Measuring the Extent of EDI Usage in Complex Organizations: Strategies and Illustrative Examples*

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Abstract

As interest into the nature and value of Electronic Data Interchange (EDI) within organizations continues to grow, it becomes increasingly desirable to establish a tactical linkage between the strategic value of EDI and observed operational benefits. This article provides such a tactical linkage by presenting an approach to EDI measurement consisting of four facets: volume, diversity, breadth, and depth of a firm's EDI initiatives. Each of these facets is defined and then described through its application within the contexts of seven case sites, where each case site represents a strategic business unit having a long, successful history of EDI use. The article concludes with suggestions for both practice and research.

Introduction

Electronic Data Interchange (EDI), or the computer-to-computer exchange of standard business documents, generally refers to a class of interorganizational information systems that provides a number of potential operational and strategic benefits (Dix and Naze, 1993; Emmelhainz, 1990; Konsynski, 1993; Nygaard-Andersen and Bjørn-Andersen, 1994). In order to better understand these benefits, as well as any associated challenges, prior research efforts have explored exemplary EDI implementations from both operational (Banerjee and Golhar, 1992; Emmelhainz, 1987; Metzgen, 1990) and strategic (Bakos, 1991; Benjamin, et al., 1990; Clarke, 1992; Malone, et al., 1987) perspectives. Operationally, EDI has been found to reduce both cycle times and costs by improving the quality, speed, and business value of standard document exchanges (Mackay, 1993; Metzgen, 1990; Monczka and Carter, 1987; Mukhopadhyay, et al., 1995; Zorfass and Michel, 1992). Strategically, EDI has enabled some organizations to fundamentally change the way their business is conducted (Cash, 1985; Malone, et al., 1987; Sokol, 1989). More specifically, EDI provides a direct means to enhance an organization's competitive presence by affecting performance and costs associated with time, resource consumption, and security and control (Wrigley, et al., 1994).

Furthermore, EDI has more recently been cast as a pivotal technology for business process

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reengineering (Engel, 1994; Johansson, et al., 1994; Teng, et al., 1994). As organizations have reconfigured their business practices along dimensions such as time (Hinterhuber and Levin, 1994), knowledge (Burrows, 1994), and alliances with external partners (O'Sullivan and Geringer, 1993; Venkatraman and Zaheer, 1994), EDI has often become the technical platform on which reengineering efforts are planned, implemented, maintained, and sustained (Swatman, et al., 1994).

Given the broad diffusion of EDI across most industries and the numerous "success stories" that populate scholarly and practitioner journals, it intrigued us, in talking with corporate (including information systems) executives, that their perception (and resulting implementations) of EDI often seemed to be lean rather than rich and narrow rather than wide. All too often, while an organization has obtained real value from its EDI applications, installed applications often reflect quite limited perspectives regarding the nature and potential of EDI.

Why might this be the case? One possible explanation is that most articles or presentations on EDI either tend to be compelling theoretical arguments of the competitive or comparative opportunities made possible through EDI (Bakos, 1991; Hinterhuber and Levin, 1994; Konsynski, 1993; Nygaard-Andersen and Bjørn-Andersen, 1994; O'Callaghan and Turner, 1995; O'Sullivan and Geringer, 1993; Premkumar and Ramamurthy, 1994; Swatman, et al., 1994; Venkatraman and Zaheer, 1994) or anecdotal accounts of how specific organizations have applied EDI to attain situational benefits (Dix and Naze, 1993; Emmelhainz, 1987; Haugen and Behling, 1994; Mackay, 1993; Moynihan and Norman, 1994; Panepinto, 1993; Paper and Rai, 1994; Seideman, 1994; Sokol, 1995; Zimmerman, 1992). What seems absent is a rich, tactical understanding that links strategic expectations regarding EDI with operational plans for potential implementations. The existence of such a tactical understanding would also help researchers better categorize and interpret their observations regarding actual EDI implementations. By developing a clearer connection between existing theory and apparent evi-

dence, a richer, more generalizable understanding of the nature and value of EDI is likely to emerge.

