Implementation of Electronic Data Interchange: An Innovation Diffusion Perspective

Article *in* Journal of Management Information Systems · September 1994

DOI: 10.1080/07421222.1994.11518044 · Source: DBLP

3 authors, including:

Katikireddy Ramamurthy
actavis pharma development centre
56 PUBLICATIONS **5,313** CITATIONS

SEE PROFILE

Sree Nilakanta
Iowa State University
62 PUBLICATIONS **2,408** CITATIONS

SEE PROFILE

Implementation of Electronic Data Interchange: An Innovation Diffusion Perspective

G. PREMKUMAR, K. RAMAMURTHY, AND SREE NILAKANTA

G. PREMKUMAR is an Assistant Professor of Management Information Systems in the College of Business at the Iowa State University. He holds a Ph.D. in MIS from the University of Pittsburgh, a master's degree in business administration from the Indian Institute of Management and a bachelor's degree in engineering. He has over nine years of industrial experience in the areas of production planning, corporate planning, and information systems management. His research papers have been published or are forthcoming in *Information Systems Research, Decision Sciences, Journal of Management Information Systems, Information and Management, Omega, Long Range Planning, International Journal of Man–Machine Studies*, and other leading journals and conference proceedings. His current research interests include strategic information systems planning, telecommunications management, adoption and diffusion of information technology, and interorganizational systems.

K. RAMAMURTHY is an Assistant Professor of Management Information Systems at the University of Wisconsin-Milwaukee. Professor Ramamurthy holds a Ph.D. degree in MIS from the University of Pittsburgh, an M.B.A. and an undergraduate degree in mechanical engineering, and a graduate diploma in statistical quality control and operations research. He has a wide industrial experience of over 19 years and has held several senior technical and managerial positions. His current research interests are in the domains of adoption, implementation, and diffusion of modern information technologies, electronic data interchange (EDI), strategic IS planning, data administration in distributed environments, DSS and GDSS, business process reengineering, and management of innovations in computer integrated manufacturing technologies. His papers have appeared in *Decision Sciences, International Journal of Man–Machine Studies, IEEE Transactions on Engineering Management, MIS Quarterly, OMEGA, Journal of Computer Information Systems—JCIS, INFOR*, and others. He is a member of TIMS, Decision Science Institute, SIM, and Beta Gamma and Sigma.

SREE NILAKANTA is an Associate Professor of Management Information Systems in the College of Business at the Iowa State University. He received his Ph.D. in management information systems from the University of Houston. His current research interests include organizational decision support systems and technologies, business process redesign and enterprise information architecture integration, and adoption of information technology. Some of his publications have appeared in *Decision Support Systems, Management Science, Journal of Information and Software Technology*, and *Journal of Strategic Information Systems*, among others.

Journal of Management Information Systems / Fall 1994, Vol. 11, No. 2, pp. 157–186

ABSTRACT: Electronic data interchange (EDI) has dramatically changed the manner in which interorganizational transactions are conducted. The electronic exchange of transaction documents has had a significant impact on business practices, particularly in the sales and purchase/merchandising functions of organizations. EDI brings in many benefits to the organization such as reduced costs, faster turnaround, better customer service, and in some firms strategic advantage over their competitors. Despite these benefits, firms still have problems in implementing EDI.

This study, drawing upon research in innovation theory and information systems, examines the relationship between various innovation characteristics (complexity, two forms of compatibility, costs, relative advantage, and communicability) and various attributes of diffusion (adaptation, internal diffusion, external diffusion, and implementation success) of EDI in organizations. The data for the study were collected from a large-scale field survey of 201 firms in the United States that have implemented EDI. Two senior executives, one from information systems (IS) and the other from the sales/purchase function, provided matched responses to a questionnaire that measured the various research constructs.

The results of the multivariate regression analyses revealed that relative advantage, costs, and technical compatibility were the major predictors of adaptation. While relative advantage and duration were important predictors of internal diffusion, technical compatibility and duration were found to be important predictors of external diffusion. Both forms of compatibility (technical and organizational) and costs were found to be important predictors of implementation success in EDI.

KEY WORDS AND PHRASES: diffusion of innovations, electronic data interchange, innovation theory, interorganizational systems, systems implementation.

A QUIET REVOLUTION HAS STARTED IN THE LAST FIVE YEARS that is changing the way organizations are conducting their business transactions with other firms. Interorganizational business transactions have a significant amount of information flow in terms of purchase order, sales invoice, shipment notice, billing, and the like. Companies generate a large number of paper-based documents in these business transactions. The creation, handling, and distribution of these documents is a relatively slow, labor-intensive, and error-prone process. Heretofore, much of the automation in firms has focused on internal operations. Very limited effort has been devoted to automating interfirm operations, primarily because of lack of extensive electronic communication networks and uniform industry standards for communicating the information [8, 23]. However, in recent years, interorganizational systems (IOS) have been increasingly used to electronically link business partners [9, 31]. Electronic data interchange (EDI), a subset of IOS, providing a structured form of communication, has become a very popular vehicle for electronic transfer of information in purchase orders, sales invoice, shipping, billing, and other tasks from one firm to another [20]. The implementation and management of EDI systems has become a key management issue, as reflected in a recent survey of top IS executives [51].

Some of the major benefits claimed for EDI are lower inventory cost, reduced operations cost, greater accuracy in information, quick response time, and reduced

paperwork [2]. For example, retail stores such as K-Mart and retail manufacturers such as Levi Strauss claim significant reduction in inventory through EDI use [28, 55]. EDI has also been extensively used in the automobile industry, where it complements the just in time (JIT) inventory management practices very well [43]. These inventory reductions result in significant cost savings for organizations. The operations costs are reduced by eliminating the expensive process of data entry and verification from paper documents. EDI increases the accuracy of information as errors incurred in transcribing information from paper documents to electronic media are eliminated. Quick response to customer orders is facilitated as delay due to mailing is eliminated.

Although in the past, EDI was primarily used to reduce cost and increase productivity, competitive pressures and potential strategic implications of EDI appear to be increasingly perceived as more important concerns over simple cost/benefit calculations [45, 59, 64]. There has been a fundamental shift in attitudes of companies. According to a service provider, "EDI is no longer just 'nice to have.' It's a 'must have.' " The threat to losing business is forcing companies to implement EDI. Companies, such as American Hospital Supply, have used electronic linkages to lock in their customers and thereby derive competitive advantage [31, 65]. Other firms have used the cost savings from EDI to become the low-cost leader and thereby enjoy competitive advantage. For example, Supervalu stores in the grocery industry and Bergen and Brunswick in the pharmaceutical distribution industry have gained significant cost savings and competitive advantage from EDI use [5].

While these benefits do appear very attractive to adopting organizations, there has not been much empirical research to validate these claims. In spite of all the positive comments about EDI, firms appear to have had mixed success. There have been some success stories as well as some failures [18]. Some companies have complained that EDI has been thrust upon them without much choice [54]. Although EDI is beneficial to the buyer, it puts additional constraints on the supplier in terms of reduced slack time for manufacturing and the need to carry a higher inventory of finished products to meet customer requirements.

The varied experiences of firms with EDI reported in case studies indicate that a more detailed analysis with a larger sample of firms would provide more meaningful insight into the implementation of EDI. Research on innovation has identified a number of innovation characteristics that could influence the adoption/diffusion of innovations such as complexity of the innovation, compatibility of the innovation with existing practices/procedures and value systems, communication of the potential of innovation, and costs (relative to benefits) of the innovation [62]. In this study, we propose to examine the implementation of EDI from an innovation diffusion perspective by examining the relationship between innovation characteristics and various aspects of diffusion of EDI.

Background

THE CHANCES OF AN ORGANIZATION ADOPTING an innovation and the extent of diffusion of that innovation is dependent on the characteristics of the innovation as

perceived by the adopting firm. Many studies in the past three decades have examined the relationship between innovation characteristics and success in adoption/diffusion of innovations [36, 56]. After an extensive review of innovation literature, Tornatzky and Klein [62] claimed that it is possible to arrive at some generalization on the relationships between a few innovation characteristics and adoption/diffusion. They found that out of the twenty-five innovation characteristics that were evaluated by prior studies, ten were most frequently studied by researchers. These ten are: compatibility, relative advantage, complexity, cost, communicability, divisibility, profitability, social approval, trialability, and observability. Their meta-analysis revealed that the findings of the past studies were inconsistent and that only three of the ten variables—compatibility, relative advantage, and complexity—were consistently found to be significant. While compatibility and relative advantage were positively related to adoption, complexity was negatively related to adoption. They attributed the inconsistency in the past findings to nonuniform operationalization of the variables, unreliable measures, and differences in the research focus (individual versus organizational).

