An Empirical Examination of Product-Process Matrix Position and EDI Implementation

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The literature proposes that the implementation of EDI should be consistent with a manufacturer's operational strategy, yet very few studies consider the relationship between these two areas. This study attempts to bridge that gap in the existing research by empirically investigating whether the four facets of EDI are being implemented in manufacturing organizations in a manner that is consistent with their position in the Product-Process Matrix. Data from manufacturing plants in three industries and four countries are classified into strategic groups according to their position in the Product-Process Matrix. These groups are statistically analyzed using ANCOVA. Manufacturers are implementing the facets of EDI that correspond with increased efficiency – in a manner that is consistent with their operational capabilities. However, we did not find evidence that manufacturers' operational strategies, as indicated by their position in the Product-Process Matrix, were being followed, when it came to the implementation of EDI Diversity.

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I. INTRODUCTION

Electronic Data Interchange (EDI), which has historically involved computer-to-computer exchange of standard business documents, is a type of standardized inter-organizational information system that allows suppliers and customers to communicate directly with one another. More recently, with advanced technology, firms are utilizing the internet to facilitate EDI-type linkages. EDI, whether through direct connections, internet enabled, through third party providers, or accomplished through other means is a form of Supply Chain Management System (SCMS) (Subramani, 2004, p. 46, Craighead, Patterson, Roth, and Segars, 2006), which are one category of inter-organizational information systems (IOS) -- systems that span the boundaries of supply chain participants (Barrett and Konsynski, 1982; Craighead, Patterson, Roth, and Segars, 2006).

EDI has been hailed as a means of improving the competitiveness of firms. Prior research classifies the perceived and realized benefits of EDI into either strategic or operational benefits (Dearing, 1990; Subramani, 2004, Craighead, Patterson, Roth, and Segars, 2006). Unfortunately, the literature is somewhat inconclusive as to the realization of perceived benefits of EDI usage (Ahmad and Schroeder, 2001; Craighead, Patterson, Roth, and Segars, 2006; Lee, Clarck and Tam, 1999). With few exceptions, the literature has been almost silent regarding why the perceived benefits are or are not realized. One explanation that has been advanced is that information technology solutions that are not closely aligned with organizational and operational strategies may not deliver the performance expectations that are expected, or that are valued by the firm's customers (Lee and Bai, 2003).

Early research indicated the implementation of EDI had been limited to larger firms, due to the capital intensity and the complexities of implementation, as well as other reasons. However, with third party facilitation of internet-based implementations of EDI, many small and medium sized firms are seeking the potential advantages of EDI. For example, in 2003, the U.S. government began providing E-business and EDI capabilities to small businesses, in order to encourage broader competition for governmental contracts. As EDI and EDI-like services and systems become more accessible to firms, the adoption and usage of these systems are likely to expand. Increasingly, firms need to understand the strategic implications of EDI adoption for operational and firm performance. In particular, firms need to understand how each facet of EDI (Breadth, Volume, Depth and Diversity) interacts with the firms' operations strategies in order to exploit EDI systems to attain competitive advantage.

II. THEORY AND HYPOTHESES

In this section, we give a brief description of the Product-Process Matrix, which we use as a means of understanding the strategic orientation of the manufacturer. Next, we define four facets of EDI that have been used in previous research. Then we discuss how the Product-Process Matrix relates to the four facets of EDI. During this discussion, we state the hypotheses to be tested.

2.1. The Product-Process Matrix

The Product-Process Matrix (Hayes and Wheelwright, 1979a, 1979b, 1984) is based on the rationale that manufactured products and production processes typically follow "life-cycles". Recent research appears to be validating the Product-Process Matrix, particularly when advanced manufacturing technologies are accounted for (DeMeyer and Vereecke, 1996; Safizadeh, Ritzman, Sharma, and Wood, 1996; Ahmad and Schroeder, 2002; Devaraj, Hollingworth, and Schroeder, 2001).

Early stages of Product and Process life cycles (Fig. 1) are often characterized by high product variety, low production volume, general purpose production technologies, low automation, and low capital investment. These stages are generally supportive of operational strategies that capitalize on innovation and flexibility, including, but not limited to broad product lines, product customization, product-based quality, and customer-responsiveness (Hayes and Wheelwright, 1979a, 1979b, 1984).

Mature stages of Product-Process life cycles are generally characterized by high volume production, standardized products, specialized production technologies that are typically highly automated, and generally require high capital investment. Late stages of the Product-Process Matrix are considered supportive of low-cost, time-based, and conformance-quality oriented outcomes that are consistent with product standardization and economies of scale – which require process specialization (Hayes and Wheelwright, 1979a, 1979b, 1984).