In an effort to provide this tactical connection, this article presents an approach toward EDI measurement that views EDI initiatives as being comprised of four distinct facets: volume, breadth, diversity, and depth. In order to illustrate the nature and relevance of these four facets, each is examined in the context of seven organizations with long and successful histories of EDI usage. After descriptions of the research methodology and the seven case sites, this approach to EDI measurement is defined and described through data collected from the case sites. The article concludes with a discussion of usefulness of the measurement strategy for both practice and research.

Research Methodology

The data used in developing and validating our ideas were gathered as part of a larger investigation concerning the organizational impacts of EDI (Massetti, 1991). In order to reduce the confounding effects of multiple, divergent business strategies, the strategic business unit was selected as the level of case analysis. Site selection was undertaken with three main objectives. First, in order to control the effects of environmental variables, it was decided to contain all sites within a set of similar industry sectors. Second, in order to increase the representativeness of the corporate views regarding the potential of EDI, industries with long histories of EDI usage were selected. Third, in order to increase variation across the case sites, two sites from each participating enterprise were included: one business unit that was recognized for exemplary EDI use, and one believed to be an EDI laggard within the enterprise. Interestingly, it was discovered that none of the supposed "laggards" actually proved themselves to be EDI laggards. All were successfully applying EDI at the time data was gathered. Apparently, corporate management had failed to recognize the actual extent of EDI usage present in the business units initially identified as laggards.

All seven case sites are large organizations involved in the manufacture of electronic components and/or the provision of telecommunications services. Two business units were included from three of these enterprises, while a fourth provided only a single unit. All case sites were guaranteed anonymity to engender more open participation.

Interviews were held with senior managers from these seven case sites by the first author using a semi-structured interview guide. These questions focussed on gaining an understanding of the following: how and why EDI was used within the business unit; the nature of the job role as well as other organizational changes perceived to have occurred because of the EDI implementations; and the nature of objective and perceived benefits and costs associated with the EDI implementations. Where possible, formal documentation supporting interviewees' perceptions was also sought.

As is detailed in Table 1, 41 individuals were interviewed. Generally, interviews were held with information systems executives and with those functional managers whose business responsibilities were directly impacted by EDI implementations. Where one individual was interviewed within a business function, that individual represented the function's senior manager (typically, a vice president). Where more than one individual was interviewed, one of these individuals held the senior management position within the business function.

Research Case Sites

As described earlier, each of the organizations operated within the electronics and/or communications industries. However, as each operated in distinct markets and offered unique products and services, a variety of organizational contexts are represented in this sample. Each case site maintained annual sales of at least $1 billion, and six were divisions of multinational corporations: *Defense* and *Electronics* were divisions of one corporation, *Voice* and *Semiconductor* were divisions of another corporation; and, *SwitchOne* and *SwitchTwo* were divisions of yet a third corporation. Only *Communicate* operated as an independent enterprise; at one time, it too had been part of a larger conglomerate. Table 2 describes the business context of each case site, the functions where EDI is used, and the timeframe each began using EDI.

Strategically, *Defense* and *Electronics* were EDI technology leaders, applying the technology to gain direct competitive advantage within existing and potential markets. Operationally, they were using EDI to streamline core processes and decrease costs. *Voice* and *Semiconductor* initially applied EDI when required to do so by external trading partners. Operationally, their concerns centered on maintaining viable business relationships. *Communicate, SwitchOne*, and *SwitchTwo* used EDI as a convenient way to solve specific operational problems (refer to Table 2). Strategically, these three organizations viewed

Table 1. Functional Specialization of Interviewees

Case Site	Marketing/ Sales	Purchasing	Information System	Finance	Logistics	Total
Communicate		1	2			3
Defense	1	1	2	3	1	8
Electronics	1	1	1	1	4	8
Voice	1	2	1	1	1	6
Semiconductor	2	2	2			6
SwitchOne		3	1		1	5
SwitchTwo		3	2			5
Total	5	13	11	5	7	41

