Know Your Supply Chain: Transactional Knowledge and Beyond

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Abstract

As goods move from raw material processors through to manufacturers, distributors and retailers, extensive coordination is required throughout the supply chain. Ordering, demand forecasting and inventory decisions at each link in the chain all depend not only an organizations immediate trading partners, but on every link in the supply chain. In the past, there was little coordination among all the participants in a supply chain — each participant communicated with their suppliers (upstream) and buyers (downstream). Recently, however, organizations have focused more attention on the supply chain as a strategic asset, and communication is no longer between pairs of participants, but instead among all the members of a given supply chain. The rise of electronic commerce has further heightened the importance of supply chain management as companies reengineer processes as they are moved online. Little work has been done however, on how agents that represent members of a supply chain can communicate with one another as their human counterparts do now. We believe that successful supply chain integration demands knowledge-intensive agents. Such agents must have more than transactional knowledge that enables them to agree on prices and quantities. They must possess detailed knowledge of the domain in which they trade. In this paper we describe the knowledge needed, and suggest ways in which XML can be used to represent the needed knowledge.

The Importance of the Supply Chain

DaimlerChrysler, Ford, and General Motors recently announced a joint venture to create an automotive parts exchange to buy and sell parts needed throughout the automobile supply chain. The anticipated exchange represents a significant transaction volume — the three manufacturers purchase $240,000,000,000 in parts annually, and their suppliers purchase an additional $500,000,000,000 in turn. The sheer size of the exchange represents a significant technical challenge, with literally thousands of suppliers bidding and offering for hundreds of billions of dollars in business

In the past, purchasing representatives for auto manufacturers invited a small set of suppliers to visit their Detroit headquarters to bid on business. As the New York Times reported, "Preliminary engineering specifications are exchanged, and suppliers are given a deadline for sending in bids and detailed blueprints. Further meetings are then held to work out the details of the contract." Much more information would likely be exchanged as well: demand forecasts, supply factors and logistical arrangements, for example. The envisioned auto exchange would offer an open marketplace for buyers and sellers to transact business. The manufacturers argue even greater benefits for exchange users. Because the exchange will be tailored to automotive manufacturing, the exchange can offer industry-specific tools and features: demand forecasting, collaborative design and order pooling for volume purchasing, among others.

Visions of savvy software agents buying and selling on behalf of companies dance in the heads of electronic commerce advocates everywhere. The planned automotive exchange would be fertile ground for such intelligent commerce agents to conduct business on behalf of parts suppliers and purchasers. However, to provide sound business advice and to execute meaningful supply chain-related business decisions, such agents must exchange the same information that their human counterparts do, and they must have the same (and more explicitly represented) domain knowledge concerning supply chains, goods and services exchanged, contracting, etc. as their business users such as supply chain managers and purchasing personnel.

Another important aspect of supply chain coordination is logistics arrangements. Although electronic commerce often leads to radical changes in the conduct of business, the logistical challenges are the same ones that face offline businesses. In fact, supply chain issues are often the Achilles heel of online businesses. At the end of well-implemented, streamlined search and ordering process, a physical good must often be shipped to the customer. To design intelligent agents that address these challenges, it is important to understand what the specific problems are, and how they are being addressed by people.

Much of the current work in agents and electronic commerce focuses on transactional knowledge — the knowledge needed to agree on a price, quantity, delivery date and other factors surrounding the immediate sale of

goods or services. However, agents' knowledge must reach beyond transactional knowledge to incorporate explicit knowledge of the supply chain to deal with issues such as managing outsourcing, supporting multi-issue decision making, and handling information sharing and other coordinative activities among supply chain partners.

We begin this paper by discussing transactional knowledge and then describe the need for knowledge beyond transactions. We also suggest the importance of knowledge representation for both transactional and other supply chain knowledge in extant frameworks such as XML.

Transactional Challenges of Supply Chain Management

Several factors must be addressed to leverage the promise of intelligent agents in business-to-business (B2B) electronic commerce. Some of these challenges involve the knowledge needed to identify participants and engage in transactions. First, the search costs associated with locating suppliers need to be reduced. For most goods, online marketplaces are widely scattered and finding a suitable exchange or auction site is a difficult task. Second, a suitable representational framework and communication protocols have to be established to enable semantically meaningful interactions among businesses, addressing the transactional needs of supply chain management.