It is important to note that the analogy of product and process life cycles does not necessarily assume that all products or all processes will follow a life cycle to completion. Some products and, or processes begin their existence with the characteristics of maturity, while other suffer an early demise. Still others seem to have materialized in one particular stage and never leave that stage. We also note it is relatively common for individual manufacturing facilities to choose to compete on one particular segment of the Product-Process Matrix. This suggests that plants often choose to limit the range of the life-cycle in which they will actively compete. This study seeks to empirically examine if manufacturers use of EDI and their position in Product-Process Matrix correspond in a way that would be expected, based upon the capabilities of various facets of Edi and the characteristics and capabilities evident in different portions of the Product-Process Matrix. While we do acknowledge that facilities may change their positioning in the Product-Process Matrix (for example, as their products and processes mature), this study does not seek to understand how firms or facilities transition between stages of the life cycle and their relative use of various facets of EDI. We focus on where a firm is at in the Product-Process Matrix and what they are doing with respect to the facets of EDI to see if the expected correspondence between competitive priorities and operational and informational technologies exists.

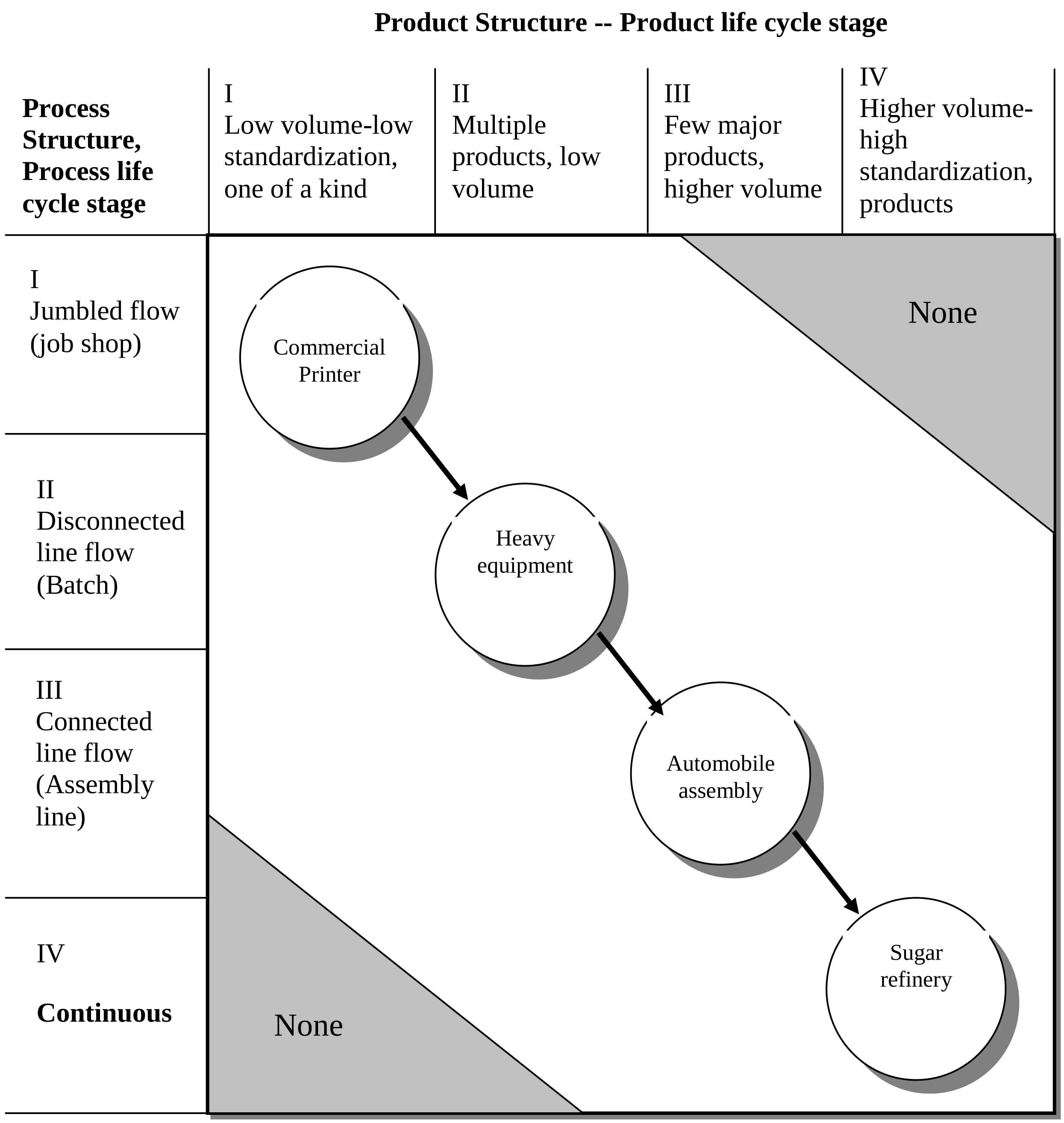

Figure 1. Product-Process Matrix.

