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Transportation Research Part E 39 (2003) 95–121

TRANSPORTATION RESEARCH PART E

www.elsevier.com/locate/tre

Adopting new technologies for supply chain management

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Abstract

Integration of supply chain activities and the technologies to accomplish it have become competitive necessities in most industries. Accordingly, the trend toward greater use of supply chain technologies is on a clear path forward. As one manager has noted: ''With almost daily technology advancement globally in every facet of the business, organizations need to synchronize by adopting and implementing new electronic commerce and supply chain technology in order to protect market share, not to mention improve market penetration''. This paper develops a model of the key factors influencing the adoption of supply chain technology. The following set of variables were hypothesized to have a significant impact upon the pace of technology adoption: firm size, organizational structure, integration of supply chain strategy with overall corporate strategy, past financial performance, supply chain partner pressure, transaction climate and environmental uncertainty. The model provides a better understanding of the supply chain technology diffusion process. The paper also includes a survey, which has been developed to test the model.

Keywords: Supply chain management; Technologies

1. Introduction

Business organizations today face a more complex and competitive environment than ever before (Ellram, 1991; Srinivasan et al., 1994; Porter and Stern, 2001). As trade barriers crumble and less developed countries enter the competitive marketplace, firms now confront a greater

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1366-5545/03/$ - see front matter
PII: S1366-5545(02)00041-8

number of competitors able to introduce new products and services faster and cheaper than ever before (Garten, 1998). The ever-expanding capabilities of information technology with the concomitant reduction in investment costs allow capital and information to flow almost instantly throughout many parts of the world. Furthermore, as consumers have become more discriminating and demanding (Ellinger et al., 1997), product life cycles have been shortened, forcing firms to contract time to commercialization (Lovelace et al., 2001) and provide higher levels of customer service and customized products. Consequently, most industries and firms have entered into a "hyper-competitive" marketplace characterized by an increase in competition, uncertainty, and complexity (D'Aveni, 1994; D'Aveni, 1999; Merrifield, 2000).

In this business environment, innovation of organizational processes and products is a major business challenge (Tornatzky and Fleischer, 1990) and critical for firm success (D'Aveni, 1994; Veliyath and Fitzgerald, 2000). Innovation has been defined as "... adoption of an internally generated or purchased device, system, policy, program, process, product, or service that is new to the adopting organization" (Damanpour, 1991, p. 556). Merrifield (2000, p. 42) argues, "The most viable strategy for both generating and sustaining a competitive advantage has become one of both continuous innovation and corporate renewal". In the past, business organizations focused on reducing costs and improving quality to gain a competitive advantage. Today, however, "companies must be able to innovate at the global frontier... and create and commercialize a stream of new products and processes that shift the technology frontier, progressing as fast as their rivals catch up" (Porter and Stern, 2001, p. 28).

One area of innovation that has been the focus of significant discussion is information technology adoption. US executives allocate 40% of new capital equipment investment to technology (Hitt and Brynjolfsson, 1996). Innovative information technologies have the capacity to impact organizational structure, firm strategy, communication exchange, operational procedures, buyer–supplier relationships, and bargaining power (Bowersox and Daugherty, 1995; Lewis and Talalayevsky, 1997; Williams et al., 1997; Clemons and Row, 1991). Information technology may also increase organizational productivity, flexibility, and competitiveness (Cash and Konsynski, 1985) and stimulate the development of interorganizational networks (Daugherty et al., 1995). Information systems have become so pervasive that they are now considered to be a requirement for doing business in today's competitive marketplace (Clemons and McFarlan, 1986; Dawe, 1994; Rogers, 1990; Rogers et al., 1992).

Supply chain management is recognized as an important area for information technology innovation and investment (Bowersox and Daugherty, 1995). Supply chain management has been defined by The Global Supply Chain Forum as "... the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders" (Lambert et al., 1998, p. 1). With implementation of supply chain management, the narrow focus of managers and the adversarial relationships between logistics providers, suppliers, and customers are replaced with strategic alliances and long-term cooperative relationships and viewing suppliers and customers as partners instead of adversaries (Tan et al., 1998) with the objective of "maximiz(ing) competitiveness and profitability for the company as well as the whole supply chain network including the end-customer" (Lambert et al., 1998, p. 4). Better information exchange between supply chain partners, perhaps the key advantage of an integrated supply chain (Lee et al., 1997; Levary, 2000), provides more up-to-date information and allows for more accurate inventory responses to changes in demand and thus

more appropriate inventory levels throughout the supply chain (Levary, 2000; Stank et al., 1999). Levary (2000, pp. 25–26) suggests the benefits of supply chain integration include

1. minimizing the bullwhip effect,
2. maximizing the efficiency of conducting activities along the supply chain,
3. minimizing inventories along the supply chain,
4. minimizing cycle times along the supply chain,
5. achieving an acceptable level of quality along the supply chain.

Though more than 90% of North American manufacturers believe supply chain management is very important or critical to their company's success, only 2% rate their management of supply chain activities as "world class" (Thomas, 1999). Perhaps the main reason for this extreme disparity is the complexity of integrating logistics operations between firms as well as within firm boundaries while bringing to bear appropriate information technologies. Successful supply chain management requires effective management of strategic alliances (Monczka et al., 1998; Whipple and Frankel, 2000) as well as extensive data management capabilities and advanced interorganizational information systems to enable greater information exchange (Gustin et al., 1995; La Londe and Masters, 1994; Bowersox and Calantone, 1998; Stank et al., 1999). Innovative information technologies provide the capabilities to transfer more accurate and up-to-date information resulting in better visibility of demand and inventory throughout the supply chain. Some authors suggest that information technology is the single, most important factor to logistics and supply chain management improvement (Dawe, 1994), while 34% of logistics executives rank technology as the most important factor in improving logistics capabilities (Bradley et al., 1999).