In addition to knowledge needed for transactions, other supply chain-related problems require a deep understanding of a particular industry or function to conduct business. In particular, the knowledge needed to coordinate activities both horizontally (a single function across multiple firms) and vertically (along a supply chain within an industry) has been given short shrift in research discussions. We begin by discussing the knowledge needed for transactions, and then shift to a discussion on knowledge needed for horizontal and vertical coordination activities.

Information search costs

Manufacturing capacities have been growing faster than demand in most industrial sectors largely due to technological advances and globalization of manufacturing. One direct result of overcapacity is the proliferation of products as well as the manufacturers that produce these products. This proliferation of choices is further accelerated by the ever-growing number of ``niche'' manufacturers and the rapidly increasing introduction of new products. According to DataGalaxy.com, a leading engineering-related intermediary offering technical information used for specification and sourcing, its internal database of commercial and government stocked parts covers 24 million items from a variety of industrial sectors as of 2000 (DataGalaxy.com 2000).

In the electronic marketplace, manufacturers and service providers advertise their capabilities to their potential buyers through the Internet and online information intermediaries. These new electronic media have the potential of reaching a potentially large consumer base at very low cost. Locating suppliers with needed products from buyers' point of view, however, is a substantial challenge. In the Business-to-Consumer (B2C) market, consumers are relatively flexible as purchasers — most consumers would be happy with any one of several competing brands, for example. In the B2B market, however, specifications are often detailed and exacting. A bolt is not simply a bolt, but instead a bolt manufactured from a particular alloy with known responses to stress and strain, sized to the millimeter, with specified thread spacing and depth. How are buyers supposed to find such bolts?

Sophisticated catalogs are needed to describe goods throughout a supply chain. Such catalogs must include detailed descriptions of the goods themselves, but must also include information on compatible and incompatible parts. It is not enough to find a bolt that meets a specification — one must find a compatible nut that meets the specification as well. The need for compatible (and incompatible) parts information argues for vertically-oriented marketplaces that can include compatibility information among parts that are likely to be used together.

An additional benefit of centralized catalogs is the opportunity for suppliers to publish updates regarding goods and services. Under a publish-and-subscribe model, agents could request to be notified when changes in relevant parts occur. In (Sawhney and Kaplan 1999), Sawhney and Kaplan argue the strategic case for third-party marketplaces (which they label hubs) becoming the dominant electronic marketplace, being preferred to supplier or buyer sponsored sites. The Ford/General Motors/DaimlerChrysler example cited at the beginning of this paper is an example of just such a (vertically-oriented) hub.

The development of the eXtensible Markup Language (XML), emerging standards for commercial document exchange promises flexible yet unambiguous sharing of information (Glushko, Tenenbaum et al. 1999). Coupled with agent technologies, XML has the potential of further reducing information search costs. RosettaNet (http://www.rosettanet.org/) is an organization devoted to defining XML standards along supply chains. RosettaNet has begun to define a framework for modeling business processes and supply chains, but the framework is not a complete specification of the needed information. RosettaNet has produced an electronic component specification that contains "roughly 460 component classes and 2400 properties" just for electronic components (RosettaNet 2000).

The act of transacting

Once a buying agent has located a suitable product, the transaction details must be negotiated. Price, quantity, delivery date, delivery pricing and many other factors must

be agreed upon. Even before a price can be agreed upon, however, both sides must agree what a price is. For example, many manufacturers quote prices including some shipping charges. A price annotated with "FOB St. Louis, MO" is free-on-board to a loading dock in St. Louis, Missouri — the buyer is responsible for shipping from there.

Businesses have long struggled with these issues, and much research has already been conducted into representing the information needed for the more mundane aspects of business. In particular, many larger businesses have decades of experience with Electronic Data Interchange (EDI), which is a standard designed to address the very issue raised by electronic transactions. Although many organizations have found it difficult and expensive to implement EDI, much insight has been gained through the process. This experience is reflected in the development of the Open Buying on the Internet (OBI) standard (Tian, Chung et al. 2000), and work on XML/EDI (Peat and Webber 1997).

