12-2001

Determinants of electronic data interchange adoption in international buyer -supplier communications

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DETERMINANTS OF ELECTRONIC DATA INTERCHANGE ADOPTION IN INTERNATIONAL BUYER-SUPPLIER COMMUNICATIONS

A Dissertation

By

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Submitted in partial fulfillment of the requirements for the degree of

DOCTORATE OF PHILOSOPHY IN BUSINESS ADMINISTRATION WITH AN EMPHASIS IN INTERNATIONAL BUSINESS

Submitted to

The Faculty of the Graduate School of

The University of Texas-Pan American

1201 West University Drive

Edinburg, TX 78539-2999, USA

December 2001

Major subjects: Production and Operations Management and International Business

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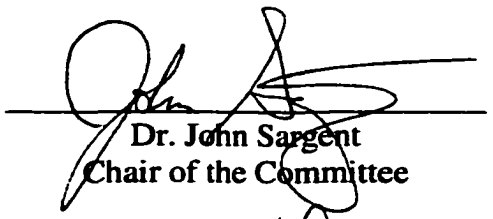

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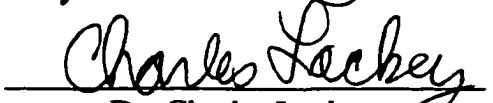

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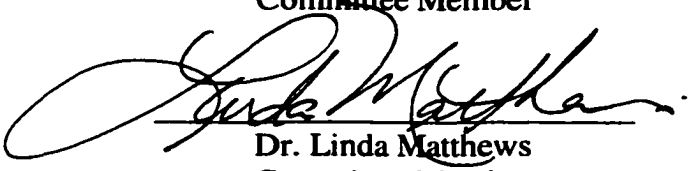

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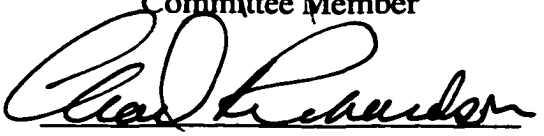

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December 2001

ABSTRACT

Gavidia, Jose V. Determinants of electronic data interchange adoption in international buyer-supplier communications. Doctorate of Philosophy in Business Administration (Ph.D.), December 2001, 136pp., 22 tables, 8 illustrations, references, 230 titles.

In spite of the increased interest in supply chain management in recent years, few studies have examined the adoption of the technologies that facilitate information flows along the supply chain. Information flows have been shown to have a positive effect on economic efficiency and supply chain partner satisfaction. The adoption and use of information technologies to communicate with suppliers can also stimulate small business growth and foster regional economic development.

This dissertation develops and empirically tests a model of the determinants of the adoption of interorganizational information systems, specifically electronic data interchange (EDI), between buyers and suppliers in international supply chains. Plant level data from the Mexican maquiladora industry allows focusing specifically on international supply chains. EDI use is measured both as a binary variable, and as a set of metric dimensions. As the main determinants of EDI adoption, this study compares economic efficiency, operationalized as the perceived benefits of EDI use, and

institutional factors, operationalized as external pressure to adopt EDI. In addition, hypotheses are tested on the impact of plant size, industry, and type of purchase, on EDI adoption. Multivariate statistical analysis is used to test the hypothesized relationships, and logit and tobit models are also used to assess the impact of variables on dichotomous and metric EDI use variables respectively.

This study provides valuable insight into the process of technology adoption in multinational corporations and new information on the use of information technology in the maquiladora industry. The conclusions drawn from this study are useful for economic development and planning, supplier development, and the management of multinational firms and supply chains.

DEDICATION

A mis maravillosos padres, José y Carmina.

ACKNOWLEDGEMENTS

I would like to express my gratitude to the members of my dissertation committee for their help and guidance. It was my privilege to have such distinguished scholars in my committee. I am also grateful to the director of the Doctoral program, Dr. Michael Minor, for his encouragement. Dr. Ercan Nasif provided motivation and assurance while I was a graduate student. The moral support of my fellow Doctoral students was instrumental during so many long nights of work.

I also wish to thank Mr. Roland Arriola for his generous support and encouragement since I came to Edinburg. Mr. Raul Zarate and Jesus Barrera from SECOFI provided me with their immense knowledge of the maquiladora industry, and gave this study institutional support. Francisco Gonzales and other personnel at UTPA CoSERVE provided extensive assistance during the data collection process, and my good friend Kenan Tas was always there with his altruistic help.

TABLE OF CONTENTS

Page

ABSTRACT iii

DEDICATION v

ACKNOWLEDGEMENTS vi

LIST OF TABLES x

LIST OF FIGURES xii

CHAPTER 1 INTRODUCTION 1

Purpose and relevance of the study 4

Timeliness of the study 6

CHAPTER 2 LITERATURE REVIEW 9

Supply Chain Management 9

Information flows in the supply chain 13

EDI Defined 14

Dimensions of EDI 16

Impact of EDI 16

Adoption of EDI 27

Determinants of EDI adoption 29

Perceived benefits. 30

Perceived compatibility with present systems 32
Barriers to EDI adoption 33
Shortcomings of EDI use 34
EDI in international transactions 35
The Mexican maquiladora industry 37
CHAPTER 3 RESEARCH METHODOLOGY 40
Research Objectives 40
Research Hypotheses 41
Target Population 48
Case studies and interviews 49
Survey Development 52
Survey Administration 54
Analytical Methods for Hypothesis Testing 56
CHAPTER 4 RESULTS OF THE PLANT INTERVIEWS AND SURVEY 58
Plant interviews 58
Statistical analysis 62
Analytical research statistics 70
Factor Analysis 71
Logistic regression 74
Discriminant analysis 76
Tobit model for EDI use dimensions 78
Test for differences in EDI use across industries. 79

CHAPTER 5 FINDINGS AND CONCLUSIONS 82

Findings 82

Implications for firms 88

Implications for policy making 90

Research directions 91

REFERENCES 93

APPENDIX A: SPANISH SURVEY QUESTIONNAIRE 111

APPENDIX B: ENGLISH SURVEY QUESTIONNAIRE 117

APPENDIX C: SURVEY COVER LETTER 123

APPENDIX D: REPORTS OF INTERVIEWS WITH MAQUILA MANAGERS ... 125

APPENDIX E: USE OF COMPUTER COMMUNICATIONS IN THE MAQUILADORA INDUSTRY 135

VITA 137

LIST OF TABLES

Table 1. Buyer-Supplier Information Documents 2

Table 2. The Content of Supply Chain Management 11

Table 3. Impact of EDI Adoption 20

Table 4. Distribution of Maquiladora Purchases in 1999 38

Table 5. Summary of Plant Interviews 62

Table 6. Survey Response Statistics 64

Table 7. Industry of the Respondents 64

Table 8. Number of Employees per Plant 65

Table 9. Use of EDI in the Maquiladora Industry 66

Table 10. Reliability Statistics 71

Table 11. Bivariate Pearson Correlations 71

Table 12. Factor Analysis of Multivariate Measures 73

Table 13. Descriptive Statistics for Users and Non-Users 74

Table 14. Independent Samples T-tests 74

Table 15. Logistic Regression Coefficients 75

Table 16. Logistic Regression Classification Table 76

Table 17. Discriminant Function Coefficients and Loadings 77

Table 18. Discriminant Function Classification Results 78

Table 19. Tobit Estimates for EDI Metric Dimensions 79

Table 20. One-way Anova for Industry Differences 80

Table 21. Use of EDI with Suppliers by Industry 80

Table 22. Summary of Statistical Tests 81

LIST OF FIGURES

Figure 1. A model for EDI adoption 49

Figure 3. EDI standards in the maquiladora industry 67

Figure 4. EDI use by industries 68

Figure 5. Decentralization of the purchasing function 69

Figure 6. Perceived benefits of EDI 69

Figure 7. Barriers to EDI adoption 70

Figure 8. Use of communication technologies 136

CHAPTER 1.