Most of the initial studies on innovation have used two distinct perspectives for analysis—adoption and diffusion [35]. While studies using the adoption perspective evaluate the characteristics of an organization or society that make it receptive to innovation and change, studies using the diffusion perspective attempt to understand why and how an innovation spreads and what characteristics of the innovation lead to widespread acceptance. After an organization has formally adopted an innovation, the use of the innovation has to spread within the organization for the innovation to provide its full benefits. Some innovations, because of their fad value or other organizational or environmental pressures, may be adopted in organizations, but because of other constraints, such as lack of top management support or costs, their use may not spread within the organization. Studying the process of diffusion of the innovation is as critical as the study of the adoption process, but most studies have focused only on adoption process [62].

Later studies, particularly in the MIS area, have emphasized the stage model of diffusion integrating the theories from organizational change, innovation, and technology diffusion literature [12, 37, 44]. The stage model includes not only the initiation and adoption stages, but also the various stages of diffusion within an organization—adaptation, acceptance, routinization, and infusion [12]. The rationale behind the stage model is that while adoption is a single event, diffusion of the innovation is over a longer time period, starting from an initial *adaptation* stage, adapting to the new product and procedures initiated by the innovation, to a final *infusion* stage, where the concern shifts to using the innovation for improving organizational effectiveness and measuring its impact on the firm. The stage model essentially captures the organizational learning process where the adopters go over the learning curve, understand the potential of the innovation, identify and develop sophisticated uses for the innovation, modify their work practices to suit the innovation, and develop suitable organizational control procedures to manage the innovation and the new work environment. These changes take time and organizations have greater success with a gradual progression

from one stage to another. Cooper and Zmud [12] strongly recommend the study of various stages of the model to better understand the innovation phenomenon.

Research on EDI, thus far, has been primarily exploratory—evaluating the benefits of EDI, status of usage of EDI in industries, and industry-specific case studies. EDI Research Inc. carries out a yearly review of the major EDI users on various aspects related to EDI. The studies found that the major benefits of EDI are quick response time, lower manpower costs, reduced purchase lead time, greater accuracy, and improved customer service. The major barriers to EDI implementation are compatibility of hardware/software between trading partners, differences in data formats between participating firms, lack of willingness among the trading partners, difficulty in justifying EDI using cost/benefit analysis, internal resistance to change due to replacement of repetitive clerical labor in document processing/delivery, and lack of knowledge about EDI and its potential [20].

While some researchers have claimed that EDI can generate competitive advantage to a firm [32, 59], others have said that it is more of a competitive necessity [4]. Monczka and Carter [48] found that implementing EDI has a significant effect on the business relationship between the partners. The key to effective use of EDI is to integrate the information collected through EDI with the internal IS applications so that the efficiency and effectiveness of the operations can be improved [29, 60]. For instance, EDI may not provide the desired benefits if the purchase order information received electronically from customers is not immediately integrated with the production planning system. Although standardization of data formats was a major issue in the past, the use of third-party vendors and good translation software have reduced such problems [29]. Similarly, economies of scale make it necessary to expand the connectivity to many external firms to realize significant cost effectiveness from using EDI.

In a recent study linking innovation and EDI literature, O'Callaghan, Kaufmann, and Konsynski [53] found that the adoption of EDI is related to the perceived "relative advantage" of the technology and the level of compatibility with existing systems.

Research Variables and Hypotheses

TWO SETS OF RESEARCH VARIABLES—diffusion and innovation characteristics—were identified based on the theoretical literature reviewed in the previous section on innovation and EDI.

Diffusion

Four variables were selected that together capture the various aspects of diffusion of EDI in organizations: adaptation, internal diffusion, external diffusion, and implementation success. These four variables were selected based on the stage model of diffusion [12], the attributes of implementation success [37], and traditional IS literature [15].

Lewin [39] used a three-stage change model—unfreezing, moving, refreezing—to

describe system implementation. Cooper and Zmud [12], in their stage model, described the adoption and diffusion of IT innovation in terms of six stages: initiation, adoption, adaptation, acceptance, routinization, and infusion. Cash et al. [9] described the same process using a four-stage model consisting of identification and investment, learning and adaptation, rationalization and management control, and widespread technology transfer and maturity. The stage models typically consist of an initial initiation/adoption stage, where a decision is made to invest in technology, followed by various stages of diffusion starting with an adaptation stage where the organization learns and adapts to the technology by trying it out in its first application, and based on that feedback expands its use captured by various other stages of diffusion leading finally to widespread transfer or "infusion" of technology within an organization. Since this study is primarily concerned with diffusion, it examines two stages of diffusion—the adaptation stage and the final infusion stage of the stage model.

The "adaptation" stage refers to the initial use of the innovation, that is, use of EDI in the first application. The "infusion" stage is characterized by using the technology in a comprehensive and integrated manner to support higher-level aspects of organizational work and widespread transfer of the technology to other system applications within the organization. In the context of EDI, using EDI for transferring basic purchase orders or sales invoices electronically, although a first step, is not a full exploitation of the technology. EDI has to be "infused" or "integrated" with other internal system applications so that EDI information can be seamlessly transferred into production planning, delivery tracking, A/C payable/receivable, and payment systems, and deliver its true potential to the organization. Evaluating internal integration becomes very important in the context of EDI since empirical evidence indicates that in some firms it is adopted to satisfy a powerful trading partner or to meet external business pressures rather than any internal need, and to that extent EDI may not get extensively diffused within the organization [54]. Hence, "internal diffusion" with other IS applications is used to represent the "infusion" stage of the model.

Unlike traditional information systems, EDI is an interorganizational system, and therefore requires the organization to expand its external electronic links to gain economies of scale and be cost effective [38]. It is also necessary to utilize the electronic links fully by expanding the communication with the partner to include more transaction sets/documents. *Computerworld* [11] highlights the need for "inter-exploitation" between partners through expansion of EDI use at both ends of the communication link. Strategic IS literature has also highlighted the importance of expanding the electronic links, as well as expanding the services on the IOS to sustain the strategic advantage [65]. Hence, expansion of electronic links and transaction sets/documents exchanged enable firms to derive the full benefits from the technology and to improve organizational effectiveness, as would be expected in the infusion stage. Hence, "external diffusion" is also used to represent the "infusion" stage of the model.

Mere measurement of internal and external diffusion of EDI may not be sufficient indicators of success until all the parties involved with EDI are satisfied with its implementation and use. There are many instances in IS where installed systems fail

to provide the benefits and satisfy the users [40, 42]. Among various measures suggested in the IS literature for measuring success in IS implementation, system usage and satisfaction have been found to be the most common [15]. These two variables are also suggested as important attributes of IS diffusion [37]. While "usage" is assessed by the extent of use of innovation (internal and external diffusion), "satisfaction" is assessed by "perceived implementation success," which measures the satisfaction with the innovation among various stakeholders—users, top management, customers/ suppliers, IS and functional manager.

Innovation Characteristics

Five innovation characteristics were found to be relevant to this study: compatibility, complexity, relative advantage, costs, and communicability. While the first three variables emerge from the meta-analysis of Tornatzky and Klein [62], the latter two were found to be important in the context of EDI [20]. A brief description of the variable, its relationship to the diffusion variables in the general context and specific to EDI, and the research hypotheses are provided below *in that order* for each of the variables.

Compatibility

Rogers [56, p. 223] defines compatibility of an innovation as the "degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of the potential adopter." Prior studies on innovation have found it to be an important variable to explain innovation adoption and diffusion [35, 62], and have found it to be positively associated with adoption [12, 19]. The more an innovation is perceived as consistent with present systems, procedures, and value systems of the potential adopter, the more likely it is that it will be adopted [56]. Schultz and Slevin [58] highlight the need for technological innovations to have both organizational and technical validity. While organizational validity evaluates if it is compatible with existing attitudes, beliefs, and value systems, technical validity evaluates if the technology is compatible with existing systems. In the context of EDI also, organizational and technical compatibility (validity) are two important issues to be addressed [2].

EDI changes/replaces many of the manual work procedures used in interorganizational transactions and can lead to significant changes in work practices and procedures [27]. Organization's resistance to change [39] due to changes in work procedures and possible loss of jobs as a result of automation of document processing functions is a major inhibiting factor in the use of EDI [20]. Another major barrier to the use of EDI is the incompatibility of the hardware/software and the data formats between participating firms for transparent transfer of data between the computers [21]. O'Callaghan et al. [53] found that system incompatibility was negatively related to the adoption of EDI.