2.2. Four Facets of Electronic Data Interchange

In an effort to provide a better understanding of links between EDI and operational plans, Massetti and Zmud (1996) highlight the need for taking a closer look at different aspects of EDI use. Specifically, they argue that the purpose for which EDI is being used in an organization and the way it is being measured are of utmost importance to understanding strategic implications of EDI usage. Based on observations at seven case sites, Massetti and Zmud (1996) provide an approach to EDI measurement consisting of four facets as described below.

EDI *Breadth* involves the extent to which a firm has developed EDI connections with its trading partners. The extent to which a firm's information exchange is handled through EDI connections indicates EDI *Volume*. The *Depth* of EDI usage is characterized by the degree to which a firm's business processes are interconnected with and hence, "inter-twined" with its trading partners. Finally, EDI *Diversity* is the extent to which different types of a firm's business documents are handled through EDI.

Most previously reported research took only one or two of the EDI facets into account (Droge and Germain, 2000). Consequently, these studies had limited ability to link EDI use to organizations' diverse strategic intents. For example, a study by Walton (1994) indicates that customer organizations adopted EDI to improve operational efficiency – one of the primary operational goals of firms at a mature stage of the Product-Process Matrix, but a relatively less-important operational goal for firms in an early stage of the Product-Process Matrix. A richer understanding of the linkages between operational strategies can be gained if one takes all four EDI facets into account. Based on the conceptualization and operationalization of four facets EDI by Massetti and Zmud (1996), we propose that various facets of EDI can appeal to different stages of Product-Process Matrix.

Hypotheses

Firms in the later stages of their product and process life cycles tend to focus their operations on obtaining and maintaining high levels of operational efficiency because they typically are competing primarily on price and operational efficiency reduces costs and supports strategies based upon price competition (Hayes and Wheelwright, 1979a, 1979b, 1984). One of the potential benefits of EDI is increased operational efficiency. Use of EDI has been credited with cost savings through reductions in error and administrative costs (Lee and Han, 2000). It stands to reason that the realization of these efficiencies should be directly contingent upon extent to which firms are able to take advantage of them. Therefore, the greater the number and or proportion of EDI connections that a firm has with its suppliers and customers, the greater the opportunity it has to reduce costs through enhanced operational efficiency. Therefore, we expect that the firms at the late stages of the Product-Process life cycles will be highly motivated to pursue EDI Breadth as a means of obtaining greater efficiency.

H1. EDI Breadth will be greater for manufacturers in the late stages of the Product-Process life cycles when compared to those who are in the early stages of the Product-Process life cycles.

While the breadth of EDI connections is expected to provide the potential for operational benefits in terms of cost efficiency, the realization of these benefits is also contingent upon the extent to which EDI connections are actually utilized. For example, if an EDI connection exists, but most transactions with supplier or customer at the other end of the connection occur through non-EDI means, then the anticipated cost efficiencies from EDI will not accrue. All other things being equal, the usage of EDI for a greater numbers of transactions with customers and suppliers should provide an increasing or cumulative cost-efficiency related benefit to the firm. Because firms in the late stages of the product and process life cycle tend to focus their manufacturing operations on cost efficiency, we would expect that they would find the potential efficiency gains through increased EDI usage to be highly attractive.

H2. EDI Volume will be greater in manufacturers that are in the late stages of the Product-Process life cycle when compared to those who are in the early stages of the Product-Process life cycle.

As previously stated, firms in the late stages of the Product-Process Matrix are seeking cost reduction and efficiency enhancement, in order to support increasingly price-based competition. In addition to previously mentioned sources of cost savings, another way in which efficiency is increased is through the integration of the stages of a production system. Increasing the inter-connectedness of the stages of production provides the opportunity to reduce or remove buffering mechanisms (such as inventory, time and physical space). Elimination of buffering mechanisms results in cost savings and increases in efficiency, because buffering mechanisms incur costs, while not providing added value.

The implementation of EDI provides the firm with another potential cost savings and efficiency enhancement opportunities by allowing the possibility of increasingly integrating the firms' internal production processes with their supplier's production and distribution processes and with their customer's purchasing and logistics processes. For example, a basic EDI connection might allow a firm to merely send an order electronically to a supplier, and receive electronic acknowledgement of that order. However, a more highly integrated EDI system may allow the firm to directly access their supplier's production scheduling to place the order, verify that production is proceeding as expected and even to expedite or delay production as needed. Increased inter-connectedness and access to customer and supplier process and systems via EDI connection provides the firm with greater opportunity to plan, schedule, monitor, and modify plans, "on the fly" as business conditions change. The ability to accomplish tasks such as those mentioned above, without the usual interpersonal interactions and typical time delays can contribute to a more efficient and less costly supply chain.