Table 2. Case Site Business Context and EDI Usage History

Case Site	Business Context	EDI Usage & History
Communicate	Southeastern U.S. provider of telecommunication services for businesses and residences.	Uses EDI primarily to support purchasing. Prior to the firm being spun off, purchasing was performed by the corporate purchasing function. With the spin-off, purchasing became a required function of *Communicate* and EDI was seen as the only cost-effective means of performing this new function. It has been using EDI since 1983.
Defense	Southwestern U.S. manufacturer of electronic equipment, such as missiles, for the Department of Defense.	Uses EDI in its marketing, purchasing, finance, and logistics functions to increase the speed and accuracy with which it fulfills its contract agreements. The EDI operations are formally managed by the parent company, which is an EDI pioneer within its industry. It began using EDI in the mid-1980s.
Electronics	Southwestern U.S. manufacturer of standardized semiconductors and electronic components.	Uses EDI to support its marketing, purchasing, finance, and logistics functions. Its EDI operations are also now formally managed by the parent company; however, the firm itself began using EDI in the 1970s as a means to interact with off-shore production facilities.
Voice	Western U.S. manufacturer of voice-paging systems, ISDN terminal adapters, and related communications equipment.	Uses EDI primarily in support of its marketing/sales function. While its EDI systems are operated by the parent company, *Voice* has considerable autonomy of the development of its EDI applications. It began to use EDI in the mid-1980s in response to a request from its largest customer.
Semiconductor	Southern U.S. manufacturer of made-to-order semiconductors and related electronic equipment.	Uses EDI to support its purchasing and marketing/sales functions in response to supplier and customer urging. Supported by the parent company, it began development of its EDI systems in 1985. However, these efforts were stalled as the parent solved system integration difficulties resulting from merger activity. It formally began EDI operations in 1988.
SwitchOne	Foreign manufacturer of digital transmission switching equipment having capacities greater than 10,000 lines.	Uses EDI primarily to support its purchasing function. Because of a need to free up space for manufacturing, it began EDI operations in 1988 by storing engineering drawings electronically so that they could be directly transmitting them to suppliers' manufacturing systems.
SwitchTwo	Southern U.S. manufacturer of digital transmission switching equipment having capacities less than 10,000.	Uses EDI primarily to support its purchasing function. Stable market demand conditions prompted the firm to implement EDI in 1989 for cost-reducing and efficiency-enhancing objectives.

EDI as an organizational resource for achieving growth and quality goals.

Where EDI was formally managed at the corporate level (*Defense, Electronics, Voice* and *Semiconductor*), each corporation condoned varying degrees of divisional autonomy regarding EDI development and use. Overall, we believe this diversity in EDI usage and history, while controlling for industry effects, provides a rich background to identify and understand the broad nature of the organizational roles served by EDI implementations.

An Approach to EDI Measurement

As mentioned earlier, our proposed approach to EDI measurement is comprised of four distinct facets—volume, diversity, breadth, and depth—that, when aggregated, allow for a robust assessment of EDI usage. Brief definitions are presented in Table 3.

Because this measurement scheme is aimed at supporting the bridge between EDI strategy and operations, it is helpful to consider each facet from both organizational and functional perspectives. The organizational perspective can aid in establishing EDI strategy and help in assessing adjustment when this strategy needs it. The functional perspective can help set specific operational targets for EDI applications and judge when these targets have been met. Hence, in order to demonstrate the full potential of this approach to EDI measurement, each of the facets of EDI usage are defined and described from both an organizational and functional perspective.

While each of the four facets have individually received attention in prior EDI literature (Forge, 1989; Goff, 1994; Paper and Rai, 1994; and Ramarapu, et al., 1994, Tapscott and Caston, 1994), they have not yet been collectively brought together as a mechanism for linking EDI strategy to operations. For example, O'Callaghan and Turner (1995) discuss several strategic theories underlying EDI and detail a variety of operational measures common to EDI research. But, little discussion of how their measures can be used as an effective way to manage a given organizational approach for using EDI is offered.

As illustrated in Table 4, prior empirical studies have varied considerably in their measurement strategies and have used, at most, three of the four facets in measuring the nature and extent of EDI usage. In the absence of a rich, consistent measurement approach, it should not be surprising that these prior studies have tended to produce disparate and incomplete views regarding the organizational impacts of EDI. In the remainder of this section, each of the four facets are described and demonstrated using information gathered from the case sites.