In summary, the importance of both information technology and supply chain management to organizational performance and competitiveness is widely recognized. However, the small percentage of firms at "world class" supply chain levels suggests that substantial barriers exist regarding integration of logistics activities and adoption of supply chain technology. The goal of this paper then is to develop a model of the environmental and organizational antecedents of supply chain technology adoption.

2. Antecedents of supply chain technology adoption

A variety of factors may affect an organization's decision to adopt and implement a particular technology. Kwon and Zmud (1987) reviewed prior innovation research and classified variables that potentially influence technology adoption into five broad categories: individual, task-related, innovation-related, organizational, and environmental characteristics. The authors suggest these factors may be important to differing degrees depending on the context or technology. For example, individual factors such as age or education are often more relevant with individual adoption of technology rather than organizational innovation where decisions are often made by committees. Additionally, task and innovation characteristics of a technology may be isolated and examined when individual technologies are being studied. In this paper, because we are interested in the organizational adoption of a considerable number of supply chain technologies, we will limit our focus to key organizational and environmental factors.

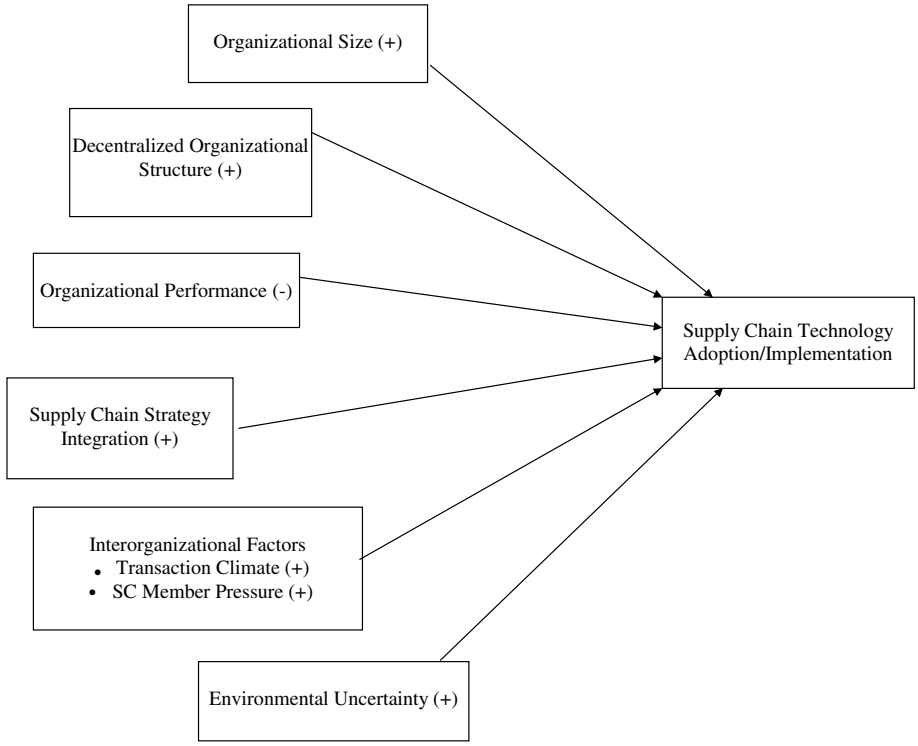

Fig. 1. Antecedents of supply chain technology adoption.

Another important consideration to this study is the concept of "adoption". A number of authors have defined "adoption" in a variety of ways and have distinguished between adoption, diffusion, initiation, development, implementation and use. While recognizing these legitimate distinctions, for this model we have chosen to use "adoption" in the broadest sense so that it encompasses "the generation, development, and implementation ..." of the technologies (Damanpour, 1991, p. 556). Furthermore, it is our belief that supply chain managers probably do not distinguish between stages of the adoption process and attempting to clearly tease out these distinctions in a survey to test the model would result in an unwieldy and complex set of survey questions that may confuse respondents.

The model in Fig. 1 presents the organizational and environmental variables hypothesized in this study and the nature of their expected relationship with supply chain technology adoption.

2.1. Organizational factors

A variety of organizational factors have been suggested to impact innovation and technology adoption. Size has been one of the most researched variables, which has led to some disagreement of the direction of the relationship. It is theorized that larger organizations have the financial and technology resources to invest in new technologies and absorb the associated risk (Grover and Goslar, 1993). Furthermore, large organizations may have slack capacity to devote to adopting and implementing new technologies as well as to enjoy the benefits of economies of scale from

adoption. Alternatively, others have suggested that smaller organizations are more likely to be innovative because of the flexibility afforded by smaller size and fewer levels of bureaucracy. Previous research, regardless of the measures used to evaluate size and adoption, has consistently indicated organizational size positively correlates with technology adoption (Dewar and Dutton, 1986; Rogers, 1990; Dawe, 1994; Germain, 1993; Germain et al., 1994). Studies examining individual technologies such as EDI, (Williams, 1994; Daugherty et al., 1995; McGowan and Madey, 1998; Premkumar et al., 1997) also found firm size to be an important factor to the adoption decision. Cragg and King (1993) showed that lack of technical knowledge and resources inhibit technology adoption in small firms. Thus, larger organizations are expected to possess the financial resources and risk capacity necessary for new technology investments and will be associated with greater levels of supply chain technology.

H1 The larger the organization, the more likely it will be to adopt supply chain technology.

Organizational structure has also been considered an important factor to technology adoption (Williams, 1994). Previous research has provided ambiguous results with some studies indicating positive effects of a centralized organizational structure (i.e., concentration of decision-making) on technology adoption while others have shown negative relationships (Gatignon and Robertson, 1989). Pierce and Delbecq (1977) suggest centralization of decision-making may reduce conflict between organizational units and foster innovation adoption. In support of this proposition, Ettlie et al. (1984) found that organizations with a centralized structure were more likely to adopt new technologies.