Whether XML is an appropriate language for representing transactional knowledge is almost moot. The ball is already rolling, and as more initiatives and more companies adopt XML as the language of choice, adopting an alternative becomes less and less likely. Work on representing knowledge in XML is still in its formative stages. Organizations such as Ontology.org (www.ontology.org), OASIS (www.oasis-open.org) and the United Nations Centre for the Facilitation of Procedures and Practices for Administration, Commerce and Transport, or UN/CEFACT (http://www.unece.org/cefact/), have already begun to develop standards for knowledge-based commerce. Together these three organizations have begun work on ebXML (www.ebXML.org), whose mission is "[T]o provide an open XML-based infrastructure enabling the global use of electronic business information in an interoperable, secure and consistent manner by all parties." (ebXML 2000)

This represents an opportunity to conduct research, while simultaneously addressing an important challenge in the growth of electronic commerce. The challenge for researchers working in knowledge-based markets becomes how to integrate perhaps better-suited, but less widely adopted alternatives. By working with the XML and business communities, computer scientists and AI researchers can influence the development of standards so that they are informed by the tools needed to support knowledge exchange.

Beyond Transactions: Coordination Knowledge in the Supply Chain

Although transactional knowledge is important, much more is needed to successfully conduct business. The rising popularity of outsourcing, emerging business practices and logistical coordination challenges all require knowledge above and beyond that needed to facilitate information search and execute business transactions. We discuss below such knowledge that to a large extent can be characterized as supply chain coordination knowledge in both vertical and horizontal sense.

Supporting Outsourcing

Due to the increasing number of accessible alternatives, competition for customers intensifies. In order to remain competitive, companies are under pressure to outsource non-core functions and focus on their core competencies. As more participants (often geographically dispersed) are involved in a given value chain, coordination becomes a key issue (Shaw and Sikora 1997). In addition, more complex value chains are required as customers are demanding more customized products and services.

The potential impact that electronic commerce has on this focus on core competencies is as follows: the electronic commerce infrastructure could provide a collaboration environment for supporting these coordination activities. Part of the reason is that information sharing between different participants is facilitated and transaction costs for coordination are negligible. There are many well-known examples where manufacturers successfully outsourced their logistics functions to third-party logistics providers. This allows them to concentrate on their manufacturing competencies. With coordination effectively supported by advanced information infrastructure, the manufacturers and their logistics partners were able to concentrate on their respective competencies.

Outsourcing previously internal operations can create thorny problems in knowledge transfer. Where previously employees performing complementary functions needed to only stroll down the hall to resolve conflicts or design cooperative solutions, outsourcing requires the same intimacy of communication but now across organizations. One of the key elements in cooperation is a shared context. Presumably, all the employees in a firm are working toward a common goal, and share the same environment and similar organizational context. Once a company outsources some operations, that shared context is lost and agents must exchange very detailed knowledge about their organizations (Fenstermacher 1999).

Emerging business practices and interactions

New business practice is gaining momentum in the electronic marketplace. New types of interactions among businesses and customers are also emerging. Two well-known examples are online auctions and purchasing consortiums. FreeMarkets OnLine Inc. is a well-known example of Web-based marketplaces for industrial goods. Industrial buyers bought $501 million worth of components and goods in 1998 using the interactive bidding services provided by FreeMarkets. These buyers have been able to cut down procurement costs by an average of 15%.

Recently purchasing consortiums have attracted increased attention for many organizational buyers. The idea is to use the leverage of buying consortiums to negotiate lower prices from suppliers or to reduce handling costs. Since the Internet provides an ideal collaborative infrastructure to support this kind of organizational buying practice, many companies are starting to join various purchasing consortiums.

Online auctions and purchasing consortiums increase the distance between buyers and sellers by: 1) placing an intermediary between buyers and seller, and 2) making it easier for buyers to switch suppliers, thus lowering switching costs. Moreover, auctions and consortiums raise several issues with regard to knowledge exchange and coordination, which we detail below.