INTRODUCTION

The process of vertical disintegration of manufacturing organizations during the 1970s and 1980s, followed by substantial mergers and acquisition activity during the 1990s, have radically changed the structure of manufacturing industries. From a largely vertical structure, where a few major corporations owned all the providers of the sub-processes and even raw materials needed for the elaboration of final consumer products, manufacturing has evolved into a more horizontal structure, in which firms specialize in key processes, gain large market shares in existing markets, expand to new ones, and take advantage of economies of scale to produce goods more efficiently (Womack, 1990).

In the context of today's increasingly horizontal structure, a few global players in each industry have specialized in their core processes, operate manufacturing plants geographically spread around the globe, and purchase from geographically spread specialized suppliers. Because of the large number of ownership layers in a horizontally integrated economy, manufactured goods cross a large number of organizational boundaries, and it is not enough to focus attention only on the immediate suppliers. The challenge today is to manage relationships along the entire supply chain, and that is the focus of supply chain management (SCM) (Cooper & Ellram, 1993; Tan, Kannan, & Handfield, 1998).

A key component of SCM is the flow of information along the supply chain (Bostrom & Heinen, 1977 a,b; Choi & Hartley, 1996; Fawcett & Clinton, 1996; Helper, 1991; Stewart, 1995; Strader, Lin, & Shaw, 1999). Table 1 lists some examples of the types of information documents exchanged between buyers and suppliers as cited in the literature. This information not only includes traditional logistics and purchasing-related documents, but also the technical and quality management documents necessary in advanced manufacturing environments (Richeson, Lackey, & Starner,1995). For example, the literature highlights the importance of sharing quality related information downstream in the supply chain (Garvin, 1983; Helper, 1991; Lin, 1991; O'Callaghan, Kaufmann, & Konsynski, 1992; Suresh & Meredith, 1985) as well as product related information through CAD/CAM files or product data management (PDM) systems (Baker, 1999; Miller, 1999).

Table 1

Buyer-Supplier Information Documents

Logistics	Technical	Purchasing	Quality
Production schedules	Drawings	Purchase orders	Part approval
Delivery schedules	Bill of Materials	Order acknowledgement	Inspection statistics
Material release	CAD/CAM files	Quotes	SPC data
Shipping notice	Specifications	Supplier ratings	Defective material notices
Inventory level	Materials	Adm. Data	Supplier quality data
Order status	Environmental requirements/data	Demand forecasts	
Transport mode		Invoices	
ID label		Billing	
Bill of lading		Catalogs	
		Supplier inventory	

The information flows in the extended enterprise can be conceptualized as a web of simultaneous multilateral communications linking not just supply chain neighbors, but

all the members of the extended enterprise. This information web creates an environment similar to a marketplace that allows economies of conjunction, that is, it allows multiple transactions otherwise independent to take place at the same place and time creating value and reducing cost. The extended enterprise uses information flows so that geographically dispersed units belonging to different firms can behave as a coherent production system without the need of vertical integration or relocation of productive resources (Greis & Kasarda, 1997; Malone, Yates, & Benjamin, 1987, 1989).

The traditional purchasing literature has identified two broad types of buyer-supplier interaction: (1) the market, with high flexibility but low integration between buyers and suppliers; and (2) the hierarchy, which requires long term commitment and trust to invest in relationship specific assets (Williamson, 1975, 1985). New information and communication technologies, such as electronic data interchange (EDI), are becoming more standardized and less relationship specific, allowing a closer inter-organizational integration without the risk involved in large expenditures in relationship-specific assets, and simultaneously overcoming the drawbacks of markets and hierarchies (Clemons & Row, 1992; Clemons et al., 1993; Malone et al., 1987, 1989; Prosser & Nickl, 1997; Holland & Lockett, 1997).

At the same time, the current explosion in internet traffic and their ease of access and low cost has made electronic communications affordable for even small suppliers (DeCovny, 1998; Deloitte Consulting, 1998). For all these reasons, the use of EDI is gaining more general acceptance and EDI related issues are becoming increasingly important to researchers (Yrle, Hartman, & Payne, 1999).

Purpose and relevance of the study

The purpose of this dissertation is to develop and empirically test a model that explains the determinants of the adoption of EDI between manufacturers and their suppliers in international supply chains. The model is tested in in-bond industrial plants in the Mexican state of Tamaulipas. In-bond plants in Mexico are generally known as maquiladoras or maquilas, and these terms will be used interchangeably throughout this dissertation.

This study specifically examines the extent to which maquiladora plants use or plan to use EDI to communicate with their suppliers, identifies the factors leading to EDI adoption in maquila plants, and determines whether plants using EDI differ from those not using EDI. The study also clarifies the type of technology maquiladoras use to communicate with their suppliers. The issue of the decentralization of the purchasing function between corporate headquarters and plant is of particular interest here because maquiladoras are typically dependent and controlled by a parent firm outside Mexico (Grunwald & Flamm, 1985).

In spite of the importance of local manager's perceptions regarding the economic efficiency of the new technology, supply chain institutions such as customers, suppliers, or industry regulatory organizations play an important role today in technology adoption decisions. For example, in previous studies of EDI use in the transportation industry, it was found that the decision to adopt EDI is more influenced by customer service considerations than by economic efficiency (Crum, Johnson & Allen, 1998; Johnson, Allen & Crum, 1992). Attempting to clarify this issue, this study compares economic efficiency, operationalized as perceived benefits of EDI use, and institutional factors,

operationalized as external pressure exerted on the plant to adopt EDI, as the main determinants of EDI adoption.

Stank, Emmelhainz, & Daugherty (1996) have shown that exchanging information with suppliers is positively related to supplier performance, and concluded that firms should include EDI implementation support in their supplier development efforts. Although the literature suggests that manufacturers should be involved in supplier development activities, there is evidence to suggest that the actual practice of buyer-supplier cooperation in information technologies is very limited. For example, a survey of suppliers in the automotive industry showed that most buyer-supplier relationships involve low levels of commitment and information exchange, although those levels were gradually increasing (Helper, 1991). In addition, a study by Walton (1996) suggests that differences in operational information exchanges, particularly in the form of EDI, account for a significant amount of variance associated with supply chain partnership satisfaction and that managers are not satisfied with the state of information exchanges with their supply chain partners.

This study addresses these important issues by analyzing the adoption of EDI between buyers and suppliers, and provides normative insight for the management of firms and supply chains. Since the ability to exchange information with supply chain partners is increasingly becoming a requirement to becoming a member of the supply chain (Choi & Hartley, 1996), the use of information technologies can stimulate small business growth which is an important factor of regional development (La Rovere, 1998; Thwaites & Oakey, 1985). To the extent that firms are using or planning to use the

ability to exchange information as a supplier selection factor, this study also has important implications for policy making and economic development.

Timeliness of the study

It has been reported that US firms lead those of other countries in the use of information technology, but this use of technology has not yet achieved its potential impact on the improvement of inter-firm cooperation (Bensaou, 1997). In spite of the numerous reports showing the positive impact of EDI on profitability and operational performance (Banerjee & Sriram, 1995; Bowersox & Daugherty, 1995; Rogers, Daugherty, & Stank, 1992), the use of this technology by organizations has been traditionally low (Ferguson, Hill, & Hansen, 1990; Hendon, Nath, & Hendon, 1998; Pfeiffer, 1992; Gottardi & Bolisani, 1996; Richeson et al., 1995), although it is gradually increasing (e.g. Crum et al., 1998).