Additionally, increasing the interconnectivity of information flow from the supplier to the firm and to the customer would provide additional benefits in terms of increased efficiency of operations. By increasing the speed of information exchange up and down the supply chain, a firm can plan and operate its supply chain more optimally. Therefore, we hypothesize,

H3. EDI Depth will be greater in manufacturers that are in the late stages of the Product-Process life cycle when compared to those who are in the early stages of the Product-Process life cycle.

Firms that are positioned in early stages of Product-Process Matrix tend to compete primarily upon innovation, flexibility and product design and they tend to be relatively less concerned about cost efficiency. These types of firms are typically characterized by the production of a wide variety of products, usually in relatively small quantities, according to individual customers' needs. Likewise, the early stages or the Product-Process Matrix are characterized by relatively low product volumes and relatively high product variety. Because the primary orientation of these types of firms is on flexibility and innovation in design and production, we would expect that they would utilize technologies which facilitate those outcomes. EDI systems may support the exchange of a broad array of document types.

Specifically, the opportunity to exchange a broad range of information through EDI is particularly valuable to firms who are competing on innovation, flexibility and product design, because the ability to rapidly and effectively submit and receive requests for bids, exchange product designs and modifications to product designs, product specifications, resolve conflicts, and communicate contracts, provides substantial benefits in terms of speed, responsiveness, error prevention, and other forms of increased effectiveness. Thus, EDI Diversity is expected to be of particular value to firms that compete on flexibility and innovation in product design and development. Therefore, we hypothesize that,

H4. EDI Diversity will be greater in manufacturers that focus on the early stages of the Product-Process life cycle when compared to those who focus on the late stages of the Product-Process life cycle.

III. ANALYSES

The data used in this study were obtained from the World Class Manufacturing (WCM) study (e.g. Flynn, Schroeder, and Sakakibara, 1995, 1996) and were obtained from manufacturing facilities in four countries: Germany, Italy, Japan, and the United States. However, we excluded the earliest data collected (in the U.S. in the early 1990's). In each country, data were obtained from three industries: electronics, machinery, and suppliers of automobile & truck manufacturing (see Table 1). These industries represent important sectors of industrialized production. Industries were identified based on four-digit SIC codes in the American portion of the sample. The specific SIC codes used for the automobile industry: 3714; for Machinery: 3531 3532 3533 3536 3537 35413542 3547 3569 3589; and for Electronics: 3572 3573 3574 3651 3661 3674. In the other countries, a comparable industry selection method was identified and used because the SIC coding system used in the U.S. is not used in other countries in the sample. A summary of selected descriptive statistics for the sample is provided in Table 2.

Table 1. Sampling Frame.

		INDUSTRY			
		Electronics	Machinery	Transportation	Total
COUNTRY	Germany	9	11	13	33
	Italy	11	13	10	34
	Japan	17	14	15	46
	USA	10	10	10	30
	Total	47	48	48	143

Table 2. Descriptive Data for the Sample.

Characteristic	All Plants	Country			
		Germany	Italy	Japan	USA
Number of Salaried Employees	430	311	385	620	174
Number of Hourly Employees	758	704	292	1276	364
Year plant built	1960	1955	1961	1960	1966
Equipment age					
Less than 2 Years Old	15%	18%	16%	13%	14%
3-5 Years Old	30%	24%	32%	30%	30%
6-10 Years Old	26%	32%	24%	27%	25%
11-20 Years Old	20%	24%	21%	17%	23%
Over 20 Years Old	11%	10%	7%	12%	9%
Manufacturing Costs					
Direct Labor (% of Manufacturing Costs)	16%	22%	23%	12%	12%
Materials (% of Manufacturing Costs)	58%	52%	60%	60%	59%
Overhead (% of Manufacturing Costs)	22%	26%	17%	16%	29%
Production Processes					
One of a kind	13%	14%	13%	15%	8%
Small Batch	29%	34%	39%	16%	45%
Large Batch	16%	25%	20%	6%	13%
Repetitive / Semi Continuous	28%	11%	24%	34%	32%
Continuous	14%	15%	4%	28%	1%

Safizadeh, Ritzman, Sharma, and Wood (1996) reason and Bozarth and McDermott (1998) concur that the plant is the most appropriate unit of analysis for the dimensions underlying the Product-Process Matrix. Therefore, we used plant level data in this study. Approximately an equal number of plants were sampled from each industry and country in a stratified sampling design. Only plants with more than 100 employees were sampled to exclude extremely small plants, which might not represent the same population in a number of ways. To insure independence of the sampling units, random samples were obtained with at most one plant from each company sampled.