However, an alternative approach reasons that organizations that have adopted a flatter, more decentralized structure would be expected to have adopted more innovative and cutting edge technology in order to enhance communication and coordination within the organization as well as with supply chain members (Bowersox and Daugherty, 1995). Grover and Goslar (1993, p. 142) suggest that the "decreased autonomy and bounded perspective" of a centralized organizational structure explain the negative relationship often found between centralization and adoption. Germain et al. (1994) found decentralization (of technology decisions) does not significantly relate to overall technology adoption but may influence decisions regarding integrative technologies. Williams et al. (1998) indicate that a centralized organizational structure is negatively related, although not significantly, to certain dimensions of EDI participation. Grover and Goslar (1993) found decentralization of decision-making was significantly related to usage of telecommunications technologies. Thus, it is expected that a decentralized organizational structure will be associated with the adoption of new technologies.

H2 The more decentralized the organization, the more likely it will be to adopt supply chain technology.

Past performance is another organizational factor that has been suggested to influence a firm's flexibility (or lack of) and willingness to adjust strategies and competitive practices, to include innovative product or process adoption, in response to changes in the environment (Clemons et al., 1996). Clemons and Hann (1999, p. 9 and 19) note that "success all too often sows the seeds

for future failure'' because managers of many successful organizations ''find it exceedingly difficult to change their business strategy radically in response to impending changes in their competitive environment.'' Previous research suggests successful past performance tends to lead to resistance to strategic change (Zajac and Kraatz, 1993; Miller and Chen, 1994; Audia et al., 2000). Lant et al. (1992) found firms that had performed better than average in previous years were less likely to initiate a strategic change within two years of the superior performance. Miller and Chen (1994) reached similar conclusions after studying the airline industry. They found a company's previous performance was negatively associated with the number of competitive practice changes. In another study, Feitler et al. (1998) found greater strategic change in poorer performing firms than in better performing firms. Finally, Audia et al. (2000) found that firms in the airline and trucking industries were more likely to continue with a strategy once success had been achieved.

Explanations for this strategic persistence are many. First, organizations are likely to repeat actions that have been successful in the past (Cyert and March, 1963; Prahalad and Bettis, 1986). Successful organizations may have established a corporate culture or a set of beliefs and behaviors that they use to explain firm success. This culture or pattern of decision-making may inhibit a firm's flexibility to respond to environmental change such as new technologies (Clemons and Hann, 1999). Moreover, successful firms may have invested heavily in old technologies or information systems that have resulted in large sunk costs, which may become ''stranded assets'' with little usefulness if new technologies were adopted (Clemons and Hann, 1999). Finally, managers of successful firms may resist change if it may affect their value or position in the firm. In light of theory and previous findings, successful organizations may not have the impetus to adopt new supply chain technologies in order to reorganize operations and modify business relationships with suppliers and customers.

> **H3** Less successful organizations in the past will be more likely to adopt supply chain technology.

An enduring theme of the strategy literature is that strategy precedes and directs structure (Chandler, 1962; Egelhoff, 1988). Some authors argue that in order to succeed, organizations must align organizational structure and management processes to changes in the external environment and firm strategy (Galunic and Eisenhardt, 1994). The alignment of an integrated supply chain/logistics strategy with firm strategy is also becoming vital for firm success (Bowersox and Daugherty, 1995; Olavarrieta and Ellinger, 1997; Gilmour, 1999; Stock et al., 1999). Cavinato (1999) suggests this integration of supply chain strategy with the overall firm strategy has become crucial for achieving and maintaining firm success. As firms realize the efficiencies gained from improved logistics, management will begin to focus on logistics strategy and incorporate it into overall firm strategy (Bowersox and Daugherty, 1995). The realization of increased competitiveness from supply chain integration and the resulting inclusion into overall firm strategy should lead to adoption of sophisticated information technology (Bowersox and Daugherty, 1995; La Londe and Masters, 1994), strategic alliances among members of the supply chain and eventually to technological integration. Rogers (1990) found the presence of a formal logistics mission statement and strategic plan positively related to technology adoption. Thus, firms that have integrated supply chain management with firm strategy will be more likely to have assumed supply chain management practices and to have adopted innovative information systems.

H4 Organizations that have integrated supply chain management strategy with overall corporate strategy will be more likely to adopt supply chain technology.

2.2. Environmental factors

Numerous innovation studies have examined a variety of environmental factors, including economic conditions, global competitiveness, transaction climate, industry concentration, and environmental uncertainty, on the decision to adopt new technologies (Grover, 1993; Premkumar et al., 1997; Gatignon and Robertson, 1989). In this paper, we will focus our attention on two key variables: interorganizational factors and environmental uncertainty.

An interorganizational factor that may influence adoption of supply chain technology is coercive pressure from supply chain partners (Premkumar et al., 1997) or from the industry (Norris, 1988). Much of the research examining the impact of trading partners on technology adoption has focused on EDI adoption (Premkumar and Ramamurthy, 1995; Truman, 2000). Typically, during the implementation of EDI, one firm initiates adoption and pressures or entices other firms in the supply chain to adopt in order to standardize data formats and improve coordination and communication within and between organizations of the supply chain (Riggins and Mukhopadhyay, 1994; Premkumar and Ramamurthy, 1995; Iacovou et al., 1995). For example, it has been well documented that large retail organizations such as K-mart and Wal-Mart have pressured suppliers to adopt EDI using threats of loss of business (Premkumar et al., 1997). Industry associations in the auto and grocery industries have also taken the lead in establishing EDI standards and then coerced organizations to adopt EDI in an effort to enhance communications and improve productivity (Norris, 1988).

Research has indicated the initiating firm often obtains more benefits than the follower (Riggins and Mukhopadhyay, 1994; Reekers and Smithson, 1994). In spite of this, many firms are forced to adopt or risk losing business. Iacovou et al. (1995) report that more than 70% of respondents to a series of recent surveys claimed that customer pressure influenced the firm's decision to adopt EDI. Bouchard (1993, p. 366) concludes an organization's decision to adopt EDI "is primarily based on what [its] business partners are doing and not on the characteristics of EDI". For similar reasons, other supply chain technologies that standardize data formats and enhance information sharing may be adopted by organizations because of the influence of partners in the chain in order to streamline transactions and improve inter-firm communication.

