field and plant inventories, even for stocks and inventories that are geographically distributed. For example, the U.S. Emergency Medical Products Inc. lowered stock levels in all parts of its inventories after it deployed an Internet-based inventory management system. Most importantly, a company can quickly locate and deliver its products to specific customers utilizing the inventory management system over the Internet.

Moreover, Internet-enabled inventory management systems can also make the replenishment of products at retailers' stores fast and efficient. For example, Tyan and Wee (2003) reported a case study that used a vendor-managed inventory (VMI) system over the Internet to increase mutual collaboration between partners and maximize competitiveness of the supply chains.

Internet-based inventory management can also enable:

- The timely and efficient tracking of important items through integrating radio frequency identification (RFID) technologies, communication technologies, and the Internet (Angeles 2005). By using these technologies, a company can implement online, real-time tracking systems that provide quality, well-timed, paperless information necessary in maintaining inventory control for specific items and enabling the company to improve profitable operations and customer satisfaction.
- Significant stock reduction or even zero inventory. Netessine and Rudi (2006) reported an inventory management practice called *drop-shipping* that is built on Internet technology. The idea of this practice is that the retailer serves as a middleman who acquires customers and accepts orders, while the wholesaler stocks and owns the product and ships it directly to customers at the retailer's request.

Transportation

Transportation is one of the highest cost components in a supply chain (Lancioni et al. 2003). To reduce the cost of transportation, many technologies that support transportation management over the Internet have been developed in the past decade, such as the Internet fleet management system, which allows customers to track their items at any time around the world. By using these technologies, item transportation productivity, including outbound truckload and carload shipments, is improved, the back-haul rate is reduced, and claims management is improved, resulting in overall economic gains. Kale et al. (2007) studied the impact of Internet-based transportation management systems on shippers and carriers in transportation communities. Results of the study suggested that carriers benefited by establishing a private community network supported by the Internet. Other gains of the Internet-enabled transportation management system are:

- Monitoring pickups and drop-offs at regional distribution centers by carriers. The data tracking shipments to regional depots can enable a company to estimate the reliability performance of the carriers it is using. It also provides managers with the information needed to inform customers about delays as they occur, and to take corrective measures to reduce any resulting negative impact.
- Improving efficiency in processing and managing various documents generated in the transportation process. Ellinger et al. (2003) reported some motor carrier companies provided services that enable customers to track and trace orders and obtain instantaneous proof of delivery messages electronically.

Order Processing

Internet technologies are widely used in the order processing of SCM. One of the benefits of ordering through the Internet is that it provides a mechanism to streamline the quotation process and lower the overall cost. The most frequent usage of the Internet technologies in order processing are:

- Order placement and order status checking. Research has shown that order processing and order status checking can reduce the costs of order processing in a supply chain (Moon 2005). A major reason of this cost saving is the reduction of paperwork and resources that involved in traditional order processing systems.

- Improvement of speed and quality of order processing. The Internet-enabled order processing system can reduce the time between when the order is placed and when it is received by a customer. It can also reduce the error rate associated with traditional paper-based ordering systems.
- Handling of returned goods and out-of-stock notification of customers. A typical functionality provided by an Internet-enabled order processing system is timely notification when the items are out of stock, the wrong items are sent to the customers, or a customer's quality requirements are not satisfied.

Customer Service

The latest research shows that customer service over the Internet has experienced considerable increase in the past several years due to significant improvement of the Web technologies (Dadzie et al. 2005). The major benefits of using Internet-enabled customer service are:

- Enabling companies to receive, and quickly respond to, customer complaints. Internet-based customer service systems can provide direct and timely responses as well as fast service to customers worldwide.
- Enabling companies to issue emergency notifications as emergencies arise.
- Providing customers 24-hour access to a company's service department, and enabling customers to immediately notify companies of any service issues or problems.
- Developing healthy customer relationships. Lancioni and colleagues (2003) stressed that the Internet could help build strong product and service loyalty and/or strengthen the good customer-company relationship. Kumar and Qian (2006) also showed that making best use of e-procurement systems can enhance opportunities of effective cooperation and create profitable customer-supplier relationships.

Production Scheduling

Scheduling production in the traditional SCM is difficult since obtaining timely information from vendors regarding customer demand and stock levels of raw material is difficult. As discussed in the previous sections, the Internet can help companies to enhance their production scheduling ability by improving communication between vendors, companies, and customers (Lancioni et al. 2003).

Drickhamer (2005) shows that by using Internet technologies, traditional electronic *kanban* systems can be more effective in implementation of just-in-time (JIT) supply chain management. *Kanban* is a manufacturing management tool implemented by Toyota to provide a demand signal to the previous production station to produce more components. Internet-enabled *kanban* systems can transfer demand signals to upstream suppliers via cable and/or wireless network no matter where suppliers are located. Palacios et al. (2006) demonstrated a scheduling tool called IS-OPTIMUS to help improve the unpredictable manufacturing environments in three industrial projects. Even under changing production conditions, the scheduling tool can consistently generate fast, flexible, and optimized schedules by utilizing the vast amount of information obtained dynamically from Web-based applications.

The applications of Internet technologies to production scheduling can also be found in many other aspects, including:

- Coordinating production schedules between companies and their vendors and suppliers. This can be done not only domestically but internationally (Lancioni et al. 2003). For example, Dell makes best use of its online ordering system, interacting with its customers to make the production system more effective and to enable more effective supply chain planning. Once it receives order information, Dell transmits the information directly to appropriate suppliers to improve the supply chain and production planning capability (Bruuna and Mefford 2004).
- Conducting customer demand analysis. Kehoe and Boughton (2001) have shown that the Internet has provided a real opportunity for customer demand data and supply capacity data to be visible to all companies within a supply chain. Using this information effectively, along with other information such as that derived from an Internet customer demand survey, a company is likely to produce more accurate forecasts of changes and/or fluctuations in the markets, thus promoting more effective production scheduling.