The plant manager was contacted by phone to request participation in the study. This approach resulted in an overall response rate of 60 percent. This atypically high response rate for a pencil and paper survey suggests that non-response bias is probably not a serious issue in this study. However, we performed t-tests to determine if the sample was different from the general population of manufacturing plants from these three industries. Data were obtained from the Annual Survey of Manufacturers conducted in the United States. This survey estimates a limited amount of industry-level data based on an annual survey. We were able to create a ratio of sales per employee from this source for the electronics and machinery industry. Sales per employee for our USA sample were not significantly different from the numbers provided by the Annual Survey of Manufacturers. While we cannot rule out non-response or self-selection bias in our sample, the preponderance of evidence suggests that it is probably not a serious concern.

3.1. Data and Measurement

The two dimensions of the Product-Process Matrix were operationalized following methods implemented in prior research (Devaraj, Hollingworth, and Schroeder, 2001). Product structure (product life cycle stage) was assessed using an index (see Appendix A) based upon the degree to which products are customized in manufacturing operations. Similarly, Process structure (process life cycle stage) was also operationalized using an index based upon Woodward's (1958, 1965) typology. Woodward's typology forms the basis for the process structure dimension of the Product-Process Matrix (Hayes and Wheelwright, 1979a, 1979b, 1984) (details are in the Appendix A).

Data were obtained from key informant managers in the production area, since it was highly unlikely that a random employee would have appropriate and sufficient knowledge of the product and production technology. A manager of Information Systems/Information Technology provided data concerning the Breadth, Volume, Depth and Diversity of EDI usage for both suppliers and customers. We followed the recommendations of Massetti and Zmud (1996) in operationalizing the EDI facets (see Appendix B). EDI Breadth was operationalized as the percentage of suppliers (or customers) linked to the manufacturer via EDI. The percentage of purchase orders (or customer orders) sent to suppliers (or received by customers) by means of EDI was used as a measure of EDI Volume. EDI Depth was measured as the percentage of purchasing (value) via blanket purchase orders (or sales) with call off (scheduling) by the plant (or by the customer). Finally, EDI Diversity was measured as the percentage of the data for design, drawing, and graphics (which are exchanged with suppliers or customers) that are exchanged electronically directly from computer to computer.

This study also incorporates plant size as a control variable. Plant size was operationalized as the annual revenues, stated in $US. The currency conversion was made at the time that data was collected.

Measures used in this study were based upon those used or discussed in prior research. Thus, the content (face) validity of the measures should be acceptable. Since most employees of a manufacturer would not have the specialized knowledge necessary to provide that data required for this study, all of the data for all measures in this study were obtained from key informants who were identified by their organizational position (responsibilities), in order to assure that we obtained valid and reliable data. While the data were obtained via pencil and paper survey, they were considered to be relatively objective; therefore, statistical analysis of the reliability and validity of the measures was deemed unnecessary (Huber and Power, 1985).

The potential for common respondent bias was completely avoided through the selection of different informants for independent and dependent variables. All data were obtained via pencil and paper survey, suggesting the potential for common methods bias. However, since the data used herein is "in principle, verifiable from other sources" or relatively "factual" (objective), Podsakoff and Organ (1986) suggest that common methods bias should be minimal, since objective data is least subject these types of bias.

The descriptive statistics (see Table 3) indicate a significant correlation exists between the process and product structure variables, which is consistent with what would be predicted by the Product-Process Matrix. Parallel measures of the customer and supplier EDI facets are all significantly correlated, ranging from .31 for Breadth and Depth of EDI to .629 for EDI Diversity, implying that an organization emphasizing a facet of EDI with its customers is likely to emphasize the same facet of EDI with its suppliers. This relationship appears to be the strongest, by a substantial margin, for customer—supplier EDI Diversity. In addition, the majority of supplier and customer EDI facets are found to be correlated. We note that the control variable (plant size) was not significantly correlated with the variables representing the Product-Process Matrix, but it was correlated with several of the supplier and customer oriented facets of EDI.

Table 3. Descriptive Statistics.

			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Mean	**s.d.**										
1. Process Maturity	306.08	103.56										
2. Product Customize	305.20	114.21	-.327**									
3. Supplier EDI Breadth	9.70	21.34	.257**	-.231**								
4. Supplier EDI Depth	39.92	37.91	.300**	-.106	.155							
5. Supplier EDI Volume	27.95	38.45	.126	-.264**	.419**	.227*						
6. Supplier EDI Diversity	7.71	16.42	.097	.120	.280**	.197*	.118					
7. Customer EDI Breadth	13.95	28.58	.174*	-.204*	.316**	.210*	.167	.157				
8. Customer EDI Depth	20.55	31.01	.160	-076	-.081	.313**	-.064	.076	.225*			
9. Customer EDI Volume	43.91	43.63	.368**	-.220*	.402**	.208*	.440**	.186*	.326**	.121		
10. Customer EDI Diversity	9.56	20.03	.114	.028	.189*	.162	-.047	.629**	.337**	.215*	.058	
11. Plant Size	200,209	438,468	.132	-.173	.389**	.224*	.172	.218*	.197*	.006	.215*	.151

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Means and standard deviations for the process and product maturity indices are based upon the values of the indices. Correlations between the values for the indices and the facets of EDI implementation were obtained based upon the re-coded values of the indices. See Appendices A, B.