EDI volume

EDI volume, which represents the extent to which an organization's document exchanges are handled through EDI connections, is determined by dividing the total number of documents a function handles via EDI by the total

Table 3. The Four Facets of EDI Usage

Facets	Definition
Volume	The extent to which a firm's document exchanges are handled through EDI connections.
Diversity	The extent to which different types of a firm's business documents are handled through EDI connections.
Breadth	The extent to which a firm has developed EDI connections with each of its trading partners.
Depth	The extent to which a firm's business processes are intertwined with those of its trading partners through EDI connections.

Table 4. Examples of Measurement Strategies Applied in Prior EDI Studies

Source	Facets Portrayed	Measurement Level	Research Method
Emmelhainz, 1987	Breadth, Depth	Functional	Comparative Case Analysis
Schatz, 1990	Volume, Breadth	Organizational	Non-Experimental Analysis
Johnson, et al., 1992	Volume, Diversity, Breadth	Organizational	Survey
Mackay, 1993	Breadth	Organizational	Survey
Swatman, et al., 1994	Depth	Organizational	Comparative Case Analysis
Wrigley, et al., 1994	Diversity	Organizational	Non-Experimental Analysis
Bort & Schinderle, 1994	Volume, Diversity	Functional	Single Case Analysis
Jelassi & Figon, 1994	Breadth, Depth	Functional	Single Case Analysis
Cox & Ghoneim, 1995	Diversity, Depth	Organizational	Survey

number of the function's documents or transactions. A determination of EDI volume is useful in that it illustrates an organization's progress toward handling its business transactions electronically. Table 5 provides estimates obtained from the case sites of functionally based EDI volumes. An empty cell reflects either that EDI was not being used to handle a function's business documents (refer back to Table 2 for descriptions of the EDI implementation at each case site) or that interviewees could not provide a reasonable estimate of this volume.

Data on EDI volume is of tactical value in directing both radical and incremental change efforts to improve an organization's business processes. Regarding radical change, unless EDI volume has reached a sufficient level, it is unlikely that the business process reengineering of associated business processes will produce significant benefits (Swatman, et al., 1994; Tapscott and Caston, 1994). Regarding incremental change, i.e., identifying business processes to enhance via EDI, it is particularly useful to determine the *document share* for each function. A function's document share, which represents the proportion of corporate documents that are involved in the function's business activities, suggests the relative advantage to be obtained from undertaking EDI initiatives within the function. For example,

Table 5. EDI Volumes Reported by Case Sites

Case Site	Marketing	Purchasing	Finance	Logistics
Communicate		48% of purchasing documents		
Defense	less than 10% of repeat buys	54% of purchasing documents for mfg. line items	45% of payments	45% of traffic documents
Electronics				
Voice	50% of marketing documents			--
Semiconductor	85% of point-of-sales transactions	40% of purchasing documents for mfg. line items		
SwitchOne				
SwitchTwo		58% of purchasing documents for mfg. line items		

it can be observed from Table 5 that Voice is electronically exchanging 50 percent of its marketing documents (sales orders, change orders, acknowledgements, etc.) via EDI. However, without knowing the corporate document share represented by these marketing documents, it is difficult to assess the appropriateness of *Voice*'s initial decision to implement EDI within its marketing function. Of course, trading partner coercion may very well have been the motivating factor behind *Voice*'s decision. Still, even when EDI is implemented primarily at the bequest of trading partners, an understanding of both EDI volumes and document share can enable an organization to identify business processes that could be integrated with "mandated" EDI linkages in order to offset imposed costs. Unfortunately, none of the case sites were formally tracking such measures.

EDI breadth

EDI breadth, which represents the extent to which an organization has established EDI connections with external trading partners, is an important tactical consideration because it indicates both how successful a firm has been and how willing it appears to be in establishing electronic linkages to interact with customers, suppliers, creditors, and other stakeholders in an expedient fashion. The more receptive an organization is to establishing such electronic relationships, the more likely that organization is to be successful in adapting and competing within the emerging electronic marketplace

(Cox and Ghoneim, 1995; Jelassi and Figon, 1994).