Relations with Vendors

As mentioned before, the Internet enables vendors and customers to handle various supply chain activities on a 24-hour a day, 7 days a week basis that provides an effective mechanism in developing good relationships between customers and vendors. Research has shown that providing vendors with ratings on the on-time performance of overall service through the Internet, a company is likely to improve its relations with the vendors (Opoku 2007). Such Internet-based evaluating systems can help companies to (1) better understand and improve the overall quality of vendors' performance, (2) lower purchasing costs, and (3) improve the productivity of vendor operations.

Engineering and Design of New Products

Complex products such as automobiles, aircraft, and weapons require significant engineering and design analysis effort involving a large number of companies, particularly those that are supplying components to the final product. The management of this type of supply chain is complex, difficult, fraught with errors, and time consuming. A typical problem encountered is the inability of small suppliers far up the chain to access technical data.

The concept of a global concurrent engineering platform used the Internet to support its intercontinental product development team. Jiang and Mo (2001) developed a distributed design system that could link designers, enabling them to co-work on the same product over the Internet. Designing a new product involves a lot of analysis and specialized computational tools. The availability of an Internet-based collaborative platform brings the most appropriate resources and expertise from different parts of the world to the design team, which can work on the product around the clock, thereby shortening the engineering development time. Likewise, Mills et al. (1999) created an information infrastructure, Systems Integration Architecture (SIA), using distributed object computing and remote process invocation methods. These systems require the use of a standardized data protocol, called STEP. STEP stands for Standard for The Exchange of Product data and is specified in ISO-10303. The standard is now widely adopted by all CAD systems as a data exchange protocol. The Internet-enabled supply chain in engineering and design can now use the standard data protocol to collaborative effectively.

IMPACTS OF INTERNET-ENABLED SUPPLY CHAINS

The Internet has dramatically changed the SCM paradigm over the past decade. The traditional primary management tools available to logistics managers, such as face-to-face management, manual tracking, paper-dominated order processing systems, and wired communication links, have become less effective. Internet technologies have greatly expanded the scope of commerce and provide tremendous opportunities for companies to succeed in the global markets. Building on the Internet technologies, many companies have deployed efficient supply chain systems to speed up the process of SCM and obtain various levels of economic benefit. It has been witnessed that the Internet is playing a significant role in lowering overall cost and improving the efficiency of the entire SCM process across industries and nations.

The latest research has shown that the companies who use Internet technologies in their SCM enhance customer value and gain strategic advantages over companies that have not deployed Internet technologies in their SCM (Ellinger et al. 2003). Moreover, it has become clear that the bigger the company, the more likely it is to devote the resources necessary to integrate the Internet into its supply chains, thereby gaining substantial competitive advantages over smaller companies.

The Internet also supports the use of market mechanisms such as online auctions to foster price competition. This provides a company the opportunity to purchase some items at a lower price. Consequently, it might enable the company to provide a competitive product to end customers. Research by Bernstein et al. (2008) has shown that more and more companies around the world are shifting to the Internet-enabled SCM paradigm for both economic reasons and strategic consideration of long-term benefits.

However, companies that plan to adopt such a paradigm should have a deep understanding about the risks associated with the adoption. The importance of optimal organizational fit and alignment in the deployment of information technology has been addressed by many researchers. Companies that made heavy investments in SCM information systems might not have reached the original expected objectives. Therefore, it is the well-tuned coordination between business strategies and technology that brings added business value to a company, not the technologies themselves.

ENABLING TECHNOLOGIES FOR INTERNET-ENABLED SUPPLY CHAIN MANAGEMENT

Over the years, new technologies have been rapidly developed to move supply chains to the Internet. These technologies are centered on the development of *e-commerce*. In this section, we provide a detailed overview of these technologies. Note that due to the large number of technologies, both existing and emerging, we will not cover all of them in this chapter. Instead, we will focus on a set of representative technologies.

Internet-based EDI

Electronic data interchange (EDI) has served as a foundation of supply chain management for many years (Boone and Ganeshan 2007). EDI is commonly defined as the interorganizational application-to-application transfer of business documents (e.g., purchase orders, invoices, and shipping notices), via a *value-added network* (VAN), between computers in a compact form. Its primary aim is to minimize the cost, effort, and time incurred by the paper-based transfer of business documents. EDI documents are structured according to a standard (e.g., ANSI X12, http://www.x12.org) and machine-processable format. Traditional EDI, however, is hardly flexible in its ability to expand the set of support document types. Introducing a new type or changing an existing type of business transaction may be complex and time consuming. Furthermore, because EDI is based on proprietary and expensive networks, organizations, particularly small and medium, could not afford EDI.

With the development of Internet-enabled supply chains, EDI has also been extended in many directions. For instance, business documents in EDI standards have been mapped to XML (Extensible Markup Language, http://www.w3.org/XML) documents (e.g., XML/EDI). More specifically, the combination of EDI and Internet technologies (i.e., Internet-based EDI solutions) seems to overcome several shortcomings of the traditional EDI (e.g., VAN charges). Indeed, several organizations are already using EDI for transacting over the Internet. For example, EDI purchase orders and invoices are now routinely exchanged via the Internet by NASA, Sun Microsystems, and Cisco Systems. One major Internet-based EDI initiative is EDIINT.

EDIINT

EDIINT (EDI Internet Integration, http://www.ietf.org) is essentially the same as traditional EDI, but uses the Internet as a communication medium instead of VANs. The aim is mainly to reduce EDI communication charges due to the use of VANs. EDIINT was initiated by the Uniform Code Council (UCC) to standardize the method used to exchange EDI documents over the Internet.

EDIINT is similar to EDI in terms of interoperability at the content and business process layers. At the communication layer, the first EDIINT standard (which emerged in 2000) was EDIINT AS1 (Applicability Statement 1). EDIINT AS1 set the rules of EDI document exchange using SMTP protocol. The second standard (completed in 2001) was EDIINT AS2 standard. It supported communication of EDI documents using the HTTP protocol. To deal with the concerns of security, EDIINT AS2 specifies standard mechanisms for securing documents using PGP ("pretty good privacy") encryption and digital signatures. The standards referenced by EDIINT AS2 include RFC1847 and multipurpose Internet mail extensions (MIME) Security with PGP EDIINT offers lower entry cost than EDI since it is Internet-based. However, the quality of service (e.g., automatic error detection and correction) associated with VANs is lost.