Process maturity is significantly correlated with suppliers' EDI Breadth and Depth and with customer EDI Breadth and Volume. These correlations, which are consistent with the hypotheses 1-3, indicate that firms that have mature production processes (e.g. continuous production/ production lines) also have relatively higher supplier and customer EDI-Breadth. They also have greater supplier-EDI-Depth, and customer-EDI-Volume. However, some correlations, while not contrary to expectations from hypotheses 1-3, did not appear supportive of these hypotheses. In particular, neither, supplier-EDI-Volume nor customer-EDI-Depth was significantly correlated with process maturity.

Product customization (higher values in the index represent higher levels of product customization; lower values represent greater product standardization) was significantly negatively correlated with both supplier and customer EDI-breadth and EDI-Volume. This is consistent with hypotheses 1 and 2. No significant correlation was observed for either supplier or customer EDI-Depth with product customization – which would be expected, based upon hypothesis 3. Similarly, the correlations between both customer and supplier EDI-Diversity with product customization were not significant; however, they were both positive, which would be expected, based upon hypothesis 4.

3.2. Analysis of Covariance

To test hypotheses H1 – H4, an Analysis of Covariance (ANCOVA) was performed. Based upon the Product-Process Matrix, plants were classified into groups. "Group A" included the Low volume-high variety manufacturers.

This group represents manufacturers that focus on the early stages of the Product-Process life cycle. According to the Product-Process Matrix, these plants are organized to compete through flexibility and innovation. These plants had scores above 300 on the product index and below 300 on the process index (see Appendix A). The High volume-low variety manufacturers were classified into "Group B." This group represents manufacturers that focus on the late stages of the Product-Process life cycle. According to the Product-Process Matrix, these plants are organized to compete through product standardization and production efficiency. These plants had scores below 300 on the product index and above 300 on the process index (see Appendix A).

Manufacturers from groups A and B were retained in the analysis. The ANCOVA was then performed as a test of mean differences between manufacturers in the two relevant groups – on each of the four facets of EDI, while controlling for plant size. For each facet of EDI considered, supplier and customer data was analyzed. Table 4 summarizes the ANCOVA results, showing p-values for tests of group differences and also for the control variable (plant size). Table 5 provides group means for the facets of EDI, for both suppliers and customers.

The ANCOVA showed significant (P<.01) differences between the mean levels of suppliers' EDI: Breadth, Volume, and Depth. These results may be interpreted as supportive of hypotheses 1-3. Implementation of EDI linkages with suppliers is consistent with strategic operational objectives regarding cost and efficiency. This is somewhat consistent with prior research (e.g. Lee and Han, 2000) which found that EDI implementation has resulted in cost efficiency gains. However, our results should be interpreted somewhat differently. Our analysis does not indicate that firms are actually realizing cost savings and efficiency gains, but rather, it shows that firms in our sample are implementing those aspects of EDI that are intended to provide these benefits, WHEN that is consistent with their operational and organizational goals.

Table 4. ANCOVA (summary).

	Group Difference (p-value)	Plant Size (p-value)
H1: Supplier EDI Breadth (CRTLN09)	0.007	0.016
H2: Supplier EDI Volume (CRJSN01)	0.027	0.514
H3: Supplier EDI Depth (CRJSN02)	0.007	0.334
H4: Supplier EDI Diversity (CRETN01A)	0.959	0.007
H1: Customer EDI Breadth (CRTLN08)	0.043	0.572
H2: Customer EDI Volume (CRJCN01)	0.000	0.264
H3: Customer EDI Depth (CRJCN02)	0.369	0.422
H4: Customer EDI Diversity (CRETN01B)	0.693	0.312

The ANCOVA of customer-EDI facets revealed similar results. Mean differences between the two groups of firms were significantly different for Customer EDI-Breadth and EDI-Volume, providing additional support for hypotheses 1 and 2. However, Hypothesis 3 was not supported in this part of the analysis – the means for the two groups were not significantly different. EDI Diversity for suppliers and customers was not significantly different for manufacturers in the two groups. These results provide no support for hypothesis 4.

Table 5. Group Means.