A listing of EDI breadth as reported by each of the case sites is provided in Table 6. Note that these organizations have measured functional EDI breadth in two distinct ways: the percentage of trading partners with whom electronic connections have been established, and the number of "top" trading partners with whom electronic connections have been established. While the majority of case sites use the top trading partner approach, the percentage approach seems intuitively more useful for two reasons. First, the term "top" is ambiguous because it can be determined on a basis of the volume of documents exchanged (Ferguson and Hill, 1989), the cost of materials involved (Davis, 1992), or other considerations (Mukhopadhyay, et al., 1995; Tadlock, 1994). Such inconsistencies result in interfunctional and interorganizational comparisons being misleading or impossible. Second, when an organization assesses its EDI breadth relative to its top trading partners, it biases its measurement toward a perpetuation of current marketplace relationships. However, today's "lesser" trading partners may very well become tomorrow's most critical trading partners. In focusing its EDI breadth measure on its top trading partner, *Defense* may be unknowingly perpetuating its long-term dependency on a deteriorating (given current reductions in defense spending by the U.S. federal government) relationship. If instead it used a more generic "percentage of trading partners" measure, *Defense* would be provided with a clearer indication of the opportunity (as well as the

Table 6. EDI Breadth Reported by Case Sites

Case Site	Marketing	Purchasing	Finance	Logistics
Communicate		top 30 suppliers	top 9 suppliers	
Defense	top customer		top customer	
Electronics	20% of customers	45% of suppliers	top 50 suppliers	70% of domestic carriers
Voice				
Semiconductor	top 5 distributors	top 7 suppliers		
SwitchOne		top 6 suppliers		
SwitchTwo		top 3 suppliers		

necessity) of applying EDI to create new trading partner relationships.

While the above discussion examines EDI breadth from a functional perspective, it is also useful to examine EDI breadth from an organizational perspective. Organizational breadth is calculated by dividing the number of a firm's electronically connected trading partners by its total number of trading partners. This measure is not a straightforward calculation because trading partners often have multiple electronic connections with an organization. By tracking both functional-level and organizational-level EDI breadth, an enriched understanding of a firm's EDI development efforts is obtained. For example, if organizational EDI breadth remains relatively constant while functional EDI breadths are increasing, then it can be surmised that more extensive electronic relationships are being cultivated with a firm's existing EDI partners. Unfortunately, the case site firms assessed only functional-level EDI breadth.

EDI diversity

EDI diversity refers to the number of distinct document types an organization handles via EDI connections with its trading partners.[1] EDI diversity is tactically significant in that it indicates the progress that has been made in comprehensively handling an organization's business transactions through electronic linkages. While EDI diversity may appear to be easily measured, it can prove itself to be the most troublesome of the four EDI facets for three reasons.

First, because different organizations, industries, and countries have independently initiated actions to facilitate the EDI activities of constituents, no single standard for the document exchange process does, or will likely, exist. Organizations striving to expand the range of their EDI document base must adapt to a variety of document exchange formats, including the American National Standards Institute (ANSI) *transaction sets*, i.e., electronic representations of business documents, established for different industry groupings (Bass, 1989)

and international standards of EDI for Administration, Commerce, and Transport (EDIFACT), developed under the direction of the United Nations (Warner, 1989). And many proprietary standards, which do not directly conform to established document standards, have been developed and implemented—most often out of necessity—by those organizations among the earliest to commit themselves to electronic commerce (Derby, 1994). As a result of conforming to a variety of document standards, an organization may find itself electronically exchanging numerous documents representative of the same value-chain flows but unable to integrate these flows in an electronic manner, internally or externally (Clarke, 1992).

Second, the above problem is compounded by internal document conversion issues, which can be complicated and overwhelming for an organization (Moynihan and Norman, 1994; Profant, 1994). In order to leverage its full EDI potential, an organization must convert the contents of its transaction databases to a vocabulary compatible with the EDI document standards to which it has agreed to conform (Dawkins, 1989). This may or may not be a straightforward conversion. In addition, the organization must also analyze, and convert if necessary, the myriad of transaction processing and support applications used to generate, transmit, receive, and process EDI documents (McGarr, 1994; Rowe, 1994).