While EDI technology has existed for decades (Emmelhainz, 1990; Pfeiffer, 1992), many firms and industries have active projects and programs designed to normalize, facilitate, and enforce EDI adoption. The increased importance of time-based competition, the implementation of the "Just-in-Time" (JIT) concept in manufacturing, and the increasing interdependence of global supply chain partners require the development of stronger links between buyers and suppliers. At the same time, the decreasing cost of communication equipment encourages firms to invest in systems that improve the exchange of information with international supply chain partners (Hendon et al., 1998). For example, the Automotive Industry Action Group (AIAG), an organization created by DaimlerChrysler, Ford Motor Company, and General Motors with the purpose of enhancing cooperation in the automotive supply chain, has established an

EDI/electronic commerce project team in order to deal with supply chain issues such as the adoption of EDI and other communication technologies between trading partners (http://www.aiag.org/projects/ecommerce.html). In compliance with AIAG regulations, first tier suppliers to the automotive manufacturers are establishing guidelines that their (second tier) suppliers must follow to ensure consistency in the use of EDI along the automotive supply chain. Accordingly, since Bosch supplies parts in North America to General Motors, Ford, and DaimlerChrysler, the firm is instructing its suppliers to implement EDI through the IBM Global Services Value Added Network (VAN) (http://www.boschusa.com/media/pdfs/Delivery2.pdf). Likewise, Delphi Automotive Systems implemented EDI using the EDIFACT standard in their facilities worldwide during the years 1999 and 2000 (http://www.delphiauto.com). In the aerospace industry, Boeing Commercial Airplanes Group is developing its supplier network EDI program to be implemented in support of their Enterprise Resource Planning (ERP) system (http://www.boeing.com/companyoffices/doingbiz/edi).

Given the recent developments in the use of information technologies for business communications such as the use of the internet, and the fact that EDI is currently being implemented in major industries, this is a critical time to analyze the determinants and barriers to EDI adoption in global supply chains. This is particularly relevant given the recent trend toward vertical disintegration.

This dissertation is organized as follows: The second chapter presents the literature review. The third chapter presents the hypotheses, model, data collection issues, and the empirical methodologies employed to test the hypotheses. Chapter 4 contains the findings of interviews and the results of the survey data analysis, and chapter

5 provides conclusions and managerial implications, limitations of the study, and suggestions for future research.

CHAPTER 2.

LITERATURE REVIEW

This chapter will position the study in the supply chain management literature, providing evidence of the critical importance of information flows in supply chains. Next, EDI will be introduced, and different aspects of its adoption and impact will be analyzed in detail. Finally, the research question will be put in an international perspective, and the Mexican maquiladora industry will be introduced.

Supply Chain Management

Although the term supply chain management has been used since the early 1980s, its increasing importance has been linked to economic and business trends such as vertical disintegration, supplier base reduction, focused operations, outsourcing, JIT supply systems, and business partnerships with suppliers (Harland, 1996). A supply chain, which has also been referred to as the value chain or the distribution channel, can be viewed as the network of organizations through which materials and information flow in order to produce a good or service for the final consumer. The supply chain involves entities such as suppliers, carriers, manufacturing plants, distributors, warehouses, retailers and final customers, and even the disposal process (Cooper, Ellram, Gardner, & Hanks, 1997; Cooper & Ellram, 1993; Lee & Billington, 1995; Lummus, Vokurka, & Alber, 1998; Stewart, 1995).

The traditional supply chain is composed of individual value chain functions loosely connected by transportation and communication links across organizational boundaries. The problems of this lack of integration in the supply chain include high rates of error and distortion, unnecessary costs, longer reaction times to market demands, and a lack of strategic alignment along the supply chain (Stewart, 1995). The above problems cause a loss of logistic performance and undermine the competitive position of the supply chain as a whole.

While the traditional concept of "logistic system" as defined by Chiu (1995) analyzes the relationships between independent components, the broader concept of supply chain emphasizes the integration of all firms performing all sequential processes that are involved in the creation of a final product. Accordingly, SCM is an integrated administration of the material and information flows within and across firms, as the product is transformed from raw material to finished good delivered to final consumers (Cooper & Ellram, 1993; Cooper et al., 1997; Ellram & Cooper, 1990). The content of the SCM paradigm is summarized on Table 2.

SCM implies a strategic view of the supply chain, utilizing and coordinating the resources of all the members in such a way that it behaves as a "virtual organization" with the ultimate goal of final customer satisfaction. The need for coordination with each organization's suppliers gives the purchasing function a strategic relevance (Tan et al., 1998). The main goal of SCM is the optimization of operations across organizational boundaries and, therefore, the reduction of costs along the supply chain. For this reason, SCM has been related to lean supply, which is based on the recognition that all waste should be removed from the entire flow of materials from raw material to final consumer

product (Lamming, 1996). Waste includes any cost derived from less than perfect execution of any process or sub-process, and its reduction requires close coordination across supply chain members. For this reason, business to business communications are of critical importance in SCM.

Table 2

The Content of Supply Chain Management

1. Channel wide management of inventories.
2. Channel wide cost management.
3. Long term time horizon for supply chain membership.
4. Information sharing across the supply chain.
5. Coordination among multiple levels of the channel, not just the immediate channel members.
6. Continuous, long term planning process, involving several entities in the channel.
7. Compatible corporate philosophies and cultures.
8. Reduced supplier base.
9. Supply chain leadership.
10. Sharing of risks and rewards across supply chain members.
11. Speed of operations through the use of information systems.

(Source: Cooper & Ellram, 1993)

The design of supply chains involves such strategic decisions as plant location, capacity allocation, design of the distribution network, design of supplier base, selection of transportation modes, and use of manufacturing and communication technologies. These factors must be optimized for shorter cycle times and lower total costs, subject to constraints such as offset trade and local content requirements. Quantitative methods such as linear programming can be used to model supply chains (Arntzen, Brown, Harrison, & Trafton, 1995).

According to Harland (1996), SCM can be understood at four levels of integration: (1) internal integration of information and material flows, (2) management of dyadic buyer-supplier relationships, (3) the management of the whole chain formed by buyer-supplier links from raw materials to finished goods, and (4) the management of the whole network of businesses involved in the provision of a final product. The first level of integration, internal integration of materials and information flows, relates to the traditional paradigm which conceptualizes the firm as a closed system. The second, management of buyer-supplier dyadic relationships, considers the firm as an open system, and is concerned only with the activities of the direct supply chain partners. The modern supply chain management paradigm, however, is represented by the third and fourth levels, where the supply chain is conceptualized as an open system which interacts with the rest of the environment, and uses a common strategic planning (Li, 1999). Cooper et al. (1997) also defined four forms of supply chain integration, but they included "keiretsu" or vertical integration as the highest form of supply chain integration through partial ownership of supply chain partners.

Consistently with the information technology perspective of the firm, some authors point out that by increasing the speed and reliability of information flows, new information technologies can reduce business to business transaction costs, and make outsourcing a more attractive option over vertical integration (Malone et al., 1987, 1989). EDI plays an important role within SCM, facilitating the information exchange between supply chain members, and having a positive effect on responsiveness, flexibility, and dependability (Crum et al., 1998).

Information flows in the supply chain

In the traditional mass production paradigm, the lack of trust between buyers and suppliers led the latter to conceal information from the buyer, especially if it was related to costs or production issues. Suppliers rightfully feared that if they released any information to buyers, they would use it to gain a larger profit share at the expense of the supplier or, even worse, provide it to alternative suppliers in order to get lower bids (Womack, Jones, & Roos, 1990).