XML-based B2B Interaction Frameworks

B2B e-commerce is a revolutionizing element of supply chain management with dramatic economic implications, and is used to link suppliers, manufacturers, and downstream customers, providing considerable additional value to supply chain activities such as purchasing, supplier management, and support (Boone and Ganeshan 2007). It should be noted that the traditional approaches for B2B interactions were not devised for the Internet. Recent research and development has resulted in a large number of B2B interaction frameworks (standards). These B2B interaction standards are based on XML. In what follows, we describe a representative set of XML-based B2B interaction frameworks including RossetaNet and ebXML. A more complete list of XML-based B2B standardization efforts can be found in the paper by Nurmilaakso et al. (2006).

RosettaNet

RosettaNet (http://www.rosettanet.org) aims at standardizing product descriptions and business processes in information technology supply chain applications. RosettaNet's supply chain includes information technology products (e.g., boards, systems, peripherals, finished systems) and electronic components (e.g., chips, connectors).

RosettaNet focuses on three key areas of standardization to automate B2B interactions. First, the vocabulary needs to be aligned. The *RosettaNet Business Dictionary* contains a vocabulary that can be used to describe business properties (e.g., business name, tax identifier). The *RosettaNet Technical Dictionary* contains properties that can be used to describe the characteristics of products (e.g., computer parts) and services (e.g., purchase order). Second, the way in which business messages are wrapped and transported must be specified. The *RosettaNet Implementation Framework* specifies content of messages, transport protocols (HTTP, CGI, SSL) for communication, and common security mechanisms (digital certificates, digital signatures). Third, the business process governing the interchange of the business messages themselves must be harmonized and specified. RosettaNet's Partner Interface Processes (PIPs) are predefined XML-based *conversations*. A conversation consists of a set of business documents (e.g., purchase order, purchase order acknowledgment) and message exchange logic (e.g., the sequencing of the actions that take place during a product quote request). A PIP is defined using a combination of textual and graphic (UML-based state machine) representations.

ebXML

ebXML (Electronic Business using XML, http://www.ebxml.org) aims at defining a set of specifications for enabling B2B interactions among companies of any size. The basic part of the ebXML infrastructure is the *repository*. It stores important information about businesses along with the products and services they offer. At the communication layer, businesses exchange messages through the *messaging service*. One important feature of the ebXML messaging service is that it does not rely on a specific transport protocol. It allows for the use of any common protocol such as SMTP, HTTP, and FTP.

At the content layer, companies interact through *business documents*. A business document is a set of information components that are interchanged as part of a business process. Business documents are composed of three types of components: *core components*, *domain components*, and *business information objects*. Core components, stored in the *core library*, are information components that are reusable across industries. Domain components and business information objects are larger components stored in the *domain library* and *business library*, respectively. Core components are provided by the ebXML library while domain component and business information objects are provided by specific industries or businesses.

At the business process layer, ebXML defines a *business process specification schema* available in UML and XML versions. The UML version only defines a UML class diagram. It is not intended for the direct creation of a business process specification but provides a representation of all the elements and relationships required for its creation. The XML version allows the creation of XML documents representing ebXML-compliant business process specifications. ebXML provides a set of common business processes specifications that are shared by multiple industries. These specifications, stored in the *business library*, can be used by companies to build customized business processes. Interactions between business processes are represented through *choreographies*. A choreography specifies the ordering and transitions between business transactions. To model the collaboration in which companies can engage, ebXML defines *collaboration protocol agreements* (CPAs). A CPA is an agreement by two trading partners which specifies in advance the conditions under which the trading partners will collaborate (e.g., terms of shipment and terms of payment).

Web Service Technologies

Web service is an emerging technology for developing loosely coupled business applications. This makes Web service one of the most promising candidates for developing supply chain management systems. In this section, we give an overview of the Web service reference model to enable better understanding of this emerging technology,

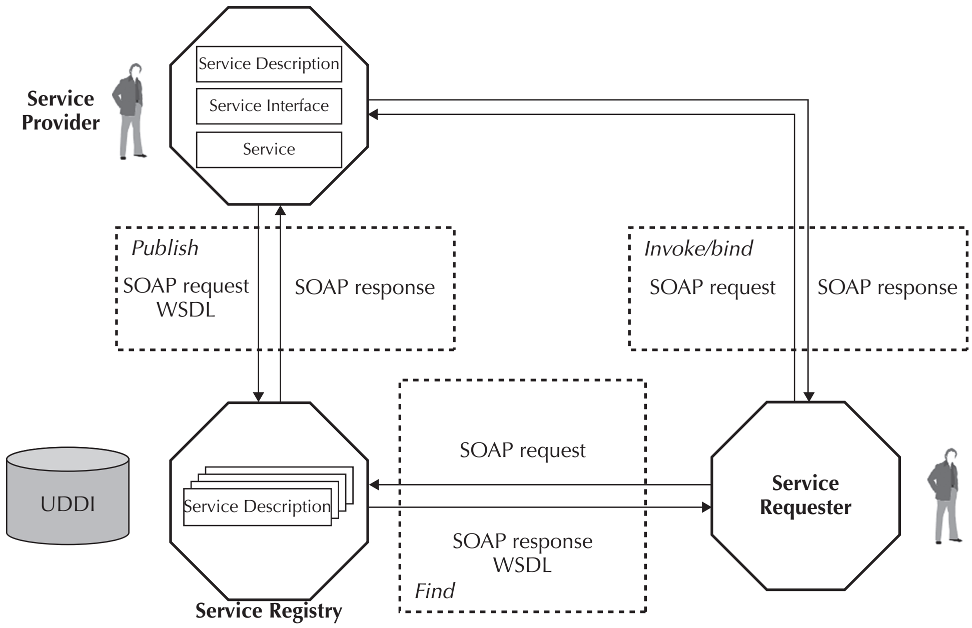

Figure 7.1: Web Service Interaction Model

as well as Web service composition, an important technique for automatic integration of supply chain partners.