Descriptive Statistics					
Dependent Variable	Group	N	Mean	Std. Deviation	Std. Error
Supplier EDI Breadth	A	40	1.20	3.60	0.57
	B	42	16.50	25.98	4.01
	Total	82	9.04	20.17	2.23
Supplier EDI Volume	A	37	16.32	28.88	4.75
	B	40	39.75	44.16	6.98
	Total	77	28.49	39.17	4.46
Supplier EDI Depth	A	37	29.96	31.46	5.17
	B	35	53.06	39.40	6.66
	Total	72	41.19	37.15	4.38
Supplier EDI Diversity	A	39	6.54	13.56	2.17
	B	42	6.07	13.12	2.02
	Total	81	6.30	13.25	1.47
Customer EDI Breadth	A	38	5.96	20.67	3.35
	B	40	22.10	35.87	5.67
	Total	78	14.24	30.38	3.44
Customer EDI Volume	A	31	21.45	35.85	6.44
	B	40	61.40	42.93	6.79
	Total	71	43.96	44.45	5.28
Customer EDI Depth	A	32	13.28	24.14	4.27
	B	38	24.74	33.15	5.38
	Total	70	19.50	29.73	3.55
Customer EDI Diversity	A	36	8.00	21.13	3.52
	B	40	10.50	20.56	3.25
	Total	76	9.32	20.73	2.38

IV. DISCUSSION

The results obtained from our ANCOVA analysis support the hypothesis that firms which follow a cost minimizing strategy will value EDI Breadth and EDI Volume because they have the potential to provide cost reductions and improve operational efficiency. This was true, both on the supply and customer side. Ideally, the greatest benefits should accrue when a relatively broad cross-section of suppliers and customers are connected to the customer firm AND when a relatively high volume of the firms transactions with suppliers and customers are executed through EDI connections. We would expect that the effects of these two facets are cumulative upon operational performance; however, we did not explore this question theoretically or empirically in this study.

The results of our analysis of EDI-Depth were somewhat mixed. While the group means were different for both customers and suppliers, only the supplier EDI-Depth showed statistically significant differences between the "High volume-low variety" group and the "Low volume-high variety" group. We interpret these results as supportive of our third hypothesis, again, indicating that firms appear to have recognized that the cost/efficiency benefits of EDI appear to be recognized and are being implemented fairly consistently with operational strategies. However, we temper that interpretation with a dose of caution and suggest that our findings in this particular hypothesis are subject to further interpretation, judgment, and additional study.

Contrary to our expectations, no difference in the average level of EDI Diversity was found between our two groups of manufacturers (High volume-low variety and Low volume- high variety). This result was the same for both supplier EDI and customer EDI. Plausible explanations for these results are discussed below.

One possible explanation of these findings is that the drivers of the usage of EDI Diversity are different from those of EDI Breadth, Depth, and Volume, especially when considering the differences between the two groups of manufacturers. For example, historically, or at least initially, EDI was adopted by firms which had access to the requisite (large) amounts of capital necessary for EDI implementation. Typically, this meant that the largest firms were first to invest in EDI. Large firms may be more likely to have relatively mature production processes and therefore, a particular desire to increase efficiency and cut or contain costs. Therefore, the initial adopters of EDI might be have been focused upon the cost and efficiency benefits of EDI and may have overlooked or not been overly concerned with potential benefits of EDI Diversity, since those potential benefits were not aligned with these firms strategic goals.

Another possible explanation of these results is that the efficiency-justification for EDI has been more clearly articulated and accepted, while the flexibility and innovation-orientation of EDI has received less attention. From a traditional operational view, this may not be surprising, since operations would generally expected to be concerned with the "efficiency-oriented" benefits of EDI, and perhaps less interested in the diversity-oriented benefits of EDI. Another consideration is the degree to which all of the facets of EDI are included in a manufacturers installed capability, whether or not a particular facet of EDI is desirable, from an operations strategy perspective. It is not uncommon to find that manufacturers install certain EDI facets regardless of their strategic orientations due to the EDI package offered by the vendor and/or influence exerted by a powerful trading partner (Teo, Wei, and Benbasat, 2003).

The preceding discussion may help explain the unanticipated results obtained in our analysis of EDI Diversity and raises some important questions: Are firms implementing EDI Diversity, even though it is not consistent with their operational strategies? Does EDI implementation necessitate EDI Diversity – as part of the EDI implementation "package"? Are manufacturers using EDI Diversity capability, even though it provides no apparent benefits? Are manufacturers missing the opportunity to capture the strategic benefits from EDI Diversity, perhaps because there has been too much emphasis placed on cost efficiency? As small firms become greater users of EDI, will we see a difference in the utilization of EDI Diversity based upon firm size? Our correlation analysis hints at a response to that last question. We observed that plant size was significantly related to supplier-EDI Diversity however, it was not significantly related to customer-EDU Diversity. Finally, will the adoption of EDI by many more small and medium sized firms, whose strategic intentions often differ dramatically from large firms, have an effect upon the behavior we have seen in our data set? Further research into the implementation of different facets of EDI and their operational benefits, may provide answers to these questions.