H5 Organizations subjected to greater pressure from supply chain partners will be more likely to adopt supply chain technology.

Social exchange theory asserts that relationships and social factors between organizations influence firm activities and transactions in addition to market factors (Premkumar and Ramamurthy, 1995). The "transaction climate" represents these relationships and social elements between organizations. A favorable transaction climate between partners has been found to enhance information exchange, improve interorganizational coordination and cooperation, and result in better decision-making (Williamson, 1975; Dwyer, 1980; Reve and Stern, 1986). The level of trust and faith between firms are key elements of the transaction climate and are expected to be important factors in the adoption of supply chain technology. A high level of trust and

commitment between firms adopting supply chain technology may be required because the automation of transactions eliminates manual oversight systems and the paper documentation that exist to ensure accurate and reliable transactions (Premkumar and Ramamurthy, 1995). Walton and Miller (1995) suggest previous history of the business relationship, an indicator of the trust and respect between partners and thus transaction climate, impacts EDI adoption. Enduring and trusting relationships between organizations have been shown to be a key motive in electronic integration (Konsynski and McFarlan, 1990). Furthermore, Nimdumolu (1995), studying the insurance industry, found that investments in interorganizational information systems are associated with a positive transaction climate. Case studies involving American Hospital Supply (Vitale, 1986) and McKesson Drug Company (Clemons and Row, 1988) illustrate the positive impact of favorable relationships with customers on interorganizational information system adoption. Thus, relationships between organizations characterized by trust and commitment are expected to be positively related to supply chain technology adoption.

H6 Organizations with a more favorable transaction climate with supply chain members will be more likely to adopt supply chain technology.

Another recurring environmental factor included in many studies has been environmental uncertainty. Droge and Germain (1998) posit environmental uncertainty may be characterized by unpredictable changes in customer demand, unreliability of supplier quantities and quality, volatile price fluctuations, unpredictable competitor actions, rapid shifts in production processes, and/or brief product life cycles. Regardless of the source, "... uncertainty exists because organizations do not have perfect information to make decisions" (Walton and Miller, 1995, p. 121).

In order to overcome imperfect information and uncertainty, organizations may institute a variety of mechanisms to "promote, advance, and strengthen coordination" between organizational subunits and partners (Truman, 2000, p. 213) or innovate in order to survive and flourish (Grover, 1993). Robertson and Gatignon (1986, p. 37) suggest demand uncertainty "heightens perceived competitive vulnerability and makes a firm more susceptible to innovation in its quest for competitive advantage." Ahmad and Schroeder (2001) argue an uncertain environment requires more frequent exchange of information between business partners so that activities can be prioritized as changes occur and delivery expectations met. Furthermore, uncertainty in today's hyper-competitive marketplace compresses the decision-making time frame and thus increases the need for faster, more accurate information. Advanced information technologies integrated within and between members of the supply chain allow firms to more quickly and accurately share demand data, sales projections and production schedules which provides greater real time inventory and demand visibility (Kwan, 1999). Conversely, Grover and Goslar (1993) suggest that organizations in relatively stable operating environments do not need innovative information technologies to cope with the established and steady information processing requirements.

Previous research has shown that higher levels of uncertainty relate positively with a greater need for changing technology and faster adoption rates (Ettlie, 1983). Demand uncertainty has also been found to be positively related to technology adoption (Robertson and Gatignon, 1986) as well as EDI adoption (Williams, 1994). Thus, firms facing above average environmental uncertainty will have a greater incentive to adopt supply chain technology to improve information exchange and manage uncertainty between organizations and their task environment.

H7 Organizations facing higher environmental uncertainty will be more likely to adopt supply chain technology.

3. A methodology to test the model

The primary purpose of this paper is to develop and present a model of the determinants for supply chain technology adoption. However, we would also like to provide a blueprint on how the model could be tested. Accordingly, a survey instrument was developed with input from the Revere Group, a consulting firm specializing in supply chain management. The survey consisted of a series of five-point Likert scaled questions typically anchored with "Not at all" and "To a great extent" as well as several open-ended questions (see Appendix A for complete survey). Unless questions were reverse coded, higher values indicate a greater level of the construct under investigation.

The first step was to develop a list of supply chain technologies to be included in the survey. The list includes a variety of technologies ranging from mature and widely used technologies such as bar coding technology to relatively new software applications such as supply chain planning systems and supply chain event management systems. The one theme that runs through all of these technologies, however, is that all are primarily concerned with managing and controlling supply chain related data and activities and information exchange within and between organizations.

The survey included several potential questions regarding each independent and dependent variable of the model. Thus, the survey allows a measure to be constructed for each construct represented in the hypotheses. A survey question on number of employees could be used to measure organizational size. Following Williams et al. (1998), organizational structure could be measured by assessing the degree of decentralized decision-making. ROA growth over the previous three years could be used to assess organizational performance. Following Kohn and McGinnis (1997), the degree of supply chain strategy incorporation into overall business strategy could be used to measure supply chain strategy integration. Averaging responses across a number of related questions could derive two of the independent variables (transaction climate and supply chain member pressure). The "transaction climate" variable could be calculated as a composite value by averaging the extent of trust and commitment between the respondent's firm and its suppliers, customers, carriers, and third party logistics providers. The "supply chain member pressure" variable could be computed by averaging the degree to which customers, suppliers, carriers, and third party logistics providers had encouraged the respondent's firm to adopt supply chain technology.

To assess the degree to which firms have adopted supply chain technology, a technology adoption score can be computed for each firm by averaging the responses across 13 functional technologies and two integrative technologies. The 13 technologies were: Product Data Management, Customer Relationship Management, Automated Quality Control Systems, Computer Aided Design Systems, Warehouse Management Systems, Manufacturing Execution Systems, Transportation Management Systems, Radio Frequency Systems, Geo-coded Tracking Systems, Bar Coding Technology, Electronic Commerce Technologies, Supply Chain Event Management, and Demand Forecasting Management. The two integrative technologies were Enterprise Resource Planning (ERP) and Supply Chain Planning Systems (SCP).