Incompatibility could inhibit further diffusion as well. It is possible for a firm to adopt an EDI system to satisfy market pressures, but to fail to diffuse it further due to

incompatibility problems with internal IS applications [54]. It may also have problems in expanding externally due to incompatibility problems arising from multiple hardware platforms and different network protocols among its customers/suppliers [1]. Organizational incompatibilities due to changes in work practices in other functional areas may also inhibit diffusion. For example, integrating EDI information in production planning or warehousing system may create major changes in the job descriptions for workers in those areas and, perhaps, might result in loss of jobs. These changes could result in encountering resistance in the diffusion of EDI in those areas.

If the EDI system is compatible with existing work practices, it would most probably lead to greater satisfaction among the users and partners. The IS manager would be more satisfied with an EDI system that is compatible with existing systems. Hence, higher compatibility can be associated with greater success in implementation through improved satisfaction of users, partners, and IS manager. Hence, we can expect:

Hypothesis 1a: The greater the technical compatibility of EDI systems, the better the adaptation.
Hypothesis 1b: The greater the technical compatibility of EDI systems, the greater the internal diffusion.
Hypothesis 1c: The greater the technical compatibility of EDI systems, the greater the external diffusion.
Hypothesis 1d: The greater the technical compatibility of EDI systems, the greater the implementation success.
Hypothesis 2a: The greater the organizational compatibility of EDI systems, the better the adaptation.
Hypothesis 2b: The greater the organizational compatibility of EDI systems, the greater the internal diffusion.
Hypothesis 2c: The greater the organizational compatibility of EDI systems, the greater the external diffusion.
Hypothesis 2d: The greater the organizational compatibility of EDI systems, the greater the implementation success.

Relative Advantage

An innovation's relative advantage is defined as "the degree to which an innovation is perceived as being better than the idea it supersedes" [56, p. 213). In their meta-analysis, Tornatzky and Klein [62] found relative advantage to be positively related to adoption. IOS, such as EDI, improve the efficiency of interorganizational transactions and can thereby create competitive advantage [31]. In a competitive market the potential to derive competitive advantage from a new technology provides significant impetus to use the technology [24]. O'Callaghan et al. [53] found "relative advantage" of EDI technology to be a significant factor in influencing its adoption in organizations.

Also, firms that recognize the true potential of EDI also realize the need to fully integrate EDI within its IS applications to realize the benefits. Recognizing the need

for "quick response" system in the retail industry and the ability for EDI to enable it, Levi Strauss has integrated its EDI systems with most of its internal IS applications [55]. Also firms that use JIT and realize the importance of EDI for JIT have integrated their EDI systems with other internal IS applications such as production planning and inventory control [47].

The efficiencies and benefits derived from initially using EDI for transmitting sales/purchase information to a single customer/supplier could motivate a firm to further expand its scope to include other trading partners and other transaction documents, thereby influencing the external diffusion of EDI. For instance, American Hospital Supply realizing the significant benefits from electronically linking to one hospital aggressively pursued its electronic links with many other hospitals to sustain the strategic advantage from their IOS [65]. Also, realizing the benefits from locking up customers to their system, they continued to enhance the system by integrating it with their other applications such as delivery tracking and providing that information (status of shipments) as value-added service to customers.

The positive perception of the benefits of the technology should provide an incentive for the users (both internal and external) to use the technology and be satisfied with its performance, thereby leading to greater implementation success [14]. Hence, those firms that perceive significant benefits from EDI are more likely to diffuse EDI aggressively within their internal and external operations, and realize greater satisfaction and success in implementation. Hence:

Hypothesis 3a: The greater the relative advantage of EDI systems, the better the adaptation.
Hypothesis 3b: The greater the relative advantage of EDI systems, the greater the internal diffusion.
Hypothesis 3c: The greater the relative advantage of EDI systems, the greater the external diffusion.
Hypothesis 3d: The greater the relative advantage of EDI systems, the greater the implementation success.

Complexity

Complexity of an innovation is "the degree to which an innovation is perceived as relatively difficult to understand and use" [56, p. 230]. Although an innovation may appear to be useful, the organization, it may not have the necessary expertise to use it. Since complexity of an innovation can function as an inhibitor to adoption, it is usually negatively related to adoption [12, 62]. It can also inhibit further diffusion, since the firm may not be able to easily integrate it with the rest of the organizational activities.

In EDI implementation one of the partners (normally a small supplier to a large firm initiating EDI) may perceive EDI to be very complex and may lack the technical capability to install EDI system in its firm. Even if it adopts EDI due to market pressures and help from trading partners, the usage may be limited to electronic

transmission of sales information or receipt of purchase information and may not be integrated with other IS applications, thereby not obtaining significant diffusion within the organization [21]. Also, while linking with a single customer/supplier may be relatively easy, extending it to multiple customers/suppliers may involve linking with different hardware/software and network protocols and managing a complex network infrastructure, which may become a very complex operation for many firms and therefore inhibit them from expanding externally. The perceived complexity of the technology and the ability to use it effectively can be expected to influence the level of satisfaction with the EDI system [14]. Hence:

Hypothesis 4a: The lower the complexity of EDI systems, the better the adaptation.

Hypothesis 4b: The lower the complexity of EDI systems, the greater the internal diffusion.

Hypothesis 4c: The lower the complexity of EDI systems, the greater the external diffusion.

Hypothesis 4d: The lower the complexity of EDI systems, the greater the implementation success.

Costs

Many studies in innovation have examined cost as a factor influencing adoption [62]. The less expensive the innovation, the more likely that it will be adopted [56]. Cost as an absolute value is less meaningful compared with using it as a relative variable, relative to the benefits that accrue from the innovation. Users typically evaluate innovation in terms of whether the benefits outweigh the costs before adopting an innovation.

Although cost is a significant inhibitor of adoption of innovation its links to diffusion are not clear. Some researchers argue that once an investment is made to adopt an innovation, higher costs could motivate firms to more actively diffuse it within an organization and make it cost-effective [66]. However, this proposition has not been tested by empirical studies. Logical arguments can also be put forth that organizational costs for further diffusion in terms of additional investments in infrastructure and training could be higher than initial investment and therefore still inhibit large-scale diffusion.

The cost of an innovation has many components—initial investment cost, operational costs, and the cost of training the users to use the innovation. The cost to set up the electronic linkage and installing the necessary hardware and software for EDI is by itself a significant inhibitor for some firms [20]. Also, because EDI is a new technology that causes large-scale changes to the work procedures, significant costs have to be incurred in training the users [7].

In the context of EDI, the cost of integrating it with other IS applications—that is, modifying existing IS applications or developing new ones—can be a substantial cost compared with the initial investment in installing EDI. It may also result in significant

organizational learning costs due to reengineering of business processes, and that could inhibit further internal diffusion. Linking with multiple customers/suppliers may require costly translation software and extensive network infrastructure inhibiting further external diffusion. If the benefits from the innovation are not commensurate to the costs incurred in implementing the innovation, the users are going to be less satisfied with the innovation and therefore exhibit lower implementation success. Hence:

Hypothesis 5a: The lesser the costs relative to the benefits, the better the adaptation.
Hypothesis 5b: The lesser the costs relative to the benefits, the greater the internal diffusion.
Hypothesis 5c: The lesser the costs relative to the benefits, the greater the external diffusion.
Hypothesis 5d: The lesser the costs relative to the benefits, the greater the implementation success.

Communicability

Rothman [57] defines communicability of an innovation as "the degree to which aspects of an innovation may be conveyed to others." For an innovation to be successfully adopted and used, it is important for the users to become aware of the innovation and what it can do to improve their job. Most innovation adoptions result in changes to jobs and organizations invariably encounter resistance to change from existing work practices [39]. Providing information on the benefits from the innovation and potential improvement to the work environment could motivate users to adopt the innovation. Typically, training programs, newsletters, and the like are used in organizations for communicating the details of an innovation. In a meta-analysis of innovation studies, Damanpour [13] found that internal communication has a positive relationship with innovation adoption. In studies on end-user computing, training and other methods of communication of the potential of PCs were found to be significant factors influencing the spread of end-user computing in organizations [6, 50].

A major problem in EDI implementation is the lack of information on EDI technology among the trading partners and their willingness to switch to EDI mode [21]. This makes it difficult for the firm to expand its electronic links with trading partners. Lack of awareness of EDI and its benefits among various functional areas within the organization will also affect the extent to which EDI information is integrated with other internal IS applications. Communicating information on EDI and thereby getting the user involved in the EDI implementation process should lead to greater success in implementation [3]. Hence:

Hypothesis 6a: The greater the communicability, the better the adaptation.
Hypothesis 6b: The greater the communicability, the greater the internal diffusion.
Hypothesis 6c: The greater the communicability, the greater the external diffusion.
Hypothesis 6d: The greater the communicability, the greater the implementation success.