- *Effective use of electronically available information* The information could come from both intra-organizational data sources as well as inter-organizational information repository and Web-based Info-sphere in general. From the viewpoint of modeling, this rich set of available information calls for models that can evaluate a large collection of supply chain configuration and sourcing alternatives and provide real-time solutions (Zeng and Sycara 1998).
- *Support multi-issue decision making* Practitioners and researchers have observed that the nature of competition in electronic commerce does not resemble undifferentiated Bertrand competition. This suggests that price alone is not the only decision criterion. Other decision criteria need to be considered. Buyers and suppliers must offer information that highlights differentiating factors. The increasing use of personal shopping agents, such as `MySimon.com`, has raised this issue in B2C commerce.

  Retailers have argued that shopping agents show only price, leading to fiercer price competition without the opportunity to highlight other factors that might cause a consumer to rank one retailer over another (Andrews 2000). The same issue exists for B2B commerce. We have not yet seen work that describes how suppliers would publish information on value-added features, and how those features could be discovered by agents. From the managerial point of view, needs for multi-issue decision-making models are twofold: From the demand side, sophisticated customers including organizational buyers demand the customized product or service; from the supply side, manufacturers or service providers may consider to offer a wide range of differentiated products or services to target highly segmented markets and to gain market share.

The Bullwhip Effect and Information Sharing

Executives at Procter and Gamble (P&G) were mystified as they reviewed orders for their popular Pampers diapers throughout the supply chain. Orders from retailers to wholesalers fluctuated substantially, but the orders that wholesalers placed with P&G varied even more wildly. Presumably, babies' demand for Pampers had held relatively steady. Why then were there such wild swings in demand?

After further investigation, the P&G executives concluded that a lack of knowledge transfer was creating a bullwhip effect in the orders seen throughout the supply chain. (Lee, Padmanabhan et al. 1997) Retailers, seeing a rise in demand (perhaps due to a movie spot featuring P&G diapers, or a price increase in a competing diaper brand), would order enough diapers to cover the increased demand plus a margin for future unexpected increases. Wholesalers, would then see the suddenly increased orders from retailers, and would follow similar logic — order enough from the manufacturer to cover the increase, and add a little more for the unexpected. As orders progressed up the supply chain, they became ever-more distorted. Procter and Gamble's orders to its own suppliers reflected this effect as well.

Many factors contribute to the bullwhip effect, but there is a single solution: better knowledge transfer. In most supply chains, only transactional information is passed from consumer to producer. Distributors know only how much was ordered by retailers, but not why retailers choose to order a given quantity. As intelligent agents begin to proxy for people in supply chain transactions, they must exchange information regarding the reasons for order placement.

Coordination constraints

Supply chains are often complex graphs that require coordination among multiple suppliers to produce complex products. For example, automobiles require parts from hundreds of suppliers, and the parts must arrive together to avoid delays in manufacturing. Agents that buy the needed parts must either purchase centralize the purchase of such parts themselves, or cooperate with agents purchasing the other parts.

As mentioned above, sophisticated catalogs must be built to ensure that compatible parts can be identified and ordered together. On a larger scale, items that are used together must be so annotated. In essence, catalogs must include associate bill-of-materials information for their myriad parts — enumerating "is a part of" and "has parts" relationships. This would allow agents to learn which parts are needed for an assembly, and ensure that purchase of the needed items can be coordinated.

Encoding knowledge

The representation needed to capture coordination constraints and exchange demand information along a supply chain goes beyond the work that has been in the markup community that has developed XML. Significant research is called for to code, manipulate, and apply knowledge regarding emerging online economic exchanges and new supply chain coordination patterns. The artificial intelligence community has a long history of work in knowledge representation and that expertise is needed to facilitate electronic commerce, if it is to fulfill its promise of reshaping the conduct of business. Beyond transactional knowledge, little work has been done to represent that knowledge described above.

Conclusions

The popularity of XML represents an important opportunity for those working in knowledge-based systems for electronic commerce. The flexibility of XML as an encoding means that lessons learned from knowledge representation in other areas can be incorporated into what is likely to be the lingua franca for electronic commerce for many years to come. The same language used by businesses to communicate with one another could be the research platform for interesting research questions regarding the knowledge exchange needed in supply chain management. The standards are being formed now, however, and if we can agree on what knowledge is needed, and offer suggestions on how to encode it, we have an important opportunity to influence the process.

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