The survey was constructed by using scale items from previously validated surveys and through extensive testing with academicians, business consultants and supply chain managers. The initial survey was developed and presented to Revere Group consultants. Items were evaluated for clarity, completeness, relevance and flow. After modifications, the survey was pre-tested on a group of about 50 Revere Clients. The respondents provided valuable feedback and qualitative comments on the topic that led us to further refine and improve the survey.

4. Conclusions and implications

Integration of supply chain activities and the technologies to accomplish it have become competitive necessities in most industries. For example, one respondent to the pre-test survey wrote, "Our senior management have now come to realize that supply chain management will enhance our ability to be successful." Another commented, "With almost daily technology advancement globally in ever facet of the business, organizations need to synchronize by adopting and implementing new electronic commerce and supply chain technology in order to protect market share, not to mention improve market penetration".

Thus, we developed a model on the antecedents of supply chain technology adoption. We theorize that firms with greater numbers of employees adopt more technologies perhaps to improve information management and activity coordination. Large organizations may have greater volumes of transactions, more geographically dispersed operations, more supply chain partners, and/or more information to manage and are thus would be more likely to adopt information technology systems to improve operational efficiency and very often lower cost.

Regarding decentralization, while this variable has been a point of contention in many studies as researchers have found both positive and negative relationships between decentralization and technology adoption, we follow Grover and Goslar (1993) who suggested that a more decentralized organizational structure leads to greater boundary scanning, greater awareness of business opportunities, and thus greater levels of technology adoption. We believe that firms that allow decision-making to be located throughout the organization may engage in more environmental scanning, which leads to a greater awareness and appreciation of potential innovations.

Previous research (Feitler et al., 1998; Audia et al., 2000) suggests that better performing firms have a tendency of strategic persistence and adopt fewer strategic changes than poorer performing firms. Considering information management systems have become essential components of firm strategy, it is, therefore, hypothesized that poorer performing firms would be more likely to adopt new technology.

The final organizational variable included in the model is supply chain strategy integration. As Bowersox and Daugherty (1995) suggested, as firms realize the advantages gained from efficient and effective supply chain operations, managers begin to incorporate supply chain strategy into their overall corporate strategy which then leads to greater technology adoption and electronic integration. Organizations that understand the competitive benefits of efficient and effective supply chain operations incorporate supply chain strategy into organizational strategy. The

elevation in importance of the supply chain in an organization then leads to the application of information technology to these operations.

In addition to organizational variables, three environmental variables are also included in the model. Those three variables are supply chain partner pressure, transaction climate with supply chain partners and environmental uncertainty. The first environmental variable examined was supply chain partner pressure. The hypothesis suggests supply chain partners successfully pressure organizations to adopt new technologies. As previously reported (Bouchard, 1993; Truman, 2000) supply chain partners have a substantial impact on a firm's decision to adopt supply chain technologies. As organizations integrate operations and technology becomes more prevalent, firms coerce members of their supply chain to adopt new technologies to satisfy the need for fast and accurate information. The pre-test written comments on the survey provide support for the notion that customers exert greater pressure than other partners in the supply chain. A typical comment was, "Most customers demand this technology or they will go someplace else".

Transaction climate represents the trust and commitment between the responding firm and its supply chain partners. Our model's hypothesis is that a positive transaction climate would lead to greater technology adoption, as constructive relationships with supply chain partners would encourage firms to invest in equipment and technology. Finally, the model includes an hypothesis that greater environmental uncertainty would lead to greater technology adoption as uncertainty creates the need for more accurate information in order to respond as environmental conditions necessitate (Ahmad and Schroeder, 2001). Organizations facing greater uncertainty employ supply chain technology to improve information management and exchange in order to be able to better respond to changing environmental conditions. As Kwan (1999) suggested, information technologies allow firms to more quickly and accurately share demand data, sales projections and production schedules which provides adopting organizations greater flexibility and responsiveness in the face of a constantly changing environment.

The model will hopefully provide important insight into the key factors leading to adoption of supply chain technology and could have important managerial implications. Managers may use this model to gain a better understanding of the different factors impacting technology adoption. Extensive investigation of many recently developed supply chain technologies has not yet taken place. As such, the model and survey to test it provides an initial starting point from which to develop more detailed analyses of many aspects of supply chain technology adoption.

Appendix A. Supply chain information technology survey

Part A: organizational characteristics and general company information

We believe that "best practice" information regarding supply chain technology would be very useful to supply chain managers and executives of companies. As such, we have compiled the following survey to assess which supply chain technology systems your company has adopted and implemented, as well as how the technology has been integrated within your organization. We will accumulate the responses to this survey and then will provide you with summary results, including

information about best practices. The names of the respondents and their respective companies will be kept confidential and will not be shared with any third party organizations. A Glossary of key terms is included at the end of the survey.

Company's name _____

Main line of business _____

Industry and SIC code (if available) _____

Your name, phone number and email address _____

Your title _____

Your address _____

Please indicate the total number of employees in your company (all locations) by checking the appropriate line:

1_____100 or fewer
2_____101–500
3_____501–1000
4_____1001–5000
5_____5001 or more

Please indicate the total revenues for your company (all locations) in 2000 by checking the appropriate line:

1_____$100 million or less
2_____MORE than $100 million, up to $500 million
3_____MORE than $500 million, up to $1 billion
4_____MORE than $1 billion, up to $2 billion
5_____MORE than $2 billion

Please indicate the geographic scope of your company's operations? (check one)

1_____Regional
2_____National
3_____Worldwide

Please indicate the extent to which you agree with the survey statements by circling your responses using the following scale.