Elapsed Time

The stage models [37, 44] have highlighted a multistage process of diffusion of an innovation in an organization over an extended time period. Organizations go through the different stages of adaptation and diffusion of an innovation, gradually gaining expertise as they go over the organizational learning curve and improving their effective utilization of the innovation. Diffusion has always been represented as a function of time in various models of diffusion [41]. Organizational learning has often been posited as an important factor in the successful usage of complex information systems [9]. Users take time to adapt to new technologies and learn new ways to perform their tasks; once they master the technology, they would promote widespread technology transfer to the rest of the organization.

EDI is an interdependent technology whose effective utilization is dependent on integrating EDI information with existing IS applications. This integration would require significant efforts and take considerable time since the current IS applications have to be modified to interface with EDI technology. To effectively use EDI, organizations have to link with many external partners, which could time-consuming since some reluctant trading partners may have to be coaxed while others have to trained in the the use of EDI technology. Also, it takes some time to establish the rules and procedures, and finalize the process details for transacting with partners in the EDI mode. Hence, the external diffusion of the innovation would also be a function of time.

Since it is a new innovation, users will take some time to get familiarized with the technology, overcome the early bottlenecks, change their work practices, and use it effectively. Hence, users would be more satisfied with EDI after the initial learning period and after they gain adequate confidence in the use of the technology. Since firms would improve in their EDI utilization over a time period it can be expected that top management would be more satisfied with the innovation with the progression of time. Hence, we can expect time elapsed to positively influence implementation success.

Hypothesis 7a: The greater the elapsed time, the better the adaptation.
Hypothesis 7b: The greater the elapsed time, the greater the internal diffusion.
Hypothesis 7c: The greater the elapsed time, the greater the external diffusion.
Hypothesis 7d: The greater the elapsed time, the greater the implementation success.

Research Methodology

Operationalization

THE INSTRUMENT USED FOR THE MEASUREMENT of various research variables is discussed below.

Adaptation was measured by the extent to which EDI is used in the first application in an organization. Typically, the first application that is developed by organizations adopting EDI is a system for sending purchase orders electronically, if implemented in the purchase area, or a system for sending sales invoices, if implemented in the sales area [21]. Hence, the extent of EDI use in either of these two activities was measured on a five-point Likert-type scale ranging from "none" to "very large extent."

Internal diffusion refers to the extent of integration of EDI in organizational activities. EDI information received through purchase orders can be integrated with other sales-related information systems in the organization such as delivery tracking, bill of lading, shipping, and distribution systems. It can also be integrated with the customer billing and accounts receivable system. Interfirm electronic payments can be established in conjunction with the banking industry's electronic funds transfer (EFT) system. Organizations also gain significant advantage from linking the EDI information with their production planning systems, since it becomes invaluable for JIT production systems where response and turnaround time are very critical. Internal diffusion was assessed as an aggregate measure of the extent to which EDI information is integrated into five major IS applications discussed above, related to the purchase/sales area, as is appropriate.

External diffusion was assessed by the extent to which the firm is successful in linking with external partners and converting its external transaction documents into electronic form. Since an absolute measure will be dependent on other characteristics of the organization (such as size) and will therefore be difficult to compare across organizations, Tornatzky and Klein [62] suggest using a relative measure—degree of implementation as a proportion of the maximum value possible of that variable. Using their guidelines, external diffusion was assessed by two items that measure the extent of total external partners (that could be electronically linked) that are linked by EDI and the extent of total external documents (convertible to EDI) that are converted to EDI.

Implementation success was measured by five items that assessed the perceived satisfaction of all the major stakeholders involved in EDI—users, top management, customers or suppliers (depending on the EDI linkage), functional and IS manager. Two stakeholders who are significantly involved in the EDI effort—IS and functional manager—provided their perceptions on the satisfaction of the stakeholders. Initially, the use of user satisfaction instrument [30] was evaluated but was not found to be appropriate in this context since we required the measurement to be specific to EDI, and also required an assessment of satisfaction of all the stakeholders.

Compatibility was examined from two perspectives; technical compatibility of EDI with the existing hardware/software, and organizational compatibility with respect to the work procedures and value systems of the actual users. They were measured with one and two items, respectively.

Relative advantage was measured by indicators that assessed both tangible benefits, such as profitability or increase in sales, and intangible benefits from the innovation. A significant problem in the operationalization of this construct is that different firms

may expect different types of benefits from EDI and therefore an aggregate composite measure may not provide a meaningful interpretation of the relative advantage of EDI for a particular firm. For example, while one firm may find EDI very useful to cut costs in operations, another may find it primarily useful to improve response time and customer service. Instead, if the importance rating for each of the benefits to the organization is also obtained, a weighted composite average of the benefits, weighted by the importance rating, would provide a more accurate indicator of the relative advantage of EDI to the firm. Eight items that assess the various benefits of EDI along with their importance ratings were used to develop a weighted measure.

Complexity was measured using a single item that assessed the perceived complexity in the use of EDI for the firm.

Costs were measured using three items that assessed the perceived cost relative to benefits of initial investment, training, and integrating EDI with other IS applications.

Communicability was measured by a single item that assessed the extent of training and communication provided to educate the users on EDI.

Data Collection

A detailed questionnaire that measures the various research variables was developed. There were multiple issues to be resolved while designing the questionnaire. First, the motivation to use EDI, ability to influence the partners to use it, and its impact on the firm's operations can widely vary based on whether EDI is implemented in the purchase or the sales function; second, while the innovation literature is flooded with studies that examine innovation from a single perspective (either the user or the implementor), there are very few studies that evaluate an innovation from multiple perspectives, which has been recommended by researchers as the most appropriate method to study innovation adoption and its diffusion within an organization [62]. Hence, to address these issues, two survey instruments were developed—one for purchase and the other for sales function.

To obtain multiple perspectives of innovation diffusion in an organization, we created two parts in the survey instrument—the first part focused on details of EDI that pertained to the IS department and was completed by the IS manager; the second part relating to EDI use in a functional area was completed by the manager of the function using it. Most of the measures were perceptual and to that extent reflect the view of the sales/purchase manager and the IS manager. However, since these respondents are sufficiently senior in the management hierarchy, it is expected that they would have responded from an organizational perspective. Also, since most of the items refer to department-level variables, relevant to the two respondents in the organization, their perceptions should reflect with reasonable accuracy the actual situation in the organization.

The survey instrument was designed to measure the research constructs discussed earlier. The items in the questionnaire were initially derived after an extensive literature review and were subjected to thorough scrutiny of the researchers. The questionnaire was pilot tested in seven different companies—four of them with EDI in the purchase end and three with EDI in the sales end. The companies also had widely

varying degrees of diffusion of EDI in their operations. At least one of the three researchers was present in all the pilot testing and got verbal feedback on the items and on the overall readability, format, and the relevance of the questions. The questionnaire was pilot tested with both the manager of the IS department and the manager responsible for EDI in the functional area. The feedback from pilot testing was very useful in refining the measurement items, creating multiple versions (sales/purchase; IS/functional area), and modifying the items to suit each version. Also, the format of the questionnaire and the data collection method from two respondents of a firm in a single questionnaire were refined during the pilot testing stage.

The data for the study were collected from a large-scale field survey of 1,200 firms in the United States, listed in the *Directory of Top Computer Executives* [16]. We matched the company name with the companies listed in the EDI yellow pages [17] to ensure that they were users of EDI before mailing the questionnaire. Two questionnaires (the sales as well as the purchase version) were mailed to the chief executive of the IS department who was asked to choose the correct version, complete the first part, and then hand it over to the appropriate (sales/purchase) functional manager to respond to the second part. Two hundred and thirty responses were received out of which 201 responses were usable.

Sample Characteristics

The characteristics of the sample are shown in Table 1. The values in the table indicate that the respondents were fairly distributed across various industry groups, sales revenue levels, and employee sizes. There is a wide distribution of companies ranging from relatively small firms (17 percent) with sales revenue below 100 million dollars to large firms (15 percent) having over 5 billion dollars sales. Likewise, we noticed a fair distribution of companies with respect to employee size also, ranging from 11 percent of the firms with fewer than 200 employees to 25 percent of them having more than 10,000 employees. We had a fair degree of representation from most industries that are users of EDI. Fifty-five percent of the responding firms had implemented EDI on the sales end of their operations and the remaining had implemented EDI on the merchandising or purchasing end. The decision to implement EDI can be either firm-initiated or partner-initiated. A greater proportion of firms (81 percent) in the purchase side are "firm-initiated" compared with the sales side (19 percent). The responding executives were from senior management rank with over 70 percent having job titles of manager or higher. The responding firms also widely varied in their experience with EDI implementation. We had firms who were relatively new to the EDI mode of operations (23 percent had less than two years EDI experience), as well as firms who had used it for a number of years (15 percent had greater than five years experience). These values enable us to generalize the results of this study to a wider cross-section of the population.