Exchanging information along the supply chain has been shown to smooth demand on a supply chain basis, decreasing the effect of the demand amplification defined in his seminal work by Forrester (1958). For example, Wikner (1991) proposed information exchange as the most effective way to reduce demand amplification along the supply chain, and that given perfect exchange of information, only one link in the supply chain would need to keep some buffer inventory. Using a computer simulation model, Lovell (1992) showed that, under perfect information flows, the whole economy could function on a JIT basis. Information technology is critical to facilitate the flow of information along the supply chain, and to the integration of logistic activities such as logistic information systems, purchasing, transportation, warehousing, inventory control, production planning, order processing and customer service (Gustin, Stank, & Daugherty, 1994; Gustin, Daugherty, & Stank, 1995).

Information exchanges with other firms can also have positive managerial effects. Basing its arguments mostly on social learning theories, the organizational theory literature has analyzed inter-organizational networks, finding that organizations that engage in networks, systems, or alliances, have an opportunity to exchange information

and learn from their peers, and they tend to adopt behaviors of their larger, more prestigious, and more successful counterparts (Burns & Wholey, 1993; Greve, 1995, Galaskiewicz & Wasserman, 1989; Kraatz, 1998; Westphal, Gulati, & Shortell, 1997; Levinson & Asahi, 1996). Sound management practices that are proven to be successful are more widely diffused, and organizations that engage in networks are less likely to adopt behaviors based on management fads (Kraatz, 1998). Although the importance of information flows along the supply chain has been persistently cited in the extant SCM literature (Choi & Hartley, 1996; Cowdrick, 1995; Fawcett & Clinton, 1996; Hammant, 1995; Helper, 1991; Stewart, 1995; Richeson et al., 1995), there is evidence that the level of adoption of inter-organization information technologies has been lower than had been previously predicted (e.g., Ferguson et al., 1990; Hendon et al., 1998).

EDI Defined

The information flows that characterize traditional supply chains, such as exchange of verbal information, mailed letters, faxes, and electronic mail, are not sufficient to satisfy the need of modern SCM. The extended enterprise needs to develop new information exchange channels that allow fast, reliable, structured, and complete information flows (Greis & Kasarda, 1997). Given the fast rate of change in information technologies, firms can exchange information electronically in an ever increasing number of formats, using a large variety of protocols and communication technologies. Some technologies that are affecting information flows in the supply chain include EDI, point-of-sale (POS) systems, process control systems, barcoding, VANs, and electronic ordering systems (EOSs) (Chiu, 1995; Post & Anderson, 2000). Although structured data interchange with suppliers and customers has a positive impact on logistic performance,

face to face communication is still needed to participate in design teams and to solve technical problems (Levy, 1997; Richeson et al., 1995).

For the purposes of this dissertation, a very broad definition of EDI is used: Any inter-organizational exchange of data, in electronic form and structured in such way that it can be communicated directly from computer system to computer system. This definition is consistent with the definition given by the British Government (Department of Trade and Industry, 1989) and with the academic EDI literature (e.g. Hansen & Hill, 1989; Banerjee & Sriram, 1995; Ferguson et al., 1990). EDI is not necessarily associated with any particular communication technology or format. Electronic data can be transmitted, for example, through a private line from business to business, through a VAN, using, a public telephone line, the internet, or a satellite link.

EDI is generally considered a part of the inter-organizational information systems (IOIS) model (Benjamin, DeLong, & Scott Morton, 1990; Banerjee & Sriram, 1995; Holland & Lockett, 1997; Crook & Kumar, 1998; Hart & Saunders, 1998; Hendon et al., 1998; O'Callaghan et al., 1992; Iacovou, Benbasat, & Dexter, 1995). An IOIS is any information system shared by different organizations, and in many cases specific to the inter-organizational relationship. Within this framework, EDI implies the ability to communicate information between two independent systems, where the information is provided on supply, and never on demand. In other words, each EDI transaction partner sends selected information to the other, but otherwise keeps control of its own information database (Pfeiffer, 1992; Barrett & Konsynsky, 1982).

Dimensions of EDI

Several EDI studies have analyzed various aspects of EDI use to develop separate dimensions. Massetti and Zmud (1996) defined the dimensions of EDI use as volume, breadth, diversity, and depth. Volume was defined as the extent to which an organization's document exchanges are handled through EDI connections; breadth was defined as the extent to which an organization has established EDI connections with external trading partners; diversity as the number of distinct document types an organization handles via EDI connections with its trading partners; and depth as the degree of electronic consolidation that has been established between the business processes of two or more trading partners. Similarly, Williams, Magee, & Suzuki (1998) defined three dimensions of EDI adoption: range is the proportion of trading partners with whom a firm exchanges information via EDI; width is the use of EDI for multiple purposes; and depth is the percentage of data processing done via EDI relative to manual systems. Given its conciseness and availability, the instrument developed and validated by Williams et al. (1998) will be used in this dissertation to measure EDI use.

Impact of EDI

The main benefits of EDI reported in the literature are cost reduction, increased speed, and reliability (reduction of errors). Paper based systems are labor intensive (Ferguson et al., 1990), and automating processes will reduce paperwork, paper handling and paper cost (Holland & Lockett, 1997). Firms that encourage their vendors to use EDI are better able to capitalize on EDI advantages such as reduced monitoring of suppliers, automatic reordering, and simplified order approval processes (Banerjee & Sriram, 1995). In addition, the use of EDI improves customer service and responsiveness to

special customer requests (Rogers et al., 1992; Bowersox & Daugherty, 1995). EDI has been reported to reduce the inventory level, improve cash flow, and streamline a company's operations (Dearing, 1990). In order to keep control of the processes, purchasers prefer monitoring suppliers, negotiating, and performing automatic reordering activities manually, even in the presence of an automated system. The use of EDI does not significantly reduce the number of purchasing agents employed, but it increases the need for training of the purchasing personnel, and improves interdepartmental coordination (Sriram & Banerjee, 1994). In the only study to date of EDI in the maquiladora industry, Stank and Lackey (1997) found that plants that are willing and able to exchange data with their supply chain partners and invest in EDI related technologies, improve their logistical performance.

The impact of EDI can be divided in four separate factors: impact on internal processes, efficiency effects, sociopolitical impact on inter-organizational relationships, and impact on market (competitive) relationships (Table 3). The first two factors correspond to what Pfeiffer (1992) labeled the "individualistic view", while the sociopolitical and market aspects correspond to the "relational view".

1. Impact on internal (intra-organizational) processes

The EDI literature addresses intra-organizational issues such as education and training requirements for EDI implementation (Carter, Monczka, Clauson, & Zelinski, 1987); intra-organizational aspects relating to EDI adoption (Monczka & Carter, 1989); control of EDI systems (Norris & Waples, 1989); and the impact of EDI adoption on internal controls (Sadhwani, Kim, & Helmerci, 1989). The impact of EDI has also been studied from a socio-technical perspective, which argues that when implementing

systems there are social and technical aspects affecting each other (Bostrom & Heinen, 1977a,b).

The adoption of EDI can have an impact on organizational structure, business processes, business network, and business scope (Teo, Tan, & Wei. 1997). EDI will not achieve its full potential benefits unless it is accompanied by significant changes in organizational and inter-organizational processes (Clark & Stoddard, 1996). Businesses must formalize information processing, and simplify or reengineer internal processes before implementing EDI. A consequence of these changes is the improvement of internal processes. For example, multi-division firms can centralize their data so that their suppliers can deal with them as a single customer, instead of maintaining communications with several divisions.