V. LIMITATIONS

This study has a number of limitations, each of which provides opportunities for further research. First, the construction of the sample is limited. Only a few countries were included in the study. Additionally, only a few industries were included. Also, the sample size is relatively small. A large scale sample that analyzes data from many industries and many countries would certainly be more persuasive. Another limitation of this study is the age of the data that were used in the analyses. EDI was an emerging technology, implemented primarily through direct connections. Since this data was collected, access to EDI technologies has substantially increased, allowing medium and even smaller firms to economically participate in EDI usage. Smaller firms are known to be more nimble and more creative than larger firms, and as such, they may lead the way in using EDI, not only for increases in efficiency, but as a means of leveraging their varied strategies. Therefore, replication studies that use more current data might shed light on the evolution of EDI usage, particularly as it relates to manufacturing strategies. Finally, we used only one methods of articulating a plant's manufacturing strategy – the Product-Process Matrix. Several other classification schemes exist for assessing or determining a firms manufacturing strategy. Future studies may consider different manufacturing strategy models or frameworks. Examination of EDI implementation, relative to other manufacturing strategy frameworks will broaden and improve our understanding of how firms manufacturing strategies and the implementation of EDI are related.

VI. CONCLUSION

Using an international sample of manufacturers from three industries within four industrialized countries, we found evidence that manufacturers are implementing EDI Breadth, Depth, and Volume that support cost-efficient manufacturing operations consistent with the manufacturers' operational strategies. However, we did not find evidence supporting the implementation of EDI Diversity in a manner that was consistent with manufacturers' operational strategies.

While reviewing the literature related to EDI implementation, Massetti and Zmud (1996: 332) noted, "What seems absent is a rich, tactical understanding that links strategic expectations regarding EDI with operational plans for potential implementations." The present study is an attempt to begin to address that concern. Our findings, while tentative, indicate that the implementation of cost-focused facets of EDI is connected to the strategic operational objectives. Future adopters and implementers of EDI and similar technologies should give careful thought to how these technologies leverage and extend the strategic operational objectives of the firm.

The present research is a cross-disciplinary study that cuts across operations management and information systems disciplines. This study extends Massetti and Zmud's (1996) case based research in the context of the Product-Process Matrix. Much research is needed to better understand how various facets of EDI interact with the stages of Product-Process Matrix and other operations strategy frameworks in order to better understand how firms may utilize EDI and related technologies to generate superior operational and organizational performance.

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APPENDIX A.

Process Type Index

The production process in this plant is best characterized as follows (what percent of product volume fall into each category)?

_____%		One of a kind (Onekind)
_____%		Small batch (Smlbtch)
_____%		Large batch (Lrgbtch)
_____%		Repetitive/line flow (Repline)
_____%		Continuous (Continu)
100%	=	(Total)

Process Index = (1* Onekind) + (2* Smlbtch) + (3* Lrgbtch) + (4* Repline) + (5* Continu)

Interpret the index as follows: Low values (100- <300) represent production of unique items, while high values (>300-500) indicate mass production. Note: For purposes of analysis, plants scoring 100 - <300 were coded with a value of zero and plants with values greater than 300 were coded with a value of one.

Key Informant: Production Process Engineering Manager

Product Type Index

Overall, how extensively are products customized in your plant (what percent fall into each category)?

_____%	Highly customized (highcust)
_____%	Somewhat customized (somecust)
_____%	Standard with custom options (stancust)
_____%	Somewhat standardized (somestnd)
_____%	Highly standardized (highstnd)
100%	(Total)

Product Index = (1* highstnd) + (2* somestnd) + (3* stancust) + (4* somecust) + (5* highcust)

Interpret the index as follows: Low values (100- <300) represent standardized products and high values (>300-500) indicate customized products. For purposes of analysis, plants scoring 100 - <300 were coded with a value of zero and plants with values greater than 300 were coded with a value of one.

Key Informant: Production Process Engineering Manager

Plant size (used as a control variable/covariate)

Sales value of production $000 (The sales value of production, stated in $US)

APPENDIX B.

Facets of EDI:

EDI Breadth

_____%_____ What is the percentage of suppliers linked to this plant via EDI?
_____%_____ What is the percentage of customers linked to this plant via EDI?

EDI Depth

_____% Percentages of purchasing (value) via blanket purchase orders with call off (scheduling) by the plant.
_____% Percentage of sales via blanket purchase orders with call off (scheduling) by the customer

EDI Volume

_____% Percentage of purchase orders sent to suppliers by means of EDI (Electronic Data Interchange).
_____% Percentage of customer orders received via EDI (Electronic Data Interchange).

EDI Diversity

What percentages of the data for design, drawing and graphics are exchanged electronically directly from computer to computer?
_____% With Suppliers
_____% With Customers

Key Informant for all EDI questions: MIS Manager