Although our effective response rate was slightly low (17 percent) due to requirements of matched responses from organizations, the sample characteristics described above give us sufficient confidence to consider the sample to be a fair representation

Table 1 Sample Characteristics

	Frequency	Percentage
Company sales revenue		
Less than 100 million	23	17
100–399 million	34	25
400–999 million	10	7
1,000–1999 million	31	23
2,000–4,999 million	18	13
Above 5,000 million	20	15
Missing	65	
Industry		
Auto and related	13	7
Retail	34	17
Food	17	8
Manufacturing	25	12
Consumer products	40	19
Computers/communication	9	5
Metals	20	10
Health	9	5
Others	34	17
EDI experience		
Less than 2 years	23	12
2 years	41	21
3 years	33	17
4 years	20	10
5 years	33	17
Above 5 years	44	23
EDI location		
Sales	110	55
Purchase	91	45

of the population of EDI adoption in these industry groups. Since nonrespondents could not be identified, it was difficult to test for response bias in the traditional manner. However, using an alternate approach [22], we compared this study's sample profile on some of the demographic characteristics with other recent studies on EDI and found that they were reasonably similar.

Validity and Reliability

The instrument was tested for various validity and reliability properties. While validity is the degree to which an instrument measures the construct under investigation,

reliability measures the stability of the scale based on an assessment of the internal consistency of the items measuring the construct [10].

Content validity, which assesses if the measurement is complete and sound, was established through the extreme care taken in the selection of items that measure the constructs and subjecting them to various stages of pretesting and pilot testing. For example, the items used for measuring internal diffusion, which were identified based on prior studies [21], were modified and reworded based on feedback from the interviews to better reflect industry practices and naming conventions. Similarly, the items measuring relative advantage were also modified to better measure the underlying concept.

Construct validity was assessed using convergent and discriminant validity. While convergent validity evaluates if all the items measuring a construct cluster together and form a single construct, discriminant validity measures the degree to which a concept differs from other concepts and is indicated by the items not correlating highly with other measures from which it should theoretically differ [33]. Principal component analysis can be used to test the various validity properties of the constructs [52]. A two-step process is recommended for testing construct validity [34]. Initially, the convergent validity of each construct needs to be evaluated by principal component analysis of the items measuring that construct. This removes outliers and identifies subdimensions (if any) for the constructs. Subsequently, discriminant validity needs to be evaluated by subjecting all the items measuring the various constructs to principal component analysis to determine if the items load on the appropriate constructs.

Following these guidelines, the psychometric properties of the instrument were evaluated using principal component analysis. The results of convergent validity testing are shown in Table 2.

An analysis of the results reveals that except two variables, relative advantage and internal diffusion, other multi-item indicators exhibit sufficient convergent validity. The five items measuring internal diffusion split into two separate factors measuring diffusion in accounting and diffusion in other IS applications. The eight items measuring relative advantage also split into two separate factors measuring different aspects of EDI benefits. Although it is technically desirable to treat them as separate factors, it may be acceptable to aggregate them as a single variable if there is sufficient theoretical justification and high correlations between the extracted factors. This approach has been extensively used in IS research, especially with the user information satisfaction measure which is a composite measure of three factors [30, 61]. There is sufficient theoretical justification to consider relative advantage and internal diffusion as single constructs since the items for both these constructs were derived from prior research and essentially measure EDI integration in different IS applications in the context of internal diffusion and different benefits from EDI in the context of relative advantage. Also, there is high correlation between the extracted factors for relative advantage ($r = 0.40, p < 0.001$), and internal diffusion ($r = 0.44, p < 0.001$) providing empirical justification. Hence, it was decided to consider relative advantage and internal diffusion as single constructs.

Discriminant validity was assessed by subjecting all the items of multi-indicator independent variables to principal component analysis. Similar analysis was per-

Table 2 Convergent Validity and Reliability Analysis

Variable	Item	Loading	Mean	S.D.	Cronbach alpha
Org. compatibility			4.96	1.20	0.82
	Compat–1	0.91			
	Compat–2	0.91			
Tech. compatibility	Compat–3		5.05	1.58	—
Relative advantage[b]			22.73	5.34	0.77
Rel.adv–1					
	Rel–5	0.73			
	Rel–1	0.72			
	Rel–3	0.70			
	Rel–4	0.65			
	Rel–6	0.60			
Rel.adv–2					
	Rel–7	0.87			
	Rel–8	0.80			
	Rel–2	0.66			
Costs			3.44	1.33	0.71
	Cost–1	0.83			
	Cost–2	0.82			
	Cost–3	0.72			
Complexity	Complex		3.65	1.50	—
Communicability	Comm–1		3.85	1.70	—
Adaptation[a]	Adapt–1		3.53	1.47	—
Internal diffusion[a,b]			2.03	1.03	0.61
Int.dif–1					
	Int–5	0.81			
	Int–1	0.67			
	Int–2	0.64			
Int.dif–2					
	Int–4	0.86			
	Int–3	0.81			
External diffusion[a]			1.62	0.91	0.73
	Ext–1	0.89			
	Ext–2	0.89			
Implementation success			5.07	1.20	0.91
	Imp–1	0.88			
	Imp–2	0.87			
	Imp–3	0.90			
	Imp–4	0.84			
	Imp–5	0.78			

[a] 1 to 5 scale. Remaining variables measured on a 1 to 7 scale.
[b] Split as two factors.

formed for the items measuring the dependent variables. Although it is preferable to perform a single analysis for all the items, researchers have recommended a less restrictive option of testing a smaller subset of variables if some correlation among the variables is suspected [33], or an even lesser restrictive option of testing pairwise discriminant validity among the variables [63]. We chose the option of testing for independent and dependent variable sets separately. The results of discriminant validity are shown in Table 3.

The results indicate that the items for the independent variables and dependent variables converged on four factors each as originally envisaged and verified by convergent validity tests. The results of convergent and discriminant validity provide sufficient confidence to consider these items as valid measures of the constructs.

The reliability of the constructs was assessed using Cronbach's alpha. The results in Table 2 indicate that all the constructs have reasonably good alpha values and therefore can be considered to exhibit sufficient reliability.

Results

A MULTIVARIATE MULTIPLE REGRESSION MODEL was used for testing the hypotheses, since the four dependent variables were observed to be correlated with one another. The dependent variables were adaptation, internal diffusion, external diffusion, and implementation success. The seven independent variables were complexity, technical compatibility, organizational compatibility, relative advantage, costs, communicability, and elapsed time. The results of the multivariate analysis are shown in Table 4. Wilk's lambda with its equivalent "F" distribution is used to test the null hypothesis that there is no relationship between the criterion and predictor variable sets. The multivariate model is significant at $p < 0.001$.

The results indicate that three innovation characteristics—technical compatibility, relative advantage, and cost—significantly lead to better adaptation of EDI in organizations, thereby supporting hypotheses 1a, 3a, and 5a. Relative advantage and elapsed time were found to influence internal diffusion of EDI, supporting hypotheses 3b and 7b. Technical compatibility and elapsed time were found to be important predictors of external diffusion, supporting hypotheses 1c and 7c. Technical compatibility, organizational compatibility, and costs were found to be significant predictors of implementation success, supporting hypotheses 1d, 2d, and 5d.

There is anecdotal evidence in trade literature to indicate that motivations and interests to implement EDI are higher in the purchase side as evidenced by the case studies of auto manufacturers (Ford and G.M.) and retail firms (Walmart, K-Mart, J.C. Penney, and Dillards) [46]. In this study a larger proportion (81 percent) of firms that implemented EDI on the purchase side have proactively initiated EDI compared with the proportion of firms on the sales side (19 percent), confirming some of the reports in the trade literature. However, to determine if there are any differences in the diffusion of EDI between the two ends (sales, purchase), separate multivariate regression analyses were performed for the two subgroups with the four dependent variables. The results of these analyses are shown in Table 5.