2. Sociopolitical impact on inter-organizational relationships

According to the information processing theory of organizational design (e.g. Tushman & Nadler, 1978) information technology is instrumental to reduce the uncertainty faced by firms. The increase in cooperation with business partners that takes place in more coordinated supply chains decreases the level of uncertainty in their decision making processes (Pfeffer & Salancik, 1978). Firms can benefit from EDI if they can leverage its potential to strengthen inter-organizational process reengineering (Lee, Clark, & Tam, 1999). The fact that firms invest in relationship specific assets such as EDI systems signals commitment to the long term relationship and trust in the partner (Hart & Saunders, 1997).

The use of EDI to communicate with suppliers is part of a procurement strategy that can also lead to better supplier performance (Walton & Marucheck, 1997; Richeson

et al., 1995; Stank & Lackey, 1997). Electronic links with customers can also contribute to improved flexibility and responsiveness to customer needs and special requests (Rogers et al., 1992). In an international study of determinants of inter-organizational cooperation, Bensaou (1997) found differences in the way U.S. and Japanese firms use information technologies to improve interorganizational processes. While U.S. firms seek to develop industry-wide "electronic marketplaces" at the industry level with an emphasis on automation of business transactions with many suppliers, Japanese firms have formed "electronic partnerships" by using IT to coordinate their business processes with those of a reduced number of suppliers. In addition to these positive impacts on inter-organizational relationships, a negative consequence of EDI adoption is the possible reduction of personal interaction (Marcussen, 1996; Azad, Erdem, & Saleem, 1998).

3. Efficiency effects

Among the efficiency advantages of EDI use are savings in costs and staff related to the relationship with customers and suppliers, particularly in the purchasing and sales departments (Wang & Seidman, 1995). The cost savings derive mainly from the automation of highly repetitive tasks (Richeson et al., 1995). A Deloitte & Touche study (as cited in Ettlie, 2000) reports that among all information technology investments made by companies, "EDI was where payoffs occurred, similar to the integrating technologies in manufacturing" (p.256).

Table 3.

Impact of EDI Adoption

Impact on internal processes	Sociopolitical impact on Inter-organizational relationships	Efficiency effects	Impact on market (competitive) relationships
Investments in training Improved internal control systems Formalized information processing Simplification or reengineering of processes	Inter-organizational process reengineering Signals commitment, trust. More complete information exchanges Lower uncertainty Improved supplier performance Improved responsiveness to customer demands Possible reduction of personal interaction	Reduction of non-value added activities: No need to re-key information, saving labor costs, less errors. Reduction in paper flow. Reduced expense in postage and telephone charges. Improvement of time-based performance. Faster transmissions shorten lead times. Facilitates JIT. Also, allows faster reaction to problems. Reduction of errors (used to be as high as 35%). Saves indirect costs. Reduces variability and uncertainty.	Buyer selection factor (for the buyer). The whole channel benefits from better customer service. Used to "lock-in" customer (by supplier)

3 a. Reduction of non-value-added activities

The main effects of EDI are derived from the automation of repetitive processes. Since data are transmitted automatically, there is no need to re-enter it manually in each organization's system, which saves labor costs, and reduces errors (Pfeiffer, 1992; Ferguson et al., 1990).

Over 70% of the data exchanged between organizations is originated by a computer system and destined to another computer system (Dearing, 1990). Given the increasing use of computers in business transactions, this percentage can be expected to be much higher today. Once business documents have been transferred from computer system to computer system, documents related to the same transaction have to be verified against each other, such as invoices against materials received. The automation of such processes is difficult using unreliable traditional communications such as mail or telephone. There is evidence that firms implementing EDI reduce their labor costs in telephone calls and computer data entry, or allocate the time of their existing personnel to more productive tasks (Chen & Williams, 1998).

3 b. Reduction in paper flow, postage, and telephone charges

EDI reduces paperwork, postage, and printing costs. In addition to the cost of paper, its handling is labor intensive and requires a whole logistic system, including purchasing paper, receiving and storing it, printing it, filing it in archives, and disposing of it. EDI contributes to the reduction of paper flow and handling. It eliminates the use of envelopes and stamps, and is much more efficient than voice phone communications, saving telephone charges (e.g. Pfeiffer, 1992).

3 c. Reduction of inventories: EDI and JIT purchasing

JIT purchasing practices include practices such as delivery in frequent, small batches, supplier base reduction, increased importance of quality and delivery reliability as supplier selection factors, elimination of incoming quality inspection, supplier responsibility for product design, use of standard containers, long term price negotiations, and paperwork reduction (e.g. Ansari & Modarress, 1987, 1988). The impact of information technologies on JIT performance has been widely documented in the logistics and information systems literatures. For example, the cost savings generated by the use of EDI have been found to be especially large in companies that use JIT and therefore make a large amount of small transactions (Banerjee & Golhar, 1993). More efficient buyer-supplier communications allow buyers to place more orders, more frequently, and in smaller quantities, which contributes to JIT performance and, therefore, increases efficiency (Marcussen, 1996; Bronx & Fader, 1997; Richeson et al, 1995).

EDI facilitates JIT purchasing because it reduces order cycle time, allowing the buyer to place more frequent orders at a lower cost (Richeson et al., 1995). This cycle time reduction can, in turn, have an impact on inventory levels (Ferguson et al., 1990). Using the economic order quantity model, Pfeiffer (1992) showed that the use of EDI leads to small reductions of inventory when neither demand nor lead time are subject to uncertainty. Under stochastic, normally distributed demand, EDI-originated lead time reductions will significantly reduce safety stocks. These estimations are derived only from the shorter order cycles caused by EDI, and do not include the impact of other EDI transmitted information such as production schedules, demand forecasts, inventory levels,

shipping notifications, which would further reduce the uncertainty on the demand and lead times. Srinivasan, Kekre, & Mukhopadhyay (1994) showed that investments in information technology can also reduce the level of discrepancies in JIT supplier shipments. It has also been reported that EDI results in substantial reductions in the number of suppliers (Holland & Lockett, 1997).

Improved communications with suppliers is a major JIT purchasing practice (Manoochehri, 1984; Freeland, 1991; McDaniel et al., 1992). In a survey of purchasing managers, Banerjee and Sriram (1995) explored the effect of EDI use on the purchasing department and the entire organization, finding that computer skills and training for purchasers were important factors during the first years of EDI use. The use of EDI saves time for purchasing personnel, who can devote more time to professional purchasing activities, and also improves the buyer-vendor relationship in terms of cooperation, commitment, and trust. Sharing data with distributors can also reduce inventories and improve the quality of forecasting and production schedules. For example, manufacturers can access daily retail sales data from distributors, and adjust production schedules to reflect market conditions.

Given the synergies between JIT and EDI cited above, it is not surprising that there is ample empirical evidence of the relationship between the adoption of JIT and EDI technologies. Larson (1998) empirically found interdependencies between carrier reduction, EDI use, and JIT use. Firms that use carrier reduction also tend to use JIT and EDI. The literature also shows that JIT use is a good predictor of EDI adoption (Germain & Droge, 1995). In spite of these and the strategic, organizational, and inter-organizational implications of the use of EDI mentioned above, it has been reported that

EDI does not change substantially the purchasing process or decision making (Emmelhainz, 1987, 1988).

EDI reduces order cycle time because faster communication links allow more frequent orders, which implies a shorter order cycle and increased responsiveness to new information. These are time based benefits, which are present only when EDI is compared to paper–based mail communications, but not when compared to other electronic media such as fax. EDI, however, allows direct computer-to-computer interaction, which results in faster order placement and processing than fax communication does, and is error free.

3d. Improvement of time-based performance.