Web Service Reference Model

The W3C (World Wide Web Consortium) defines a Web service as a "software application identified by a URI (Uniform Resource Identifier), whose interfaces and binding are capable of being defined, described and discovered by XML artifacts and supports direct interactions with other software applications using XML-based messages via Internet-based protocols" (Booth et al. 2004). Figure 7.1 shows the interactions of the Web service model. From the figure we can see that there are three roles involved in Web service applications: service provider, service registry, and service requester. The interactions between the three roles are publish, find, and invoke/bind. Web services are implemented and published by service providers. They are discovered and invoked by service requesters. Information about a Web service (i.e., service descriptions) is kept within a service registry.

Web services depend on three important standardization initiatives to support interactions among Web services (Figure 7.1):

1. WSDL (Web Services Description Language, http://www.w3.org/TR/wsdl).WSDL is an XML-based language for describing the operational features of Web services. WSDL descriptions are composed of *interface* and *implementation* definitions. The *interface* is an abstract and reusable service definition that can be referenced by multiple *implementations*. The *implementation* describes how the interface is implemented by a given service provider.
2. UDDI (Universal Description, Discovery, and Integration, http://uddi.xml.org). UDDI defines a programmatic interface for publishing (*publication API*) and discovering (*inquiry API*) Web services. The core component of UDDI is the *business registry*, an XML repository where businesses advertise services so that other businesses can find them.
3. SOAP (Simple Object Access Protocol, http://www.w3.org/TR/soap). SOAP is a lightweight messaging framework for exchanging XML formatted data among Web services. SOAP can be used with a variety of transport protocols such as HTTP, SMTP, and FTP. A SOAP message has a very simple structure: an XML element (called *envelope*) with two child elements: the *header,* which includes features such as security and transactions, and the *body,* which includes the actual exchanged data.

Web Services Composition

Web services can be composed with each other in the context of interorganizational business processes (e.g., supply chain systems), leading to composite (Web) services. Composite services allow supply chain partners to form alliances, to outsource functionalities, and to provide one-stop shops for their customers. The past decade has witnessed prosperous research and standardization activities on Web services composition. Following is an overview of some representative standardization efforts and research prototypes for Web service composition. A comprehensive survey on this topic can be found in Dustdar and Schreiner (2005). Major standards for composing Web services include BPEL4WS and OWL-S:

- BPEL4WS (Business Process Execution Language for Web Services, BPEL for short, http://xml.coverpages.org/bpel4ws.html). BPEL is an XML language for Web services composition. Developed by BEA, IBM, Microsoft, SAP, and Siebel, BPEL is currently standardized by OASIS. In BPEL, the composition result is called a *process*, participating services are called *partners*, and message exchange or intermediate result transformation is called an *activity*. BPEL defines a collection of primitive activities such as *invoke* to execute a Web service operation. These primitive activities can be combined into more complex primitives using any of the structure activities provided in BPEL. These include the ability to (1) define an ordered sequence of steps (*sequence*); (2) have branching using a "case-statement" approach (*switch*); (3) define a loop (*while*); (4) execute one of several alternative paths (*pick*); and (5) indicate that a collection of steps should be executed in parallel (*flow*).

- OWL-S (http://www.daml.org/services/owl-s/1.0). OWL-S, previously DAML-S (DARPA Agent Markup Language for Web Services), provides the ability for describing and reasoning over services semantically. OWL-S consists of three upper ontologies: *service profile*, *process model*, and *grounding*. The service profile is used to describe services for the purposes of discovery. Service descriptions and queries are constructed from a description of functional properties (e.g., inputs, outputs, and preconditions) and nonfunctional properties (e.g., QoS parameters). In addition, the service profile class can be subclassed and specialized for the support of creating *profile taxonomies* that subsequently describe different classes of services. OWL-S process models describe the composition and execution of Web services. The process model is used both for reasoning about possible compositions (e.g., validation) and controlling the enactment and invocation of a service. Finally, the grounding of a service specifies the details of how to access the service. The process model is mapped to a WSDL description of the service, through a thin grounding. Each atomic process is mapped to a WSDL operation, and the OWL-S properties used to represent inputs and outputs are grounded in terms of XML data types. Additional properties pertaining to the binding of the service are also provided (e.g., the IP address of the machine hosting the service, the ports used to expose the service).

There is also a huge number of service composition research prototypes in the literature. Two representative prototypes are as follows:

- Self-Serv (compoSing wEb accessibLe inFormation and buSiness sERVices) (Benatallah et al. 2005). The Self-Serv project proposes a process-based language for composing Web services based on a UML state machine. It also defines a *peer-to-peer* Web service execution model in which the responsibility of coordinating the execution of a composite service is distributed across several peer components called *coordinators*. The coordinator is a lightweight scheduler which determines when a state within a state chart should be entered and what should be done when the state is entered. It also determines when a state should be exited and what should be done after the state is exited. The knowledge needed by a coordinator to answer these questions at run time is statically extracted from the state chart describing the composite service operations and represented in the form of routing tables.
- CrossFlow (Grefen et al. 2001). The CrossFlow project aims at providing high-level support for workflows in dynamically formed virtual enterprises. The main contribution of the project is in using the concept of *contracts* as a basic tool for cooperation. Businesses specify their interactions through contracts. Partially defined contracts can be used by service providers to advertise their services and allow consumers to search for relevant services. The CrossFlow architecture supports both *contract matchmaking* and *contract (service) enactment*. When a service provider wants to advertise a service, it uses its contract manager to send a contract template to a trader. When a service consumer wants to outsource the enactment of a service, it uses a contract template to search for service providers via a trader. When a match between a consumer requirement and a provider's offer is found, an electronic contract can be made by filling in the template. Based on specifications in the contract, a dynamic contract and service enactment architecture is set up. The symmetrical architecture contains proxy gateways that control all communication and support services for advanced cooperation functionality. The dynamically created modules can be deleted after the contract is completed.

Deployment Platforms

Many software vendors (e.g. IBM, Microsoft, Oracle) are currently working on implementing B2B interaction platforms. The purpose of this section is to overview the main features of major platforms.