Table 3 Discriminant Validity

Item	Fac–1	Fac–2	Fac–3	Fac–4
		Innovation attributes		
Rel–1	0.71			
Rel–6	0.69			
Rel–4	0.69	0.33		
Rel–3	0.68			
Rel–5	0.65			
Rel–7		0.87		
Rel–8		0.81		
Rel–2	0.38	0.65		
Cost–1			0.83	
Cost–2			0.79	
Cost–3			0.75	
Compat–1				0.90
Compat–2				0.89
		Dependent variables		
Imp–1	0.85			
Imp–2	0.87			
Imp–3	0.89			
Imp–4	0.83			
Imp–5	0.75			
Ext–1		0.88		
Ext–2		0.84		
Int–1			0.80	
Int–2			0.77	
Int–5			0.55	0.38
Int–3				0.85
Int–4				0.77

Although the predictors for the four dependent variables are to some extent similar to the ones reported for the overall model, there are some differences as well. On a general note, the explanatory power of the models for the purchase side was better than those of the sales side models, except for implementation success. The model for internal diffusion in the sales side and the model for implementation success in the purchase side were not significant.

Table 4 Mutivariate Multiple Regression Results

Multivariate analysis

Wilk's lambda = 0.503 $F = 3.86$ Sig. = 0.001

Univariate analysis

Dependent	Independent	Beta	Sig.	Adj. R^2	F	Sig.
Adaptation				0.188	6.06	0.001
	Relative_adv	0.264	0.001			
	Costs	–0.228	0.006			
	Tech_compat	0.146	0.06			
Internal diffusion				0.07	2.63	0.01
	Relative_adv	0.196	0.02			
	Elapsed time	0.156	0.05			
External diffusion				0.104	3.54	0.001
	Elapsed time	0.307	0.001			
	Tech_compat	0.141	0.083			
Implementation success				0.246	8.14	0.001
	Org_Compat	0.295	0.001			
	Costs	–0.274	0.001			
	Tech_compat	0.147	0.05			

Discussion of the Results

Adaptation

TWO OF THE THREE PREDICTORS OF ADAPTATION, relative advantage and compatibility, whih emerged as important in this study, are the same factors identified by Tornatzky and Klein [62] in their meta-analysis of all studies related to innovation. An organization uses an innovation essentially to satisfy an internal need [67] and unless the innovation provides the benefits that meet the needs, it is going to have less chance of being used. Relative advantage (a measure of perceived benefits) is therefore an important criterion for an organization to use an innovation. This is consistent with results from prior studies that have emphasized the need for technology push as one of the primary forces for initiating adoption of an innovation [49, 67], and a recent study specific to EDI [53]. Compatibility of data formats and hardware/software standards has always been a major problem in linking multiple suppliers with multiple customers [53] and has also emerged as an important predictor of adoption of EDI in

Table 5 Subgroup Multivariate Analysis

	Sales				Purchase			
Multivariate results								
	Wilk's lambda = 0.399 $F = 2.77$ Sig. = 0.001				Wilk's lambda = 0.456 $F = 1.76$ Sig. = 0.01			
Univariate results								
Dependent	Independent	Beta	Sig.	Adj. R^2 (sig.)	Independent	Beta	Sig.	Adj. R^2 (sig.)
Adaptation				0.082 (0.05)				0.101 (0.06)
	Relative_adv	0.203	0.08		Relative_adv	0.220	0.06	
					Costs	−0.219	0.07	
Internal diffusion				N.S.				0.133 (0.02)
					Relative_adv	0.214	0.07	
External diffusion				0.079 (0.06)				0.215 (0.003)
	Complexity	0.252	0.03		Elapsed time	0.362	0.002	
	Elapsed time	0.256	0.01					
Implementation success				0.361 (0.001)				N.S.
	Costs	−0.337	0.001					
	Org_compat	0.415	0.001					
	Tech_compt	0.208	0.02					

this study. Implementing EDI could involve significant costs and, unless the firms perceive commensurate benefits relative to the costs, they may be unwilling to use it. Therefore, the results indicate that firms that perceive significant benefits from EDI technology and low costs relative to benefits and have limited (or no) compatibility problems will have better adaptation of EDI in the organization.

The mean values for adaptation in the two subgroups (sales = 3.13, purchase = 4.01; $t = 4.32, p < 0.001$) indicate that it is higher in the purchase side. The low explanatory power for the model in the two subgroups may be attributed to smaller sample size in the subgroups. The very low value of R^2 for the model in the sales side seems to indicate

that there may be other variables, not captured in this study, that could better explain adaptation. Since a large proportion of firms in the sales side implemented EDI based on external requirement (partner's initiative) rather than internal requirement, we can speculate that these firms used EDI to meet the minimal external requirements as evidenced by the lower mean value. Perhaps there were other interorganizational forces influencing its adoption and subsequent adaptation.

Internal Diffusion

Two factors were found to be important in influencing internal diffusion: relative advantage and elapsed time. Typically, an innovation is implemented in a particular area of an organization on a trial basis. Subsequent diffusion of the innovation to other areas in the organization is dependent on whether the other areas also perceive similar benefits from the innovation. Thus, relative advantage still continues to play an important role in influencing the diffusion of innovation in the organization. The integration of EDI with other IS applications may require significant changes to existing programs and therefore takes time to schedule these IS projects along with other competing projects. Also, the diffusion of EDI in other applications will be gradual over a period of time, riding over the learning curves of the initial applications, accumulating those experiences, and applying them to new applications. Hence, elapsed time came out as an important variable.

The level of integration of EDI information in various IS applications (including the first application) for the sales and purchase side is shown in Table 6.

The full potential of benefits from EDI can only be realized if the information received through EDI is integrated with other IS applications. EDI is extensively integrated with sales invoicing (typically the first application of EDI in the sales side), but has hardly progressed further in terms of integration with payment, accounting, and shipping systems. A similar pattern exists on the purchase side too. While EDI information is extensively integrated with purchase ordering, the level of integration with other applications such as payment, inventory control, accounting, and production planning is minimal.

These results clearly show that except for the first application (purchase order/sales invoice captured by adaptation), the other applications are lagging behind. Typically, the innovation (first application) is initiated by a champion in the organization and therefore the person or the department has significant motivation to ensure its success and will be willing to make changes to their work practices to ensure successful implementation. Subsequent diffusion to other departments becomes more complex and problematic, as it may require major changes to organizational work practices and substantial commitment for the innovation across the organization. Similar findings have been reported in implementation of other IT innovations such as material requirement planning (MRP) systems [12].

The subgroup regression results indicate that those firms in the purchase side that recognized the potential of EDI technology were motivated to better integrate EDI with other IS applications, while others, it seems, were content with using EDI for

Table 6 EDI Integration

Application	EDI integration[a] mean value
Purchase side	
Purchase order	4.01
Production planning	2.34
Inventory control	2.03
Accounts payable	2.02
Delivery tracking	1.63
Supplier payment	1.60
Sales side	
Sales invoicing	3.13
Shipping/distribution	2.73
Accounts receivable	1.78
Delivery tracking	1.67
Customer payment	1.61
Finished goods inventory	1.41

[a] Max. value = 5.

only the first EDI application. On the sales side the model was not significant. Since more firms in the sales side implement EDI based on partner's initiative (81 percent), there may not be sufficient initiative to integrate it with other IS applications.

External Diffusion

Technical compatibility and elapsed time were found to be important predictors of external diffusion. Unlike internal diffusion, external diffusion involves interacting with external trading partners to increase the scope of EDI coverage, in terms of both documents transacted as well as number of partners electronically linked. The problems of compatibility increase multifold when many firms with a variety of data formats and hardware/software standards try to communicate with each other. The early adopters developed firm specific standards either due to lack of standards or to lock-in partners [1, 65]. This greatly inhibited diffusion beyond that central hub. The growth of electronic marketplace and common standards should reduce compatibility problems and greatly facilitate external diffusion in the future. Organizations normally start with one application, either in the sales or the purchase area, that has significant potential for improving efficiency or reducing costs. Subsequently, they expand it to include other interorganizational documents and other EDI partners. Since organizations typically expand their coverage in a phased manner over a time period, and there is an organizational learning period from one phase to another, elapsed time has a significant impact on external diffusion success.

The subgroup analysis reveals that the mean values for external diffusion in the two groups are significantly different (purchase = 1.83, sales = 1.47, $t = 2.71$, $p < 0.007$). Also, the explanatory power of the two models is significant with time as an important variable in both models.

Implementation Success

For successful implementation, EDI systems have to satisfy the needs of many constituents—top management, internal users in the functional areas, external users (customers/suppliers), and IS personnel. Each group has different stakes in the system. For example, the sales department may have been thrust with EDI by its major customer, which will reflect in a very satisfied customer but perhaps an unsatisfied functional area user. For a system to be truly successful in implementation, it must satisfy all (or most of) the stakeholders.