Time based competition has gained importance as a source of competitive advantage (e.g. Blackburn, 1991). EDI increases speed of transmission, and faster transmissions shorten lead times, and provide more timely information about process disruptions taking place in other points of the supply chain, which can allow faster reaction to problems (Monczka & Carter 1989). For example, firms can exchange CAD/CAM data electronically in order to speed up product development, or transmit quality related data to customers, in order to speed up quality system procedures and documentation, avoiding delays in the use of purchased materials (O'Callaghan et al., 1992; Lin, 1991).

3e. Reduction of errors

Data entry and re-entry errors are a major source of non-value-added activities. By reducing data entry errors, EDI reduces variability and uncertainty. Reduced errors means less delays in the collection of payments, and fewer disruptions in production and

quality control (Ferguson et al., 1990). According to Malone et al. (1987), data-entry error rates are as high as 2 to 5%, and the error level when using telephone or fax orders can be as high as 60% (Verity, 1996). If the errors are detected on time, they can be fixed in the computer system at the cost of the labor required to their detection, verification, and correction. If the errors remain undetected and action is taken based on the erroneous information, the costs can include manufacturing and shipping the wrong products or quantities, with the consequence of disruptions on material flows and production schedules, increases in express transportation costs, delays in delivery, and increased inventory costs. If the error leads to the manufacture of the wrong product (e.g. wrong specifications, dimensions, material, color, or model) in addition to the above costs, the material could be unusable and have to be discarded. Data entry errors can also cause the material to be shipped to the wrong address or customer, in which case there would be a disruption in the schedule and the material would have to be returned to the supplier, and re-shipped to the correct address. Since electronic communications are virtually error free, a major benefit of EDI is the elimination of all data entry error related costs.

4. Impact on competitive relationships

The ability of a firm to use EDI can affect market relationships. First, a buyer can require their suppliers to be EDI capable, or use this capability as a supplier selection factor. From the perspective of the supplier, EDI can become a strategic necessity.

4 a. EDI use as a supplier selection factor.

The use of EDI can be an important supplier selection factor, and its use can be required by supply chain or industry organizations (Emmelhainz, 1987). Since EDI provides superior communicability of the information, any event related to a particular

order taking place anywhere along the supply chain can be instantly communicated all the way to the final customer (Pfeiffer, 1992). By linking with shipping and trucking companies, firms can provide their customers with detailed information about the physical location of a shipped order, helping them to plan their operations accordingly (O'Callaghan et al., 1992). Because of this communicability of data, EDI can improve customer service along the whole supply chain and customers can limit their inventory risk (Ferguson et al., 1990). Once a buyer has implemented EDI and incurred a fixed investment cost, the buyer has an incentive to require its suppliers to implement EDI. Previous research has noted that, although many buyers are not yet requiring their suppliers to be EDI capable, they are expected to gradually increase this requirement (Marcussen, 1996). EDI capability can, therefore, become a supplier selection factor for the buyer.

4 b. Use of EDI to "lock-in" the customer: The perspective of the supplier

EDI use helps protect market share and tie-in customers by formalizing the relationship with the customer and making it more stable, as well as improving customer satisfaction (Wang & Seidmann, 1995). O'Callaghan et al. (1992) found that establishing EDI links with customers will increase supplier market share. Although EDI capability can be a factor of competitive advantage for early adopters, allowing them to secure their customers from shifting to other suppliers, this advantage will be short lived: The nonproprietary character of EDI and the increasing standardization of EDI documents will lower the switching costs, allowing the buyers to choose any EDI compliant supplier. As the use of EDI becomes generalized, the cost of implementing EDI for a supplier will be considered less of an investment in competitive advantage and more a part of the cost

of doing business (Benjamin et al., 1990; Marcussen, 1996; Senn, 1992). In industries that require the use of EDI from their suppliers, such as automotive, firms wait passively until they are required to implement EDI by their customers (Tuunainen, 1998). Once suppliers have implemented EDI, they are more likely to keep their existing customers, although not necessarily increase their sales (Marcussen, 1996). Given the differences in IT efficiency between suppliers, the requirement to implement EDI can affect the competitive relationships among suppliers and force suppliers with less IT resources out of the market (Barua & Lee, 1997).

Adoption of EDI

Although the term "diffusion" is sometimes used interchangeably with the term "adoption," they are not the same. Diffusion of innovations is an intra-firm or inter-firm communication process where the message is a new idea susceptible of being implemented (Rogers, 1983). The process of diffusion takes place between an innovator or a change agent, and a population of potential adopters. The result of the diffusion process is knowledge of the new technology, the persuasion to adopt it, the adoption decision, the actual implementation and use, performance evaluation, and the confirmation that the decision to adopt or not to adopt was appropriate.

The adoption of technological innovations takes place as a function of the proportion of the population of potential adopters that already have adopted the new technology. That is, potential adopters are more likely to decide to adopt an innovation after a larger percentage of the population have decided to adopt it (Rogers, 1983). This is especially true in the case of interactive communication technologies such as EDI, that require compatibility with other adopters in order to be usable. Some researchers use the

concept of "network externalities" to refer to the fact that "the total utility a consumer derives from the use of a good or service is not only dependent upon its functional characteristics and specific demand conditions, such as idiosyncratic environmental circumstances, but also upon the number of other consumers using the same, a compatible, or a complementary good or service" (Pfeiffer, 1992, p. 117). The concept of network externalities and the theory of rate of diffusion support the notion that technologies such as EDI are widely adopted after a "critical mass" of potential adopters had adopted the technology (Newman, 1986; Markus, 1987). This idea supports the S-curve theory of technological innovation, which states that the dynamics of technology adoption follow an S-shaped or logistic curve, showing small rates of growth at the initial and late stages of the technological cycle, and highest growth rates during the middle stages (Christensen, 1992).

It has been reported that, as of 1998, leading industries like computing had hit critical mass in internet-based commerce, and the technology had entered a stage of hyper-growth (Bell, Dolberg, Cheema, & Sharrard, 1998). This process is initiated by innovative firms who adopt the new technology, and pressure suppliers to use it. Suppliers, in turn, pressure average sellers to adopt the technology, while the innovators start a new cycle of technological innovation.

Regarding the strategic intent of EDI adoption, Holland et al. (1992) proposed five generic strategies for EDI adoption: (1) The "follow" strategy is used by smaller supply chain members or those with less IT skill. In this case, the level of EDI involvement is limited to the requirements of the adopter's partners. (2) The "new roles" strategy allows businesses to take on new roles in the supply chain. (3) The "new

products and services" strategy consists of using EDI to develop new products and services. (4) The "tie-in" strategy consists of protecting market share by establishing electronic links with customers. (5) Finally, the "time based competition" strategy allows faster reaction to market needs. These five strategies closely mirror the factors leading to EDI adoption, and can be prioritized to match the factors driving each adoption of EDI.

Determinants of EDI adoption

Recent studies (Adams, Nelson, & Todd, 1992; Davis, 1989; Mathieson, 1991; Moore & Benbasat, 1991; Taylor & Todd, 1995) have analyzed the determinants of information technology adoption in organizations. Factors that influence the decision to adopt EDI include the expected efficiency and customer service gains (Rogers et al., 1992; Bowersox & Daugherty, 1995; Suzuki & Williams, 1998; Iacovou et al., 1995; Jimenez-Martinez & Polo-Redondo, 1998), and anticipated system compatibility (O'Callaghan et al., 1992). The most consistently identified variable affecting information technology adoption in small businesses is its expected benefits (Cragg & King, 1993).