Microsoft .NET

Microsoft .NET embraces the concept of Web services to enable B2B interaction. It consists of three key elements: .NET Framework and tools, .NET Enterprise Servers, and .NET Service Building Blocks. .NET Framework and tools provide the standard base tools for SOAP, WSDL, and UDDI. .NET Enterprise Servers provides the core components for building Web services. These include database like SQL Server 2000, messaging software like Exchange 2000 Server, business process technology like BizTalk Server 2000, and Internet Security and Acceleration Server. .NET Service Building Blocks contains predefined Web services created using the .NET infrastructure (e.g., Passport and HailStorm).

SOAP is used as the main transport protocol in the communication layer. Interoperability at the communication layer is also supported by Microsoft Message Queue (MSMQ), supplemented with gateways for sending and receiving documents in various formats from trading partners. Microsoft Host Integration Server is used to support connection to proprietary systems like IBM mainframes. Heterogeneity at the content layer is addressed by adhering to open standards (XML and WSDL) and the wrapping of applications as .NET Managed Components. Building business processes (called *orchestration*) is done through BizTalk Server.

IBM WebSphere

IBM WebSphere (http://www.ibm.com/software/websphere) is a family of IBM products for B2B interactions. The *application server* is the cornerstone of WebSphere. It aims at providing database and back-end integration as well as security and performance capability (e.g., workload management). The WebSphere application server Advanced Edition adds support for J2EE specification. It also extends J2EE with direct access to advanced CORBA services for greater flexibility and improved interoperability. The advanced edition integrates support for key Web service standards such as SOAP, UDDI, and WSDL. Additionally, it provides distributed transaction support for major database systems including IBM's DB2, Oracle, and Sybase.

Other products make up the WebSphere platform. These include WebSphere Business Components, WebSphere Commerce, and WebSphere MQ Family. The WebSphere Business Components provides prebuilt, tested, and plug-and-play components for building new applications or extending existing ones. WebSphere Commerce provides mechanisms for building B2B sites, including catalog creation, and for payment processing. WebSphere MQ Family is a family of message-oriented middleware products that enable communication between applications running on different hardware platforms.

Other Platforms

- BEA WebLogic Integrator (http://www.bea.com/products/weblogic/integrator)**.** BEA WebLogic Integrator is the cornerstone of BEA WebLogic E-Business platform. It is built on top of a J2EE-compliant application server and J2EE connector architecture. It supports current Web service standards such as SOAP, UDDI, and WSDL. The Integrator is composed of four major modules: *application server*, *application integration*, *business process management*, and *B2B integration*. The application server provides the infrastructure and functionalities for developing and deploying multitiered distributed applications as EJB components. The application integration leverages the J2EE connector architecture to simplify integration with existing enterprise applications such as SAP R/3 and PeopleSoft. The business process management provides a design tool and execution engine for business processes. The B2B integration manages interactions with external business processes. A separate module called *B2B integration/collaboration* is used to manage different B2B protocols (such as RosettaNet PIPs, BEA's eXtensible Open Collaboration Protocol) and quality of service (QoS) of the trading partners.
- Apache Tomcat (http://tomcat.apache.org). Apache Tomcat is a popular platform for deploying Java-based Web applications. More specifically, Tomcat is a servlet container for the Java servlets and JavaServer Pages (JSPs). It provides a Java Virtual Machine and associated elements to give a complete Java run-time environment, and Web server software to make that environment accessible on the Web. Configuration and management tools are also provided where configuration data are largely represented in XML. The major components of the Apache Tomcat consist of *Catalina*, the servlet container portion of Tomcat; *Coyote*, the Web connector; and *Jasper*, the JSP engine of Tomcat. The *Tomcat Manager* is a useful application that runs in one of the standard Tomcat containers to control loading, reloading, and unloading of individual applications or of the engine as a whole.

CHALLENGING ISSUES IN DEVELOPING INTERNET-ENABLED SUPPLY CHAINS

With the advancement in Internet technologies in the past decade, supply chains rely more and more on the information technology and communication infrastructure to do business. However, common issues in supply chain operations could include short product life cycle, supply variability, collaboration, confidentiality, intellectual property conflicts, opportunity loss, capacity constraints, and others. The use of information and communication technologies alone is not enough to support effective decision making. A strategic framework is required to integrate the upstream and downstream managers in the supply chain as a team to create and add value to the products that end up in the hands of the consumers. Therefore, future supply chains face significant challenges as technology enables supply chains to do business over the Internet. These challenges can be categorized in three major aspects: *social*, *technical,* and *economical*.

Social Issues

A supply chain consists of a number of organizations with different business perspectives (such as suppliers, manufacturers, distributors, and customers). Its effective management requires integration of all parts of the supply chain. Although the usage of electronic commerce has been increasing, the rate of its adoption in supply chain management has been slower than expected. One of the critical issues is the social pressure exerted among supply chain partners. Lai et al. (2006) found that managers in the supply chain should be aware of the institutional pressure placed upon their supply chain partners. They might face, in the course of adopting IT for the management of their supply chains, possible problems and injunctions. Different types of institutional isomorphism, namely coercion, mimesis, and norms, could drive different levels of drawbacks, from deteriorating supply chain performance to losing business opportunities.

Therefore, a crucial task in building a supply chain is to define clearly the *social context* with which the supply chain is going to operate. The organizations that are potentially involved in the supply chain, whether willingly or unwillingly, need to spend time to determine the physical and structural properties of collaboration—the culture, business practices, security processes, and governance issues. Potential problems in the supply chain—for example, conflict of interest, confidentiality, intellectual property ownership, and so on—should be identified well beforehand.

Compliance of Business Process and Business Culture

A supply chain comprises a number of enterprises which are driven by individual business goals and which can collectively find advantages to being linked through transactions and contracts. Participation in a supply chain depends on whether there is any benefit to the enterprise. Enterprises in a supply chain can come and go as they wish, unless they are under contractual restrictions, which are not prohibitive. It is important that a supply chain have a unified business process that is efficient and effective in dealing with day-to-day business. More importantly, the interface between companies and processes, in this case, the interface via the Internet, should be carefully designed to foster a cohesive culture among the members of the supply chain.