Not at all	Very little	Somewhat	A significant amount	To a great extend	No functional need for system
1	2	3	4	5	NA

1. Please indicate the extent to which you agree with the following statements.

	Not at all			To a great extent	
(a) Company decision-making is highly concentrated at top management levels	1	2	3	4	5
(b) My company has a clearly stated and comprehensive supply chain management strategy	1	2	3	4	5
(c) My firm extensively utilizes cross-functional work teams for managing day-to-day operations	1	2	3	4	5
(d) My firm has reduced formal organizational structure to more fully integrate operations	1	2	3	4	5
(e) In my company supply chain management planning is well coordinated with the overall strategic planning process	1	2	3	4	5
(f) My company's supply chain management strategy is clearly incorporated into the organization's overall business strategy	1	2	3	4	5

2. What is the company's annual budget for operating/maintaining its supply chain technology?

_____

3. How many information technology employees are dedicated to supply chain technology?

_____

4. Please indicate the level of your firm's performance in the following measures compared to major industry competitors.

	Well below average		Average	Well above average	
(a) Market share	1	2	3	4	5
(b) Return on total assets	1	2	3	4	5
(c) Average annual market share growth (over the past three years)	1	2	3	4	5
(d) Average annual sales growth (over the past three years)	1	2	3	4	5
(e) Average annual growth in return on total assets (over the past three years)	1	2	3	4	5
(f) Average production costs	1	2	3	4	5
(g) Overall customer service levels	1	2	3	4	5
(h) Overall product quality	1	2	3	4	5
(i) Overall competitive position	1	2	3	4	5
(j) Overall cost to serve	1	2	3	4	5

Part B: environmental factors

5. Please indicate the extent to which you agree with the following statements.

	Not at all			To a great extent		
(a) Compared to other industries, the competitive environment for my company's products and services is extremely intense	1	2	3	4	5	NA
(b) My firm's supply chain is extremely complex (number of customers/sellers, geographical dispersion, delivery timing requirements, etc.)	1	2	3	4	5	NA
(c) The demand for my company's goods and/services is stable	1	2	3	4	5	NA
(d) My company is facing much change and uncertainty	1	2	3	4	5	NA
(e) The industry in which my company participates is facing much change and uncertainty	1	2	3	4	5	NA
(f) My company's customers are generally quick to adopt new technology	1	2	3	4	5	NA
(g) My company's suppliers are generally quick to adopt new technology	1	2	3	4	5	NA
(h) My company's carriers are generally quick to adopt new technology	1	2	3	4	5	NA
(i) My company's 3rd Party Logistics Providers are generally quick to adopt new technology	1	2	3	4	5	NA
(j) The number of suppliers of my company has remained stable over the past 3 years	1	2	3	4	5	NA
(k) The percentage of certified suppliers for my company has remained consistent over the past 3 years	1	2	3	4	5	NA
(l) The supply of components from my firm's suppliers is stable	1	2	3	4	5	NA
(m) The quality of components from my firm's suppliers is consistent	1	2	3	4	5	NA

6. Please comment on environmental factors that may have led your company to adopt and implement any new electronic commerce or supply chain technology.

_____

_____

_____

_____

Part C: supply chain relationships

7. Please indicate the following:

(a) Total number of customers	< 100	100–500	501–1000	>1000
(b) Number of *strategic* customers				

_____

(c) Total number of suppliers	< 100	100–500	501–1000	>1000
(d) Number of *strategic* suppliers _____				
(e) Total number of carriers	<10	10–50	51–100	>100
(f) Number of *strategic* carriers _____				
(g) Total number of third party logistics providers _____				
(h) Number of strategic third party logistics providers _____				

8. What is the percentage of customers with whom your firm conducts electronic commerce? _____%

9. What is the percentage of suppliers with whom your firm conducts electronic commerce? _____%

10. What percentage of all documents (including invoices, manifests, purchase orders, etc.) is transmitted to customers/suppliers/carriers via technology versus manual systems? _____%

11. Please indicate the extent to which you agree with the following statements.

Customers

	Not at all			To a great extent		
(a) There is a strong commitment between my company and its customers	1	2	3	4	5	NA
(b) My company's customers can be trusted to do what is right	1	2	3	4	5	NA
(c) My company is generally satisfied with the level of cooperation between our firm and its customers	1	2	3	4	5	NA
(d) My company is generally satisfied with the exchange of information between our firm and its customers	1	2	3	4	5	NA
(e) My company's implementation of supply chain technology has encouraged customers to implement the technology	1	2	3	4	5	NA
(f) Implementation of supply chain technology by my company's customers has encouraged my company to implement the technology	1	2	3	4	5	NA
(g) My company switches customers more often than before	1	2	3	4	5	NA

(h) My company's relationships with customers tend to last longer than before	1	2	3	4	5	NA
Suppliers						
(i) There is a strong commitment between my company and its suppliers	1	2	3	4	5	NA
(j) My company's suppliers can be trusted to do what is right	1	2	3	4	5	NA
(k) My company is generally satisfied with the level of cooperation between our firm and its suppliers	1	2	3	4	5	NA
(l) My company is generally satisfied with the exchange of information between our firm and its suppliers	1	2	3	4	5	NA
(m) My company's implementation of supply chain technology has encouraged suppliers to implement the technology	1	2	3	4	5	NA
(n) Implementation of supply chain technology by my company's suppliers has encouraged my company to implement the technology	1	2	3	4	5	NA
(o) My company switches suppliers more often than before	1	2	3	4	5	NA
(p) My company's relationships with suppliers tend to last longer than before	1	2	3	4	5	NA
Carriers						
(q) There is a strong commitment between my company and its carriers	1	2	3	4	5	NA
(r) My company's carriers can be trusted to do what is right	1	2	3	4	5	NA
(s) My company is generally satisfied with the level of cooperation between our firm and its carriers	1	2	3	4	5	NA
(t) My company is generally satisfied with the exchange of information between our firm and its carriers	1	2	3	4	5	NA
(u) Implementation of supply chain technology by my company's carriers has encouraged my company to implement the technology	1	2	3	4	5	NA