Third, although Value Added Networks (VAN) have been established to aid organizations in coping with such document exchange issues, VANs frequently prove themselves to be imposing, non-supportive, and costly (Cafiero, 1994; Jackson, 1994). As an example, *Communicate* had to build a private telecommunications pathway in order for it to exchange a very voluminous document type with one of its major trading partners because no VAN could support the huge data flow required. Consequently, organizations must still be prepared to take ultimate responsibility for the success of their EDI initiatives; and, as new document types, formats, or intermediaries are added, the potential always exists for

new layers of computerized complexity to emerge.

At a functional level, EDI diversity is measured by how many different document types a given organizational function routinely exchanges with trading partners via EDI. As is shown in Table 7, a composite of several diversity measures is generally needed in order to grasp the progress being made regarding EDI diversity. More specifically, an organization able to exchange a large variety of document types across many of its functions using multiple EDI formats is positioned to gain further benefits through additional EDI interconnections with its trading partners. *Electronics*, in fact, was actually offering certain of its trading partners the use of its EDI network to exchange documents electronically among themselves in the belief that the goodwill generated through this gesture would further strengthen its business relations with these trading partners. Moreover, because the competitive advantage to be gained from any single EDI linkage is likely to be sustained for only a short period of time (Cox and Ghoneim, 1995; Wrigley, et al., 1994), increasing EDI diversity becomes necessary in order to further a business strategy focusing on the development of electronic interconnections with trading partners.

The greater the variety of documents exchanged, the more automated and standardized are that function's document generation, transmission, and reception processes; and it is largely through this automation and standardization that the efficiency benefits of EDI arise (Mackay, 1993; Nygaard-Andersen and Bjørn-Andersen, 1994). Such benefits are not limited to an organization's externally oriented transaction flows. For example, *Electronics* began its EDI activities in order to move information between geographically dispersed business units in a more efficient way.

Tactically, there are two approaches to increasing functional EDI diversity. First, the number of distinct document types being electronically exchanged by a function can be increased. Because the data comprising one function's documents often comes from related processes within that same function or from the organization's other functions, such actions invariably increase the extent of data integration across the organization. *Communicate*, for example, developed an internal electronic connection between its purchasing and accounting functions to enable more efficiency in exchanging invoices and other purchasing documents (i.e., purchase orders, change orders, and acknowledgements) with nine of its suppliers. Similarly, *Voice* developed an electronic link between its marketing and production functions to enable it to more efficiently process sales orders accepted via EDI.

The second approach for increasing functional diversity is to increase the number of formats by which a given document can be electronically exchanged in order to increase the accessibility of the function's documents to external trading partners. However, as this strategy often requires the acquisition or development of translation or data extraction software as well as other format-related software enhancements, it initially may not prove cost-effective (McLauchlin and Sturrock, 1994; Profant, 1994). Only one of the case sites, *Electronics*,

Table 7. EDI Diversity Reported by Case Sites

Case Site	Number of Business Functions	Number of Document Types	Standards Supported
Communication	2	6	ANSI
Defense	4	12	ANSI & proprietary
Electronics	5	11	ANSI & proprietary
Voice	1	6	ANSI
Semiconductor	2	6	ANSI
SwitchOne	1	3	ANSI
SwitchTwo	1	5	ANSI

was actively expanding the formats with which it could exchange EDI documents.

EDI depth

EDI depth refers to the degree of electronic consolidation that has been established between the business processes of two or more trading partners.[2] While notions related to EDI depth most often reference the technological sophistication of the connections between trading partners (Emmelhainz, 1987; Forge, 1989; Jackson, 1994), the existence of rather "deep" connections between technologically unsophisticated trading partners within a few of the case sites suggests that EDI depth might best be understood through an assessment of the nature of the business process connections among trading partners.

As is shown in Table 8, three levels of EDI depth are defined. The shallowest of the three involves file-to-file connections. In this case, an electronic document generated in one organization is electronically transmitted to and electronically accepted by a trading partner. However, once accepted, the document is downloaded in an offline mode and manually entered into the receiving organization's document or transaction processing system. For example, an EDI/FAX arrangement whereby an EDI-capable organization transmits an elec-

tronic document to a trading partner that can only accept facsimile transmission would fall into this category.