Alexakis et al. (2004) used four prototypical examples of networks of enterprises, such as Nike, to illustrate the advantages as well as challenges. In this study, the inhibitors to the success of supply chains were in various areas of business processes and culture. Organization, finance, loss of competence, corporate identity, communication, and intellectual property management were cited as the main inhibitors if they were not managed well.

Chouinard et al. (2005) studied problems related to the integration of reverse logistics activities within a supply chain. *Reverse logistics activities* refers to the recovery and processing of unused products and to the redistribution of reusable materials. This study showed the need for a new organizational system, in terms of operational processes and management of resources, as better control and management of these activities ensured a compatible business process throughout the supply chain.

An Internet-enabled supply chain provides an excellent opportunity for companies to participate and co-create the business culture, but at the same time allows companies to maintain an effective back-end business system in support of the participation. This new management model fits well to the evolving social characteristics of supply chains.

Competencies of Employees

Success of a supply chain depends on many factors. One important factor is the dedication of employees of member companies. Park et al. (2001) studied the Korean automotive supply chain to explore whether quality management practices were different among suppliers with different performance ratings. They found that the highest-rated suppliers valued process management and employee satisfaction to a greater degree than the lowest-rated suppliers. In a study by Arda and Hennet (2006), a supply chain was profitable if the staff could manage multiple dispatches of orders, given that the customer orders came randomly and there were random delays from suppliers.

The preceding cases show that staff members operating in an Internet-enabled supply chain environment face the challenges of adapting to more complicated processes, which demand faster responses. There are transition problems related to the competencies of staff working with new technologies when companies migrate their systems to match the technology level of their partners.

Contract Laws and Government Regulations

E-government is the use of Internet portals to disseminate government information, messages, and services to the public. The study of government enterprise architecture investigates the most effective e-government structure to achieve this goal. However, for various reasons, government regulations and systems could quickly change. A supply chain interacting with government services must be able to maintain compliance with the relevant government information systems and technology. In general, individual companies should be able to cope with the requirements, but not all companies have to comply, making it difficult for the supply chain to work within the e-government framework.

Lee and Kim (2007) interviewed 26 government authorities to reveal their underlying perceptions of Internet-based information systems. They concluded that the overarching frame of reference that evolved among the perceptions of e-government authorities is the concept of *growing systems*. This means e-government services will grow together with the requirements of the community. For smaller enterprises, compliance with changing e-government processes could be difficult. The challenge is for the partners in Internet-enabled supply chains to work with the bureaucracy for incorporating new government services and complying with changing regulations as part of their integrated business process.

Technical Issues

An Internet-enabled supply chain requires product information to be transferable in electronic format. A crucial condition to enable this capability is the compatibility of product life-cycle information models in different parts of product development cycle: manufacturin, and sales and services processes. The knowledge and information needed for supporting the whole of a supply chain operation can be represented as a cyclic process, as shown in Figure 7.2. The fundamental resources required are information systems models, smart embedded systems, short- and long-distance wireless communication technologies, data management and modeling, design for X and adaptive production management for the beginning of the product's life cycle, statistical methods for predictive maintenance for the middle, and planning and management of end of the product's life cycle.

The use of the Internet as a means of providing support services to customers for high-value products was explored by Mo and Nemes (1998). Extending on this basis, Mo et al. (2003) developed a context and content capturing process that assisted the alignment of Web-based information with the business processes of the company in a Web portal. The key to these Internet-enabled innovations is to put the functionality of the supply chain into a structure that can be manipulated readily.

Supply Chain Visibility and Efficient Tracking

The need for managing the supply chain with better tracking technology has been recognized in many application areas. Prater and Frazier (2005) illustrated in the grocery industry that item-level identification must be the foundation for enabling visibility in supply chain management. The latest item-level identification technology, radio frequency identification (RFID), has the advantage that no physical contact is needed with product items, allowing for increased handling efficiencies.

Tracking in large-scale (national or intercontinental) supply chains using RFID inevitably requires the use of

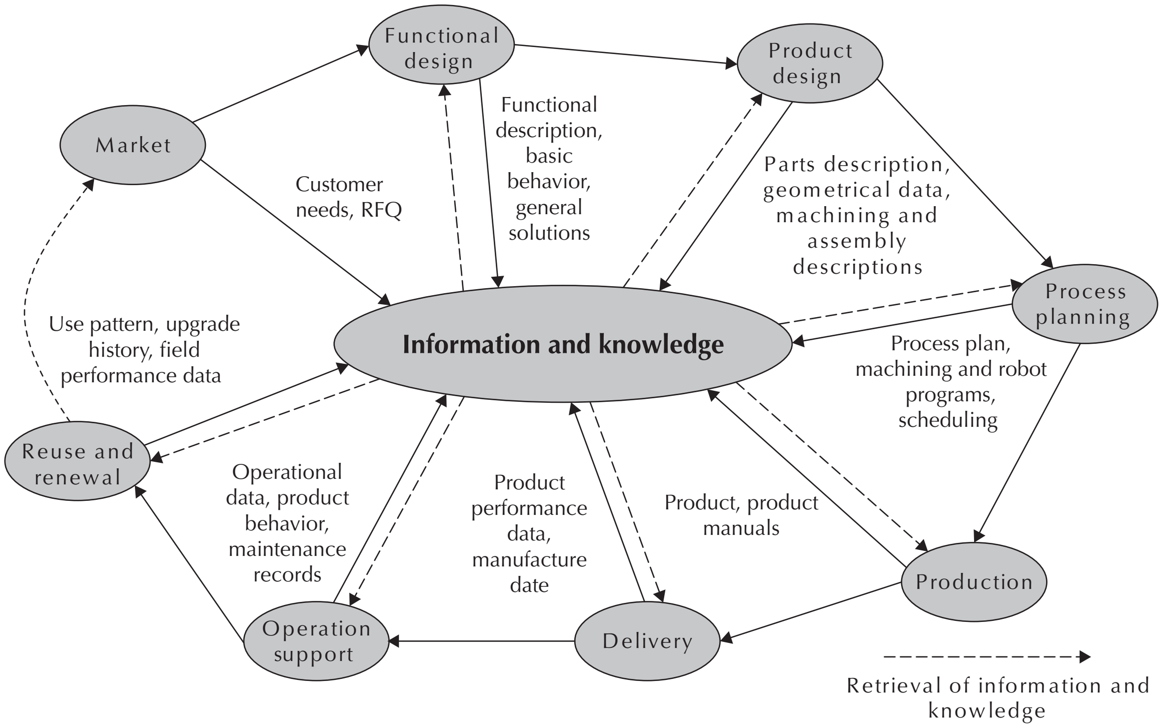

Figure 7.2: Information and Knowledge Flow in Supply Chain
Source: J. P. T. Mo and M. Zhou, "Tools and Methods for Managing Intangible Assets," *Computers in Industry* 51 (2) (2003).