(v) My company's implementation of supply chain technology has encouraged its carriers to implement the technology	1	2	3	4	5	NA
(w) My company switches carriers more often than before	1	2	3	4	5	NA
(x) My company's relationships with carriers tend to last longer than before	1	2	3	4	5	NA
3rd Party Logistics Providers (3PLP)						
(y) There is a strong commitment between my company and its 3PLP	1	2	3	4	5	NA
(z) My company's 3PLP can be trusted to do what is right	1	2	3	4	5	NA
(aa) My company is generally satisfied with the level of cooperation between our firm and its 3PLP	1	2	3	4	5	NA
(bb) My company is generally satisfied with the exchange of information between our firm and its 3PLP	1	2	3	4	5	NA
(cc) My company's implementation of supply chain technology has encouraged its 3PLP to implement the technology	1	2	3	4	5	NA
(dd) Implementation of supply chain technology by my company's 3PLP has encouraged my company to implement the technology	1	2	3	4	5	NA
(ee) My company switches 3PLP more often than before	1	2	3	4	5	NA
(ff) My company's relationships with 3PLP tend to last longer than before	1	2	3	4	5	NA

Part D: adoption of supply chain information technology

12. The following supply chain technology systems have been adopted and implemented.

	Not at all			To a great extent		
(a) Product Data Management (PDM)	1	2	3	4	5	NA
(b) Customer Relationship Management (CRM)	1	2	3	4	5	NA

(c) Automated Quality Control (AQC) system	1	2	3	4	5	NA
(d) Computer Aided Design (CAD) systems	1	2	3	4	5	NA
(e) Warehouse Management Systems (WMS)	1	2	3	4	5	NA
(f) Manufacturing Execution Systems (MES)	1	2	3	4	5	NA
(g) Transportation Management Systems (TMS)	1	2	3	4	5	NA
(h) Radio Frequency (RF) systems	1	2	3	4	5	NA
(i) Geo-coded Tracking systems	1	2	3	4	5	NA
(j) Bar coding technology	1	2	3	4	5	NA
(k) Electronic Commerce Technologies	1	2	3	4	5	NA
(l) Supply Chain Event Management (SCE)	1	2	3	4	5	NA
(m) Demand Forecasting Management	1	2	3	4	5	NA

13. The following organizational functions have adopted and implemented the appropriate information technology systems from the above list.

	Not at all			To a great extent		
(a) Accounting	1	2	3	4	5	NA
(b) Transportation	1	2	3	4	5	NA
(c) Warehousing	1	2	3	4	5	NA
(d) Manufacturing/operations	1	2	3	4	5	NA
(e) Inventory Management	1	2	3	4	5	NA
(f) Order Management	1	2	3	4	5	NA
(g) Customer Service	1	2	3	4	5	NA
(h) Research & Development	1	2	3	4	5	NA

14. To what extent has supply chain technology been incorporated (replacing manual transactions with automated processes) within the following functions:

	0–20%	21–40%	41–60%	61–80%	81–100%	
(a) Accounting	1	2	3	4	5	NA
(b) Transportation	1	2	3	4	5	NA
(c) Warehousing	1	2	3	4	5	NA

(d) Manufacturing/operations	1	2	3	4	5	NA
(e) Inventory Management	1	2	3	4	5	NA
(f) Order Management	1	2	3	4	5	NA
(g) Customer Service	1	2	3	4	5	NA
(h) Research & Development	1	2	3	4	5	NA

15. The most significant supply chain technology hardware/software was implemented in the following functional areas:

	Not implemented	Within last year	1–3 yr ago	3–5 yr ago	More than 5 yr ago	
(a) Accounting	1	2	3	4	5	NA
(b) Transportation	1	2	3	4	5	NA
(c) Warehousing	1	2	3	4	5	NA
(d) Manufacturing/operations	1	2	3	4	5	NA
(e) Inventory Management	1	2	3	4	5	NA
(f) Order Management	1	2	3	4	5	NA
(g) Customer Service	1	2	3	4	5	NA
(h) Research & Development	1	2	3	4	5	NA

16. The following integrating information systems have been implemented by my company to link functional areas:

	Not at all			To a great extent	
(a) Enterprise Resource Planning (ERP) (Examples include SAP, Oracle, JD Edwards, PeopleSoft)	1	2	3	4	5
(b) Supply Chain Planning System (SCP) (i2Technologies, Manugistics, Logility systems)	1	2	3	4	5

17. The following supply chain information systems were implemented:

	Not implemented	Within 1 yr	1–3 yr ago	3–5 yr ago	More than 5 yr ago
(a) Enterprise Resource Planning (ERP) (Examples include SAP, Oracle, JD Edwards, PeopleSoft)	1	2	3	4	5

(b) Supply Chain Planning System (SCP) (i2Technologies, Manugistics, Logility systems)	1	2	3	4	5

18. To what extent has adoption and implementation of the information technology systems discussed so far resulted in cost savings in each of the following functional areas?

	Not at all			To a great extent	
(a) Accounting	1	2	3	4	5
(b) Transportation	1	2	3	4	5
(c) Warehousing	1	2	3	4	5
(d) Manufacturing/operations	1	2	3	4	5
(e) Inventory Management	1	2	3	4	5
(f) Order Management	1	2	3	4	5
(g) Customer Service	1	2	3	4	5
(h) Research & Development	1	2	3	4	5

19. The following supply chain information technology systems have either been implemented or are planned to be adopted within one year:

	Not at all			To a great extent		
(a) Enterprise Resource Planning (ERP)	1	2	3	4	5	NA
(b) Product Data Management (PDM)	1	2	3	4	5	NA
(c) Customer Relationship Management (CRM)	1	2	3	4	5	NA
(d) Automated Quality Control (AQC) system	1	2	3	4	5	NA
(e) Computer Aided Design (CAD) systems	1	2	3	4	5	NA
(f) Supply Chain Planning (SCP) System	1	2	3	4	5	NA
(g) Warehouse Management Systems (WMS)	1	2	3	4	5	NA
(h) Manufacturing Execution Systems (MES)	1	2	3	4	5	NA
(i) Transportation Management Systems (TMS)	1	2	3	4	5	NA
(j) Radio Frequency (RF) systems	1	2	3	4	5	NA

(k) Geo-coded Tracking systems	1	2	3	4	5	NA
(l) Bar coding technology	1	2	3	4	5	NA
(m) Electronic Commerce Technology	1	2	3	4	5	NA
(n) Supply Chain Event Management (SCE)	1	2	3	4	5	NA
(o) Demand Forecasting Management	1	2	3	4	5	NA

20. Please comment on your experiences with adoption, implementation, and integration of supply chain information technologies and the level of success in comparison with expectations.