Williams et al. (1998) hypothesized that technological uncertainty, EDI document standards, investment in EDI, length of EDI use, firm size, organizational structure, and partner selectivity have an impact on EDI adoption, measured by the three dimensions cited above. This study found that investment, length of EDI use, and partner selectivity are significantly related to all three dimensions of EDI adoption. The existence of EDI document standards was related, as hypothesized, only to range; and organizational size, only to width. No relationship was found between decentralized structure and EDI adoption. This study also tested the relationship between the three dimensions on

perceived value of EDI, and found that only range is significantly related to perceived value.

Chen and Williams (1998) related the use of EDI in small businesses to the power of customers, the organizational culture, and the personal opinion of the managers. The determinants of technology adoption have been found to be similar in developed and developing countries (Dasgupta, Agarwal, Ioannidis, & Gopalakrishnan, 1999).

Perceived benefits.

Perceived benefits, relative advantage, need pull (Zmud, 1984), internal need (Premkumar & Ramamurthy, 1995), or efficiency advantage have been cited in the literature as factors influencing the decision to adopt EDI. Unless there is a perceived need or benefit associated with the technology, adoption is unlikely. No matter what the efficiency advantage perceived by the potential EDI adopters, fixed investment in EDI capability will be most profitable to larger firms with more resources and potential use for the system, and to firms with more potential partners to communicate with (Tuunainen, 1998). Another determinant for the potential advantage of EDI is the length of the supply chain, measured by the number of ownership stages from producer to the end customer (Holland, Lockett, & Blackman, 1992).

The decision to adopt EDI is often triggered by a trading partner, usually a customer, who exercises some form of market power over the firm (Jones & Beatty, 1998; Webster, 1995; Holland et al., 1992; Hart & Saunders, 1997; Richeson et al., 1995). If a firm is required to adopt a technology, but is not subject to specific guidelines directed to enhancing performance, or these specific requirements are not assessed by external audits or inspections, the firm is likely to limit the implementation to meet the

minimal requirement, without taking full advantage of the new technology (Meyer & Rowan, 1977; Scott, 1987). In the case of EDI, firms showing this type of reactive behavior will neglect the implementation process, and will simply become "EDI capable." Bare EDI capability will ironically serve the interest of the firm that coerced them to adopt, but will not result in internal efficiency gains for the firm. This type of behavior, labeled "acquiescence" by Oliver (1991), can only justify its economic rationality in the improvement of market relationships. The alternative, labeled "avoidance," consists in refusing to adopt the technology, and is economically irrational.

The empirical evidence of the distribution of benefits of EDI between the customer and supplier is mixed. Although a large part of the literature reports efficiency gains for suppliers, some studies report no such financial gains for suppliers.

Empirical evidence suggests that strong communication links between buyers and sellers have a positive impact on supplier performance (Richeson et al., 1995; Stank et al., 1996). Lee et al. (1999) analyzed differences in performance between EDI adopters and the champion who coerced them to adopt EDI, finding that suppliers increased inventory turns, and reduced stockouts as a result of using EDI to facilitate inter-firm process reengineering.

In spite of the evidence of improved supplier performance, it has been shown that suppliers do not perceive they benefit from EDI as much as they could, and that the benefits of EDI are not well distributed between buyers and suppliers (Marcussen, 1996; Tuunainen, 1998). In their study of EDI use in the transportation industry, Crum et al. (1998) report that the largest perceived benefit of EDI is in the area of customer service as opposed to efficiency gains, and carriers report that their customers are more satisfied

with the EDI system than they are. According to this view, purchasers exert power on their suppliers to force them to implement EDI, and benefit financially from the improved purchasing decisions while suppliers do not recognize enough financial gains derived from the use of EDI technology.

Comparing internal efficiency gains to perceived benefits as a driver of EDI adoption is crucial because, using exclusively on the binary adoption/non adoption variable, previous studies have attempted to measure the impact of EDI on performance. Low performance in a reactive firm may reflect only a poor or partial implementation.

Perceived compatibility with present systems

The degree to which a new technology is consistent with present values, systems and procedures is an important determinant of technology adoption (Rogers, 1983). O'Callaghan et al. (1992) defined two factors of EDI incompatibility with the present systems of the potential adopter: system incompatibility and organizational incompatibility. System incompatibility involves hardware and software connectivity issues such as communication protocols, message standards, and the need for modification existing systems in order to implement EDI. For example, the literature has identified conflicting standards as one reason for the low adoption of EDI in most industries (e.g. Brousseau, 1994; Tuunainen, 1998, Chen & Williams, 1998; Suzuki & Williams 1998). The need for EDI standards does not relate exclusively to message formats and communication protocols, but also to the required standardization of the inter-business coordination processes (Brousseau, 1994).

Organizational incompatibility is a broader category of factors related to consistency in operating procedures, staffing and skill requirements of EDI. Given the

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depth of organizational factors that can affect EDI adoption, organizational compatibility should be evaluated before technical compatibility in order to evaluate the potential of EDI adoption.

Compatibility also determines the ease of integration into internal systems. For example, as a consequence of the lack of standards, firms tend to implement EDI as a minimal stand alone system which is not integrated with the internal information system, and is able to communicate with only one or a few business partners (Iacovou et al., 1995; Chen & Williams, 1998). If the EDI system is run on a dedicated PC and the documents are printed on paper, the system becomes a complex and expensive fax machine, and very few of its advantages are realized.

Barriers to EDI adoption

In spite of the abundance of theoretical and empirical studies showing the many efficiency benefits of EDI use, the adoption rates have been much lower than what would be expected. Firms tend to be reactive in the decision to implement EDI, and most of them only implement it when coerced by powerful customers (Tuunainen, 1998; Chen & Williams, 1998; Hart & Saunders, 1997). Among the main barriers to EDI adoption are high setup cost, lack of compatibility, lack of training and awareness of EDI benefits, and the lack of industrywide standards (Brousseau, 1994; Suzuki & Williams, 1998; Johnson, Allen & Crum, 1992; Crum, Johnson & Allen, 1998; Ferguson et al., 1990; Crum, Premkumar & Ramamurthy, 1996; Murphy & Daley, 1996).

One of the main barriers to EDI adoption is the difficulty of adapting the systems to fit the different standards or requirements of several customers (Chen & Williams, 1998). In order to work efficiently, a large number of users of a communication system

must use a common standard. Firms can use proprietary, company specific standards or rely on widely used national or international standards such as EDI for Administration, Commerce, and Transport (EDIFACT), created by the United Nations in 1987, or the X12, created in 1979 by the American National Standards Institute (ANSI) (Emmelhainz, 1990). Once an individual user has implemented a standard, the benefits it will derive from the system will increase as the number of other users with which it can communicate increases. Since there are fixed costs associated with the implementation of each standard, a firm's decision to implement an EDI system will become more likely in the presence of widely used standards from which they can derive network externalities. While manufacturers can impose a single standard on their suppliers, suppliers will face the pressure to adopt several standards to satisfy the requirements of different customers, being unable to benefit from network externalities (Barua & Lee, 1997). Other barriers to EDI adoption include lack of customer focus, employees' resistance to change, fear of losing control, lack of capital to invest in an EDI system, poor application software, and overly restrictive software (Hendon et al., 1998).

Shortcomings of EDI use

In addition to the cost and effort associated with the adoption of EDI (LaLonde & Emmelhainz, 1985; Hendon et al., 1998), some potential shortcomings of its use, particularly at early stages, include the absence of audit trails, and problems of loss of control due to lack of data integrity. The problem of data integrity is especially common when an EDI partner starts making transactions (Banerjee & Sriram, 1995).

Audit trails used in traditional communication include signatures on documents and hard copies of documents. The problem of auditability in electronic transactions can

be solved using existing technologies, and some researchers found that electronic transactions can be audited more efficiently than paper based transactions (Ferguson, 1990).