the Internet as the communication platform. Attaran (2007) concluded from the Wal-Mart project that the RFID technology implemented on the Internet-enhanced applications streamlined business processes with the suppliers, created visibility in the supply chain, and improved productivity by generating the fastest, lowest-cost method of acquiring data across company boundaries. Similarly, a pilot project in Australia, the National EPC Network Demonstrator Project (NDP), tracked fast-moving consumer goods and moveable assets and examined the processes of intercompany transactions and change of ownership (Mo 2008). EPC stands for *electronic product code*, which is a unique code embedded in RFID tags for identifying the item attached to a given tag.

These projects show that supply chain visibility can only be achieved with both implementation of tracking technologies and transparency of data. Data transparency requires enforcement of data flow and contextual integrity in the supply chain, which can be achieved by synchronizing corresponding business processes among trading partners.

Supply Chain Performance Management

Unlike a normal enterprise, the supply chain is formed from a number of autonomous enterprises. An individual enterprise may choose to work in certain a way to optimize its own performance but this may not optimize the ultimate performance of the supply chain. It is therefore necessary to develop key performance indicators that can reflect whether the goal of the entire supply chain is met. However, partnering companies have their own practices and data structures. The incompatibility of data and systems among supply chain partners make it difficult to measure the overall performance of the whole supply chain.

Yee et al. (2006) developed a strategy deployment chart to assist managers in addressing the issue of performance management in the supply chain. The tool enabled managers to visualize the interplays of strategic downstream supply network decisions. The process, which consisted of semistructured interviews and site visits, uncovered many unique interactive relationships among manufacturers, dealers, and end users. To cope with the frequent network changes in a dynamic global supply chain, the process requires significant enhancement before users are able to assess the performance of Internet-enabled supply chains.

To measure the performance of a supply chain, it is necessary to establish an agreed reporting structure. Zhou et al. (2005) developed a communication framework that served staff across company boundaries in a collaborative alliance. The Web-based document management system was designed to capture the explicit knowledge of individual partners and participating staff to a knowledge repository. Having this environment, the supply chain was able to keep up-to-date progress data and generate reports relevant to the time of decision making.

An example of a monitored supply chain producing benchmarking data is the NDP Extension project (Mo et al. 2007). The project demonstrated how pallets could be tracked using the EPC process and measured an average efficiency gain of 18.1 percent and a cost savings of A$2.25 per delivery for the partners (see Table 7.1). It can be seen that individual companies benefited

Table 7.1: Process Efficiency Improvement in the Internet-enabled Supply Chain

Site	Standard/ Current Process Time (minutes/ delivery)	Pilot RFID/EPC Process Time (minutes/ delivery)	Gained Labor Productivity ($/delivery)	Gained Productivity (minutes/ delivery)	Process Efficiency
Erskine Park	35	23	6.4	12	34.3%
Ballarat	35	30	2.3	5	14.3%
Scoresby	38	36	0.8	2	5.3%
Arndell Park	35	30	1.9	5	14.3%
Yennora	45	35	5.2	10	22.2%
Average	37.6	30.8	3.5	7.5	18.1%

differently due to the nature of their business, the extent of their involvement, and their willingness to try new technologies.

To assess the performance of a supply chain, three elements are essential:

1. Mapping of the interrelationships between the partners in the form of a network or process map.
2. An effective information infrastructure allowing continuous data flow among the operating sites for compilation of performance indicators.
3. Facilities enabling sharing of knowledge and action plans in the supply chain.

The criteria for adopting a system that has these three elements must be cost effective and constantly evaluated against the benefits such as efficiency gain and waste reduction in the whole system as well as individual companies.

Security and Privacy

The use of the Internet brings inherent security and privacy risks to a supply chain. In the development of an Internet-based management system for a merchandise supply chain, James et al. (2004) implemented measures such as firewalls, IP address monitoring, caller identification, and password controls when they dealt with over 300 clients. Miller (2006) examined the complexity of businesses and supporting information systems and found that for each business process there would be a number of headline systems that it relied upon. These interrelationships should be mapped to information systems so that system operational risk, leading to real business risk and subsequently vulnerability, could be identified and determined.

Since the late 1990s, the emergence of RFID as a potential supply chain technology has gained attention. However, using RFID in conjunction with the Internet had fundamental security and privacy concerns. Knospe and Pohl (2004) found that RFID transponders did not protect the unique identifier so that unauthorized readers in the proximity could gather IDs. The collected data (e.g., information on consumer goods) could be linked with location information and a customer profile and could be accessed on the Internet. This functionality presents serious privacy issues to the community as well as to individuals handling the RFID-enabled item using Internet-enabled supply chain data channels.

Potter (2005) highlighted the concern that consumers were afraid of their buying habits being tracked; travelers were concerned about the privacy issues of RFID in passports; and businesses were worried that the current state of the technology was not sufficient to keep hackers at bay. Attacks against RFID tags could be common, and privacy concerns were everywhere. Until new standards and more advanced chips could be made, RFID tags would remain easy targets for attackers determined to cause havoc or commit crimes.