Part E: benefits of supply chain information technology systems

Please indicate the extent to which you agree with the following statements.

21. Adoption of supply chain information technology systems has provided the following benefits:

	Not at all			To a great extent		
(a) Reduced the cost of placing orders with suppliers	1	2	3	4	5	NA
(b) Reduced the cost of processing customer orders	1	2	3	4	5	NA
(c) Reduced inventory levels	1	2	3	4	5	NA
(d) Improved inventory turnover	1	2	3	4	5	NA
(e) Improved shipment accuracy	1	2	3	4	5	NA
(f) Reduced lead time from receipt of order to delivery	1	2	3	4	5	NA
(g) Improved customer service	1	2	3	4	5	NA
(h) Increased customer satisfaction	1	2	3	4	5	NA

(i) Provides better understanding of our cost to serve	1	2	3	4	5	NA
(j) Improved product to market speed	1	2	3	4	5	NA
(k) Increased time to product	1	2	3	4	5	NA
(l) Improve on-time delivery from suppliers	1	2	3	4	5	NA
(m) Provides better distinction of types of inventory (raw materials, work-in-process, finished goods, intransit inventory)	1	2	3	4	5	NA
(n) Improved information sharing with suppliers and customers	1	2	3	4	5	NA
(o) Improved coordination of logistics activities with suppliers and customers	1	2	3	4	5	NA
(p) Increased trust in suppliers and customers	1	2	3	4	5	NA
(q) Increased commitment to supply chain relationships	1	2	3	4	5	NA

22. The impact of the implementation of supply chain technology and E-Commerce on the performance of the entire supply chain that my company is a member of has been:

Highly negative	Somewhat negative	Neutral	Somewhat positive	Highly positive
1	2	3	4	5

23. Please discuss the benefits gained from implementation of supply chain technology and E-commerce in comparison to expected benefits.

Glossary

The following are examples of the types of supply chain information technology that may help you interpret questions throughout the survey:

Term	Definition
Enterprise Resource Planning (ERP) systems	ERP offers a centralized system to control information flow through a manufacturing environment. ERP covers functions such as capacity planning, cost and accounting, order entry, production management, inventory, and finance. Examples: SAP, Oracle, JD Edwards, PeopleSoft
Product Data Management (PDM)	PDM tools are used to support collaborative engineering. Features such as revision tracking, document workflow, redlining and other tools help make the design engineering and manufacturing process integration easier. Examples: Windchill, Documentum, SDRC
Customer Relationship Management (CRM)	CRM is an intelligent relationship management tool that can offer Web-based analytic and operation systems to unify all inbound and outbound sales, service, and marketing customer interactions. With a single enterprise-wide view of each customer, CRM solutions analytically help a company better understand and proactively serve customers in real time. Examples: Siebel, Vantive
Automated Quality Control (AQC) systems	AQC Systems help monitor quality assurance process, inspection procedures, specifications, and gauge calibration statistics. Examples: Power Way, Pilgrim Software
Computer Aided Design (CAD) systems	CAD systems are generally stand-alone design tools. CAD tools are used to design everything from parts to tools and fixtures. Examples: AutoCad, PTC
Supply Chain Planning (SCP) systems	SCP systems, such as supply and forecasting planning, demand planning, and advance planning and scheduling (APS), are applications that coordinate limited material and capacity resources in accordance with business dynamic changes. These systems deal with strategic and tactical planning issues that generally have long time spans. Examples: i2, Manugistics, Logility
Warehouse Management Systems (WMS)	WMS track and control the movement of inventory through the warehouse, from receiving to shipping. WMS manages utilization of resources such as space and personnel. It also offers systematic management of material handling to optimize and shorten fulfillment cycle time reducing cost. Examples: Catalyst, EXE, Manhattan, Optum
Manufacturing Execution Systems (MES)	MES software provides a single flexible platform for managing customer orders through multiple plants and processes. MES software can deliver real-time visibility and control of manufacturing operations from equipment, materials, and people to the manufacturing processes. It assists companies in responding effectively to unexpected customer requirement changes. Many

	MES packages offer Internet capability, which offers the visibility and control of production system to suppliers and customers. Examples: CAMSTAR, CINCOM, Intellution, Kronos
Transportation Management Systems (TMS)	TMS are intended to achieve enterprise-wide load control centers by allowing companies to address the complex requirements of transportation between channel partners. TMS solutions can offer sophisticated planning algorithms to optimize different shipping scenarios. Examples: i2, Manugistics, Descartes, nPassage, Capstan
Radio Frequency (RF) systems	Technology or tools that support wireless communication to read and transmit data from data points such as bar codes. Example: NORAND, Intermec, Symbol
Geo-coded Trackingsystems	Satellite or cellular tracking devices most commonly used in trucks or trailers to ascertain position and feed the information to ancillary systems such as TMS, Routing or WMS. Examples: Qwest
Bar coding technology	Systems or products that are used in conjunction with any of the above systems to produce bar codes for any purpose. Example: Intermec, NORAND, Zebra Technologies, Symbol
Electronic Commerce Technologies	Technologies that enable computer-based business transactions conducted via private, proprietary networks such as EDI or conducted via the publicly accessible internet.

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