The mid-level of EDI depth involves application-to-application exchanges. With such interconnections, documents are automatically generated, sent, received, acknowledged, and processed by software applications operated by the electronically linked trading partners. More specifically, the EDI-enabled application of the initiating partner generates the document, or transaction set, and sends it electronically to the EDI-enabled application of the receiving partner. The receiving EDI-enabled application electronically acknowledges receipt of the document, or transaction set, by responding to the initiating partner with an electronic reply known as a functional acknowledgement. Once the functional acknowledgement has been transmitted, the EDI-enabled application of the receiving partner proceeds to process the document, or transaction set, electronically. It is this type of electronic connection that is most frequently referred to in literature as an "EDI application" (Bass, 1989; Cox and Ghoneim, 1995; Haugen and Behling, 1994; Mackay, 1993).

The most sophisticated of the three levels of EDI depth entails coupled work environments. Under this arrangement, computer-based applications of one, or both, trading partners can directly access data maintained within the

Table 8. EDI Depth Reported by Case Sites

Case Site	File-to-File	Application-to-Application	Coupled Work Environment
Communicate	finance	purchasing	
Defense	logistics	marketing purchasing logistics	finance logistics
Electronics	logistics	marketing purchasing finance logistics	logistics
Voice		marketing	
Semiconductor	marketing	purchasing	marketing
SwitchOne			purchasing
SwitchTwo	purchasing		

computer-based systems of the other trading partner. At this level of EDI depth, computer-based applications automatically handle specific operational transactions, and humans within the organizations handle the more subtle or less-defined tasks and decisions associated with the affected business processes.

Given the economic and strategic costs of increasing EDI depth, this aspect of EDI usage is unique among the four facets given that it is not the case that establishing greater EDI depth is always desirable. Similar to the rules of ABC analysis for grouping inventory items into categories for more effective materials management (Krajewski and Ritzman, 1994), decisions regarding the depth of the EDI linkage to be established with a specific trading partner can be based on the frequency and information value of the transactions involved with the trading relationship. The frequency of transaction exchanges enables the direct efficiency benefits of EDI, while the potential to obtain salient process information can affect both efficiency and effectiveness. Trading partners with a high frequency of and value to their functional transactions are desirable candidates for coupled work environments. For example, *SwitchOne* has developed a coupled work environment with its most important suppliers of mechanical components and equipment. Under this arrangement, manufacturing instructions and design specifications for *SwitchOne*'s purchase orders are electronically generated and sent to the suppliers' production systems. Upon arrival, the suppliers' production systems are automatically configured and scheduled. This relationship has resulted in both efficiency and product quality improvements.

Trading partners with high frequency but marginal value transactions are good candidates for application-to-application work environments. To illustrate this relationship, consider *Voice*'s EDI-based marketing relationship with its customers. By off-loading order-taking from its sales force (orders are handled through EDI connections), its sales staff is able to focus interactions with customers on determining how better to meet current and future customer needs instead of simply taking orders.

For trading partners characterized by low transaction frequency and value, file-to-file EDI depth may very well suffice, enabling many of the efficiency benefits of EDI to be realized without having to bear the investments typically associated with more sophisticated electronic linkages. *SwitchTwo*, for example, utilizes application-to-application EDI connections for its manufacturing purchases but file-to-file EDI connections for its less frequent, less significant purchases of office supplies.

It is also important to recognize that EDI depth depicts the permeability of an organization's boundaries. While greater permeability does increase an organization's flexibility and adaptability, it can also result in the organization being more vulnerable to external intrusions and/or influences. By selectively deploying EDI depth levels to account for these business process concerns, it is possible for an organization to strike an effective balance between responsiveness and independence.