Dynamic and Scalable Processes Integration

Supply chains are dynamic and often affected by customer preferences such as seasonal requirements. Fisher (1997) described a simple framework that could help managers understand the nature of demand on their products and devise a supply chain that best satisfied that demand. Based on this work, Wong et al. (2006) further developed a structural approach to assess the responsiveness of a volatile and seasonal supply chain based on a case study in an international toy company. Four risk-influencing determinants—*forecast uncertainty*, *demand variability*, *contribution margin*, and *time window of delivery*—were identified as key elements for assessing the responsiveness of the toy supply chain.

Customers demand products individualized in design, which forces changes upstream in the supply chain, not only in satisfying quantity but also in meeting variety expectation. The effect is created by *mass customization*, a scalable manufacturing system that can integrate large numbers of design alternatives with flexible manufacturing facilities while managing fluctuations in production volume (Steger-Jensen and Svensson 2004).

There are two aspects of the customization process. First, customers should be given the opportunity to specify their needs. In a traditional supply chain, this is normally done by the customer visiting a showroom or a salesperson visiting the customer. This customer feedback process can now be handled via the Internet when the supply chain is enabled with the appropriate portal and functionality.

Second, the supply chain should have built-in functionality that can respond to individual customer specification. The underlying principle of this aspect is the identification of common parts that can be interchangeable among product models, and the development of quick-to-change production processes. The key to implementing this principle is a simple-to-implement product information structure for production planning and control with minimum impact to the available manufacturing facilities.

It is clear that a strategy based on a reliable information infrastructure for supporting dynamic supply chains is important. The use of an Internet-enabled supply chain will enhance information flow among the collaborating partners. To meet the need of a particular customer order, good decisions on the best production routes within the supply chain could be made with reliable data.

Economic Issues

A supply chain is a loosely coupled entity that is driven by economical reasons—that is, to share the benefits of trading for fulfilling customer demand. Guo et al. (2006) developed a macro prediction market model that classified partners' incentives in two parts: *systematic* and *idiosyncratic* risks. They were able to show that risks can be mitigated by sharing market information across the supply chain so that member companies could consider risk management opportunities to hedge against aggregate economic risk. Problems such as partner selection, operation management, and information exchanges and their standards, could affect the economic viability of the supply chain. However, they are difficult to quantify, and evaluation of risk would require more sophisticated analytical methodology.

Investment and Return

There is a considerable gap in understanding the bottom-line implications of supply chain strategies in which e-commerce scenarios are playing an ever greater role. Using three scenarios—traditional, electronic point-of-sales-enabled, and vendor-managed inventory—Naim (2006) investigated the impact of using the net present value (NPV) on parameter selection in the ordering policy of a production planning and control system. The study showed that the resulting management implications are sensitive to the selection of the NPV variance parameters.

In a retail supply chain, large retailers could benefit from high IT investments through several fronts. In this case, the consideration for investment in new IT systems did not rely solely on return. Research by Ettlie et al. (2005) showed that there were obstacles to investing new Internet-based technologies in companies that had prior investments in earlier generations of e-commerce technology such as EDI. Bottani and Rizzi (2008) studied the economic impact of RFID on a fast-moving consumer goods supply chain. The study showed that RFID and EPC implementation was not profitable for all parties examined.

Kärkkäinen and Holmström (2002) believe one of the greatest challenges for the adoption of advanced supply chain technologies such as the Internet and RFID is the lack of investments in infrastructure. There are always disagreements about the sharing of investments in the technology and the benefits obtained. Business investors are unsure about their returns on investment. Even if they have some indicative information, the returns so far are not attractive. However, to achieve reasonable benefit of Internet-enabled supply chain technology, massive participation is required. The challenge for entrepreneurial supply chains is to increase community confidence in order to generate a larger scale of participation.

CONCLUSIONS

The key ingredient for successfully managing a supply chain is fast and accurate information, which enables organizations to react quickly to market changes. The Internet is an incredible medium that provides such information and allows supply chain activities to be carried out in a truly synchronized fashion. It is now widely agreed that Internet-enabled tools and solutions will play a significant role in the development of cost-efficient and service-effective supply chains.

In recent years, Internet-enabled supply chain management has become a vibrant and rapidly expanding area of research and development. Many researchers and vendors are currently engaged in proposing solutions needed for the development of Internet-enabled supply chains. Along with the current efforts, we encourage more insight into the problems of this area, and more development in solutions to the open issues of social, technical, and economical aspects as described in this chapter.

GLOSSARY

Business-to-business (B2B): A term commonly used to describe commerce transactions between businesses, like the one between a manufacturer and a wholesaler, or between a wholesaler and a retailer.

BPEL4WS: Business Process Execution Language for Web Services, an XML language for Web services composition.

ebXML: Electronic Business XML, a set of specifications for enabling B2B interactions among companies.

Electronic data interchange (EDI): A standard defining the interorganizational application-to-application transfer of business documents via a value-added network (VAN), between computers in a compact form.

Fast-moving consumer goods (FMCG): Refers to the lowest-cost consumable items for daily use.

IBM WebSphere: A family of IBM products for B2B interactions.

Kanban: A manufacturing management tool implemented by the Japanese car manufacturer Toyota. The objective of the tool is to provide a demand signal to the previous production station to produce more components.

Open Buying on the Internet (OBI): A standard that leverages EDI to define an Internet-based procurement framework.

Radio frequency identification (RFID): A technology that uses radio frequency to transmit information from a transponder (device containing the identification data) to a reader.

RosettaNet: A standard for product descriptions and business processes in information technology supply chain applications.

Simple Object Access Protocol (SOAP): A lightweight messaging framework for exchanging XML-formatted data among Web services.

Universal Description, Discovery, and Integration (UDDI): A language that defines a programmatic interface for publishing and discovering Web services.

Vendor-managed inventory (VMI): A service that helps manage companies' inventories to increase mutual collaboration between partners and maximize competitiveness of the supply chains.

Web service: An emerging technology defined by W3C as "software application identified by a uniform resource identifier (URI), whose interfaces and binding are capable of being defined, described, and discovered by XML artifacts and supports direct interactions with other software applications using XML-based messages via Internet-based protocols."

Web Services Description Language (WSDL): An XML-based language for describing the operational features of Web services.

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Cross-references to come.

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