Both the compatibility variables were found to be important predictors of implementation success, thereby indicating that some of the operational constraints in terms of incompatible systems, standards, and work procedures could significantly influence the satisfaction of the participants. New technologies, such as EDI, invariably lead to changes in work procedures and sometimes even to loss of jobs. There is always some resistance to introduction of innovations in organizations. Hence, organizational compatibility is as important as technical compatibility, to obtain the full benefits of innovation, which is consistent with Schultz and Slevin's [58] findings of the importance of organizational and technical validity for ensuring success in implementation. In the context of EDI, if an organization is already used to computerized procedures for internal operations such as an automated purchase order system, then it is only a marginal change in terms of sending the purchase orders electronically to the supplier. However, if the organization does not have an internally automated purchase order system, it is a significant change to switch to a totally automated interorganizational purchase order system. The purchase department will also be reluctant to relinquish its control over the ordering activities. This may be due to the inherent feeling either that the innovation may be faulty or that the organizational subunit or individuals may lose control over the decision making activity and to that extent lose power in the organization. Hence, compatibility of the EDI system with present work procedures (organizational compatibility) influences the satisfaction of the users. Also, technical compatibility with existing hardware/software and standards can reduce the problems of electronic interaction with the EDI partner and to that extent improve the satisfaction of the users, EDI partner, and the IS manager.

Surprisingly, unlike the other three subgroup models, the model was significant for the sales side and insignificant for the purchase side. This seems counterintuitive and the reasons for this result needs to be further explored in future studies. Perhaps other variables not captured in this study may better explain the success in implementation for firms in the purchase side.

Summary

THIS STUDY EXAMINED THE RELATIONSHIP between seven major innovation characteristics—relative advantage, complexity, technical compatibility, organizational compatibility, communicability, cost, and elapsed time—and four diffusion variables—adaptation, internal diffusion, external diffusion, and implementation success. The results indicate that relative advantage, technical compatibility, and cost are important determinants of adaptation; relative advantage and elapsed time are important determinants of internal diffusion; technical compatibility and elapsed time are important determinants of external diffusion; costs and technical and organizational compatibility are important determinants of implementation success.

Implications for Practitioners

The results of this study have significant implications for practitioners. Although the explanatory power of the internal diffusion model is low, it highlights the importance of building an awareness of potential of EDI for successfully integrating it with other IS applications. The extent of integration of EDI in IS applications (shown in Table 6) is very low in most areas, except in purchase orders and sales invoices, and is therefore a serious cause for concern. Since the true potential of EDI is not harnessed by merely automating the document printing and mailing operations of sales invoice or purchase orders, it is important for organizations to realize the importance of an integrated system and to take concerted efforts to further diffuse EDI in other important functional IS applications. Since this integration could involve significant business process reengineering and coordination with functional areas, user involvement is essential to its success.

The results indicate that the mean values of external diffusion are also very low. Technical compatibility issues still plague widespread external diffusion of EDI. No customer or supplier would like to handle multiple standards/data formats for interacting with its various trading partners. Unless standardization efforts such as ANSI X.12 are actively implemented, EDI coverage will be greatly inhibited. This is especially true in international transactions where the potential for EDI use is very large, but the problems of compatibility are also equally daunting. Although the use of third-party value-added networks and translation software has to some extent alleviated the problems, the ultimate long-term solution will be to develop a set of global standards that could be used regardless of country, industry, or product. Also, while ANSI X.12 standards provide transaction-level standards, there is still considerable work ahead in developing standards for communication across different networks and hardware platforms. A common standard evolving around ISO-OSI protocols should be able to resolve the communication issues. The active involvement of industry associations in developing these standards and fostering EDI should greatly facilitate external diffusion of EDI, as is evidenced in some industries such as the grocery industry. Also, to improve external diffusion, firms should find innovative ways to change the business processes to derive benefits from the electronic linkage.

Substantial efforts are required to coordinate with external agencies such as the transport carriers and banks to bring about significant increase in electronic integration. Some of these agencies may not be ready for implementation of EDI as is evidenced by the slow start in the banking industry [25].

One of the important determinants of diffusion was the elapsed time since adoption, which highlights the organizational learning curve, and the time and efforts required to reach a significant level of EDI usage. Unlike other innovations, the use of EDI is dependent not just on the acquisition of the technology, but also on integrating it with existing IS applications and phasing in the required changes to work practices in the organization. It seems that these activities are much more time- and effort-consuming than mere acquisition of the technology. Hence, practitioners, especially senior management, must realize that there are many hidden costs and supporting activities involved in the implementation of EDI and should not expect overnight results. Needless to emphasize, an implementation plan with well-defined strategies for integrating with existing IS applications should greatly facilitate the diffusion of EDI.

Since implementation success is influenced by organizational compatibility, it would be worthwhile for organizations to actively pursue change management strategies by highlighting the potential of EDI and building an awareness of the technology so that inhibitions to the use of the technology and fears of its impact on their work are minimized. This should also facilitate internal diffusion since greater awareness of the innovation (relative advantage) would motivate more usage of EDI.

Implications for Researchers

The results of the study have significant implications for research as well. This is perhaps among the very few studies that have rigorously examined the diffusion of EDI from a theoretical and empirical perspective. A number of interesting issues have surfaced from this study that could be considered for future research. Interorganizational systems, unlike traditional IS, require the cooperation of two or more firms for its successful implementation and operation. The finding that more firms that initiate EDI are in the purchase area and more firms that adopt EDI based on partner's initiatives are in the sales area suggests that interorganizational business relationships play a significant role in the adoption of EDI systems. Since purchase departments can be expected to have greater influence (or power) over their suppliers compared with sales departments over their customers, it can be expected that power and dependency relationships may, to some extent, be instrumental in making the purchase department more proactive in their adoption of EDI. A study examining these issues from both perspectives (sales and purchase) should provide very useful and interesting findings.

Although this study found that the integration of EDI in internal IS applications was limited, it did not explore the reasons for the low diffusion. Rather than speculate, it may be worthwhile to examine in detail the various factors that inhibit the diffusion of EDI internally within the organization. Also, the low explanatory power of some of the diffusion models suggests that there may be other variables that need to be

included to better explain diffusion. Future research could identify additional organizational and interorganizational variables and examine their influence on EDI diffusion.

Limitations

The results of this study have some limitations that need to be recognized. Although the need for matched responses and other requirements reduced our response rate to 17 percent, it is still a cause for concern on response bias. Hence, the results of this study have to be viewed with caution. The average size of the respondents was slightly larger than other comparable studies on EDI and hence the results can only be generalized to larger firms. The study used a single item to measure some variables. A more elaborate operationalization may have been desirable. Implementation success was measured as satisfaction of all stakeholders as perceived by the IS and functional manager. Obtaining the perceptions from top management and trading partner independently would have provided a better assessment of implementation success. The study did not collect any information from nonadopters and therefore was constrained from comparing adopters and nonadopters. Also, the cross-sectional nature of the study limits our ability to study the diffusion process in detail.

REFERENCES

1. Barber, N.F. Hubs and spokes: a paradigm shift. *EDI World*, 1, *11* (1991), 6–9.

2. Barber, N.F. Simultaneous process re-engineering. *EDI World*, *2*, 8 (1992), 5–11.

3. Barki, H., and Hartwick, J. Rethinking the concept of user involvement. *MIS Quarterly*, *13*, 1 (1989), 53–64.

4. Benjamin, R.I.; de Long, D.W.; and Scott Morton, M.S. Electronic data interchange: how much competitive advantage? *Long Range Planning*, *23*, 1 (1990), 29–40.

5. Bone, R.W. Electronic communication at Bergen Brunswig. *EDI Forum*, *1* (1988), 41–43.

6. Brancheau, J.C., and Wetherbe, J.C. The adoption of spreadsheet software: testing innovation diffusion theory in the context of end-user computing. *Information Systems Research*, *1*, 2 (1990), 115–143.

7. Carter, J.R.; Clauson K.S.; Monczka, R.M.; and Zelinski, T.P. Education and training for successful EDI implementation. *EDI Forum*, *1* (1988), 89–95.

8. Cash, J.I., and Konsynski, B.R. IS redraws competitive boundaries. *Harvard Business Review*, *63*, 2 (1985), 134–142.

9. Cash, J.I.; McFarlan, W.F.; McKenney, J.L; and Applegate, L.M. *Corporate Information Systems Management: Text and Cases*, 3d ed. Homewood, IL: Irwin, 1992.

10. Churchill, G.A., Jr. A paradigm for developing better measures of marketing constructs. *Journal of Marketing Research*, *16* (1979), 64–73.

11. *Computerworld*. Electronic data interchange—white paper. 1992.

12. Cooper, R.B., and Zmud, R.W. Information technology implementation research: a technological diffusion approach. *Management Science*, *36*, 2 (1990),123–139.