Discussion and Conclusion

We believe that measurement strategy represented by these four facets of EDI usage presents a comprehensive schema for both directing an organization's EDI initiatives and framing research efforts examining the nature and impacts of such initiatives. Most important, our approach to measuring EDI usage offers a robust conceptualization for linking EDI strategy to operations. When a limited perspective of EDI is used to direct a firm's EDI efforts, misguided expectations and suboptimal outcomes are likely. For example, when depth concerns are emphasized at the strategic level, the resulting perception is that full-scale electronic integration is needed for EDI to provide sustainable competitive advantage (Swatman, et al., 1994); or, when breadth is emphasized at the strategic level, industry standards, customer capabilities, and trading partner relationships become fundamental to sustained competitive advantage from EDI (Mackay, 1993). But, when breadth and depth are considered together strategically, EDI use becomes a versatile service that attracts new and old cus-

tomers while improving internal operating efficiency (Jelassi and Figon, 1994). Because each facet emphasizes its own set of considerations and impacts, initiatives that apply a limited view of EDI tend to produce ambiguity regarding exactly how the organization will benefit from EDI use. Applying the broader view of EDI reflected by all four EDI usage facets, an enriched understanding of why, where, and how to apply EDI is more likely to arise across an organization's managers and business professionals.

Applying the framework developed in this article, Table 9 suggests how organizations and researchers might measure the nature and extent of EDI usage. Similar to the concept of ratio analysis in determining an organization's financial health, tracking the four facets over time can enable an organization to assess how well it is adapting to the electronic market place. Adopting a consistent approach to EDI measurement is even more important for research. As indicated earlier, most empirical studies of EDI use and EDI impacts have employed a diverse rather than narrow set of measures (refer back to Table 4). Without a

consistent context for exploring EDI, there can be no definitive way to generalize findings across applications, organizations, or industries. In fact, the popular belief that EDI is not yet worth the cost (McLauchlin and Sturrock, 1994) and the common action of waiting for coercion to implement EDI (Johnson, et al., 1992) may both stem from the lack of a consistent and effective means to document and track the nature and extent of EDI applications.

In conclusion, the proposed EDI measurement strategy offers a comprehensive context in which to conceptualize, understand, and measure EDI usage. We anticipate that, through the use of this (or a similar) measurement approach, organizations will be able to develop more robust and effective EDI applications, and researchers will be able to employ more robust and consistent assessments of the impact of EDI initiatives on intra- and interorganizational business processes. Finally, we hope both managers and researchers will be motivated to apply our measurement strategy and, most importantly, to identify refinements, extensions or other improvements.

Table 9. Measures of EDI Volume, Diversity, Breadth, and Depth

Facet	Measurement Level	Measures	Interpretations
Volume	Functional	% of function's documents exchanged via EDI	Intensity of EDI activity within the function
	Organizational	% of organization's documents exchanged via EDI	Intensity of EDI activity within the organization
Diversity	Functional	% of function's trading partners linked via EDI	Function's openness to EDI relationships with partners
	Organizational	% of organization's trading partners linked via EDI	Organization's openness to EDI relationships with partners
Breadth	Functional	Number of document types exchanged via EDI; Specific standards used	Extent of electronic document integration and exchange within the function
	Organizational	Number of functions using EDI; Number of document types exchanged via EDI	Extent of electronic document integration and exchange within the organization
Depth	Functional	% of EDI linkages at each depth level	Nature of the electronic relationship with partners
	Organizational	% of EDI linkages at each depth level	Permeability of an organization's boundaries

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Endnotes

1 Our notion of diversity has been previously defined in the literature as "internal integration" (Iacovou, et al., 1995). We are suggesting the term "diversity" as an alternative for the following reasons. The term "integration" has been and commonly continues to be used within the field of information systems to refer to a variety of electronic connections that have nothing to do with EDI. Moreover, we feel the term "internal" is not as explicit as "diversity" in suggesting tactics to managing EDI implementations.

2 Our notion of "depth" has already been referred to in the literature as "external integration" (Iacovou, et al., 1995). We prefer the term "depth" for the following reasons. First, in addition to its general overuse, we feel the term "integration" emphasizes the technological aspects of EDI connections between trading partners that may or may not be significant for a given application. Second, we feel the term "external" re-enforces the notion of separation between partners that EDI, by its very existence, is attempting to overcome.

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