13. Damanpour, F. Organizational innovation: a meta-analysis of effects of determinants and moderators. *Academy of Management Journal*, *34*, 3 (1991), 555–590.

14. Davis, F.D.; Bagozzi, R.P.; and Warshaw, P.R. User acceptance of computer technology: a comparison of two theoretical models. *Management Science*, *35*, 8 (1989), 982–1003.

15. DeLone, W.H., and McLean, E.R. Information systems success: the quest for the dependent variable. *Information Systems Research*, *3*, 1 (1992), 60–95.

16. *Directory of Top Computer Executives*, East ed. Phoenix: Applied Computer Research, 1990.

17. *EDI Yellow Pages*, ed. 6. Dallas, September 1990–August 1991.

18. Emmelhainz, M.A. Strategic issues for EDI implementation. *Journal of Business Logistics, 9*, 2 (1988).

19. Ettlie, J.E., and Vellenga, D.B. The adoption time period for some transportation innovations. *Management Science, 25*, 5 (1979), 429–443.

20. Ferguson, D.M., and Hill, N.C. The state of U.S. EDI in 1988. *EDI Forum, 1* (1988), 21–29.

21. Ferguson, D.M., and Hill, N.C. The state of U.S. EDI in 1989. *EDI Forum, 2* (1989), 1–24.

22. Fuller, M.K., and Swanson, B.E. Information centers as organizational innovations: exploring the correlates of implementation success. *Journal of Management Information Systems, 9*, 1 (1992), 43–62.

23. Gant, D.R. The evolution of communication protocols in EDI: past, present, and future. *EDI World, 2*, 1 (1992), 34–37.

24. Gatignon, H., and Robertson, T.S. Technology diffusion: an empirical test of competitive effects. *Journal of Marketing, 53*, 1 (January 1989), 35–49.

25. Gentry, D.J. Banks: the key to making financial EDI work. *EDI World, 2*, 12 (1992), 26–32.

26. Hansen, J.V., and Hill, N.C. Control and audit of electronic data interchange. *MIS Quarterly, 13*, 4 (1989), 402–413.

27. Heflin, R. Changes to business practices created by quick response, EDI, and bar coding. *EDI World, 1*, 4 (1992), 16–17.

28. Hill, N.C., and Hansen, J.V. The impact of EDI on inventory levels. *EDI Forum, 1* (1988), 55–61.

29. Horan, T. Electronic data interchange: outlook and opportunities. *EDI Forum, 1* (1988), 35–40.

30. Ives, B.; Olsen, M.; and Baroudi, J.J. The measurement of user information satisfaction. *Communications of the ACM, 26*, 10 (1983), 785–793.

31. Johnston, H.R., and Vitale, M. Competitive advantage with interorganizational systems. *MIS Quarterly, 12*, 2 (1988), 153–166.

32. Keen, P.G.W. *Competing in Time: Using Telecommunications for Competitive Advantage*. Cambridge, MA: Ballinger, 1988.

33. Kerlinger, K.N. *Foundations of Behavioral Research*. New York: Holt, Rhinehart, and Winston, 1973.

34. Kerlinger, K.N., and Kaya, E. The construction and factor analytic validation of scales to measure attitude toward education, In G.F. Summers (ed.), *Attitude Measurement*. Chicago: Rand McNally, 1970.

35. Kimberly, J.R. Managerial innovation. In P.C. Nystorm and W.H. Starbuck (eds.), *Handbook of Organizational Design*. New York: Oxford University Press, 1981, pp. 84–104.

36. Kimberly, J.R., and Evanisko, M.J. Organizational innovation: the influence of individual, organizational, and contextual factors on hospital adoption of technological and administrative innovations. *Academy of Management Journal, 24*, 4 (1981), 689–713.

37. Kwon, T.H., and Zmud, R.W. Unifying the fragmented models of information systems implementation. In R.J. Boland and R.A. Hirschheim (eds.), *Critical Issues in Information Systems Research*. New York: John Wiley, 1987, pp. 257–252.

38. Lavery, H. Getting a bigger EDI bang. *EDI World, 2*, 7 (1992), 6–9.

39. Lewin, K. Group decision and social change. In T.M. Newcomb and E.L. Hartley (eds.), *Readings in Social Psychology*. New York: Henry Holt, 1952, pp. 459–473.

40. Lucas, H.C., Jr. Empirical evidence for a descriptive model of implementation. *MIS Quarterly, 2*, 2 (1978), 27–41.

41. Mahajan, V.; Muller, E.; and Bass, F.M. New product diffusion models in marketing: a review and directions for research. *Journal of Marketing, 54* (1990), 1–26.

42. Markus, M.L. Power, politics, and implementation. *Communications of the ACM, 26*, 6 (1983), 430–444.

43. Martin, E.W.; DeHayes, D.W.; Hoffer, J.A.; and Perkins, W.C. *Managing Information Technology: What Managers Need to Know*. New York: Macmillan, 1991.

44. McFarlan F.W.; McKenney, J.L.; and Pyburn, P. Information archipelago—plotting a

course. *Harvard Business Review, 61*, 1 (January–February 1983), 145–156.

45. McGee, J.V. *Electronic Data Interchange—Background Note*. Boston: Harvard Business School Press, 1987.

46. Meyers, R.B., and Canis, R.J. Preparing for the 21st century with EDI and bar coding—part 2—global status. *EDI World, 2*, 1 (1992), 23–28.

47. Millhorn, T., and Romeu, J. EDI capabilities grow to include complex data transfer. *EDI World, 2*, 1 (1992), 31–33.

48. Monczka, R.M., and Carter, J.R. Implementing electronic data interchange. *Journal of Purchasing and Materials Management, 25*, 1 (1988), pp. 26–33.

49. Munro, H., and Noori, H. Measuring commitment to new manufacturing technology: integrating technological push and marketing pull concepts. *IEEE Transactions on Engineering Management, 35*, 2 (1988), 63–70.

50. Munro, M.C.; Huff, S.L.; and Moore, G.C. Expansion and control of end-user computing. *Journal of Management Information Systems, 4*, 3 (1987), 5–27.

51. Niederman, F.; Brancheau, J.C.; and Wetherbe, J.C. Information systems management issues for the 1990's. *MIS Quarterly, 15*, 4 (1991), 474–500.

52. Nunnally, J.C. *Psychometric Theory*. New York: McGraw-Hill, 1978.

53. O'Callaghan, R.; Kaufmann P.J.; and Konsynski, B.R. Adoption correlates and share effects of electronic data interchange systems in marketing channels. *Journal of Marketing, 56* (1992), 45–56.

54. Pitts, J.M. Really working together. *EDI World, 1*, 11 (1991), 18.

55. Rochester, J.B. The strategic value of EDI. *I/S Analyzer, 27*, 8 (1989), pp. 1–14.

56. Rogers, E.M. *Diffusion of Innovations*. New York: The Free Press, 1983.

57. Rothman, J. *Planning and Organizing for Social Change: Action Principles from Social Science Research*. New York: Columbia University Press, 1974.

58. Schultz, R.L., and Slevin, D.P., eds. *Implementing Operations Research/ Management Science*. New York: American Elsevier, 1975.

59. Sokol, P.K. *EDI: The Competitive Edge*. New York: McGraw-Hill, 1989.

60. Stern, L.W., and Kaufman, P.J. EDI in selected consumer goods industries: an inter-organizational perspective. In R. Buzzel (ed.), *Marketing in an Electronic Age*. Boston: Harvard Business School Press, 1985.

61. Tait, P., and Vessey, I. Effect of user involvement on system success: a contingency perspective. *MIS Quarterly, 12*, 1 (1988), 91–109.

62. Tornatzky, L.G., and Klein, K.J. Innovation characteristics and innovation adoption-implementation: a meta analysis of findings. *IEEE Transactions on Engineering Management, 29*, 11 (1982), 28–45.

63. Venkatraman, N. The concept of fit in strategy research: toward verbal and statistical correspondence. *Academy of Management Review, 14*, 3 (1989), 423–444.

64. Venkatraman, N., and Zaheer, A. Electronic integration and strategic advantage: a quasi experimental study in the insurance industry. *Information Sustems Research, 1*, 4 (1990), 377–393.

65. Vitale, M.R. American Hospital Supply Corp.: the ASAP system. Harvard Business School Case Services No. 9–186–005, Harvard University, Boston, 1985.

66. Zaltman, G.; Duncan, R.; and Holbek, J. *Innovations and Organizations*. New York: John Wiley, 1973.

67. Zmud, R.W. An examination of push-pull theory applied to process innovation in knowledge work. *Management Science, 30*, 6 (1984), 727–738.