Other disadvantages of EDI cited in the literature include the need to use checks and controls as protection from data entry errors, security problems such as the vulnerability to hacker attacks, the high level of frustration caused while the system is down and employees have become accustomed to the speed of communications, and the inflexibility of proprietary EDI systems (Hendon et al., 1998). Banerjee and Sriram (1995) also found a perception of inflexibility correlated with the percentage of purchasing transactions processed through EDI. An additional shortcoming of EDI use is a possible reduction of personal interaction with trading partners (Marcussen, 1996; Hendon et al., 1998).

EDI in international transactions

Longer supply chains increase the uncertainty, delay technical support, require longer demand forecasting periods, and higher levels of inventory (Levy, 1995, 1997). Frequent internal process disruptions, high processing cost of international trade paperwork, the ability of EDI to overcome traditional cultural, language, and bureaucratic barriers to international trade, and the need to improve productivity derived from international competition, make EDI use critical in international transactions (Levy, 1995). In addition, the high cost of international travel limits the frequency of personal communication (Lawrence & Lewis, 1993). All these factors provide an incentive for firms to rely on electronic communications for their information flows. At the same time,

enhancing the flow of information and materials is costly and difficult to achieve, particularly in international supply chains.

A single business transaction can give rise to the exchange of between five and twelve documents in domestic transactions, and up to thirty documents in international transactions (Emmelhainz, 1990). The use of EDI in international transactions results in expedited cargo releases, entry summaries, payment through automated clearinghouses, shipper's export declarations, and other international transportation procedures (Murphy & Daley, 1996). EDI will standardize, simplify and increase the speed of information flows in international transactions (Janssens & Cuyvers, 1991). In spite of the abundant theoretical and empirical support of the benefits of EDI use in international transactions, Ferguson et al. (1990), found limited use of EDI in firms engaged in international transactions.

In order to facilitate international EDI use, the International Standards Organization (ISO) and the United Nations have developed the EDIFACT (Electronic Data Interchange for Administration, Commerce, and Transport) EDI standard. The U.S. Customs service has agreed with its counterparts in Mexico and Canada on using EDIFACT standards to perform import-export communications via EDI.

In addition to longer and more variable transportation times, reliance on international suppliers makes it more difficult to involve suppliers in solving quality problems and improving designs. Since manufacturing firms in Mexico rely largely on international suppliers, their communication needs are intense and involve several functions, especially quality assurance, production, and engineering (O'Neal, 1987). This intense communication between manufacturers in Mexico and their international

suppliers is extremely difficult because of language differences, and unreliability of traditional communication services such as telephone and mail.

In summary, the literature provides strong evidence of the beneficial impact of EDI adoption, particularly in international business-to-business transactions, and its large potential for growth due to network externalities in communication technologies. Although there seems to be evidence that both suppliers and customers benefit from the use of EDI, some suppliers feel that the implementation is an imposition of the customers who benefit financially from EDI use. In order to analyze the EDI adoption decision in international supply chain, data were collected from Mexican in-bond or maquiladora plants.

The Mexican maquiladora industry

The increasing level of globalization and international competitiveness, particularly from Asian countries, is forcing US manufacturers to transfer critical processes into low cost countries such as Mexico. The Mexican maquiladora industry was created in 1965 through an agreement between the United States and Mexico, the Border Industrialization Program (e.g. Sklair, 1989; Stoddard, 1987; Szekely, 1991; Grunwald & Flamm, 1985). The purpose of this program was to bring down very high levels of unemployment in Northern Mexico by encouraging foreign firms to establish production sharing facilities, which can take advantage of the abundant labor force in the area. Through this program, components can be imported into Mexico with no tariffs, to be assembled in a maquiladora plant, and re-exported (Stoddard, 1987). Today, the maquiladora industry has expanded into the interior of Mexico, employs more that 1,200,000 people in more than 3,500 plants (INEGI, 2000), is the third source of foreign

exchange only after oil and tourism, and has become a factor of economic stability for Mexico and border areas in the United States (Botzman, 1999).

Although many suppliers are gradually moving closer to the location of the maquiladoras, the vast majority are still located in remote areas, particularly in the Midwest U.S. states. This geographical distance can be problematic since suppliers have to deal directly with maquiladora plants for purchasing, logistics, design and quality issues (Dowlatshahi, 1998). As Table 4 shows, about 97 percent of the purchases in the maquila industry are imported. This percentage is even higher in border states such as Tamaulipas (INEGI, 2000).

Table 4

Distribution of Maquiladora Purchases in 1999

Total for Mexico:			
	Millions of pesos	Millions of US dollars	Proportion of total
Imported	426,912	44,563	97.19%
National	12,337	1,288	2.81%
Total	**439,249**	**45,851**	**100.00%**
State of Tamaulipas:			
	Millions of pesos	Millions of US dollars	Proportion of total
Imported	82,506	8,612	98.87%
National	939	98	1.13%
Total	**83,445**	**8,710**	**100.00%**

Source: Instituto Nacional de Estadística, Geografía e Informática (INEGI)

Maquiladora operations have become more technologically sophisticated in later years. Once dominated by simple assembly operations, today's maquilas use sophisticated equipment to perform capital intensive, complex manufacturing operations that are key processes in the supply chain. The growth of high technology industries such

as computers and medical equipment has contributed to the increase in the technological level in maquiladora plants. Maquilas have also become involved in the design process, which requires close cooperation with suppliers and customers (Fawcett & Smith, 1995; Fawcett, Stanley, & Smith, 1997).

Since nearly all maquiladora purchases are made from suppliers in other countries, the Mexican maquiladora industry is an optimal location to analyze information flows in international supply chains. In spite of its potential for exploring international supply chains, only Stank and Lackey (1997) analyzed the impact of EDI in the maquiladora industry as part of a model linking logistical capabilities to logistical performance in maquiladora firms. Their study found a significant impact of information exchange on logistic performance measures such as order cycle time reduction, and routing and scheduling improvements.

In spite of increasing technological sophistication and strategic relevance of maquiladora operations, maquiladora managers have taken a reactive stance in strategic logistic decisions (Fawcett & Smith, 1995). Since using EDI is a critical determinant of logistical performance (Stank & Lackey, 1997), a better understanding of the determinants of EDI adoption in maquiladora plants will provide crucial guidance for maquiladora firms and supply chains.

CHAPTER 3.

RESEARCH METHODOLOGY

This chapter explains the research methodology, and is structured in seven sections: (1) research objectives, (2) research hypotheses, (3) target population, (4) case studies and interviews, (5) survey development, (6) survey administration, and (7) analytical methods for hypothesis testing.

Research Objectives

The objective of this study is to examine the EDI adoption decision process in international buyer-supplier communications. The review of the literature shows the importance of the local manager's perceptions regarding the economic efficiency of the new technology. On the other hand, recent increases in supply chain integration have translated overall power, and in particular technology adoption decisions, to other institutions in the supply chain such as customers, suppliers, or supply chain regulatory organizations. Based on these factors extracted from the academic literature, as well as preliminary interviews and focus groups with managers and industry experts, this study develops and tests a model of EDI adoption.

Research Hypotheses

Based on an extensive literature review, a model of EDI adoption decision process is developed in this section. According to this model, the main determinants of EDI adoption are efficiency factors such as perceived benefits and compatibility of the EDI system, and institutional factors such as external pressure to adopt the technology. These factors are hypothesized to depend, in turn, on other structural factors such as the size of the plant and the industry to which it belongs. Economies of scale justify a direct relationship between plant size and EDI use. The level of centralization of the purchasing function is also hypothesized to have an impact on EDI use. Given the differences in industry structure and organization, the external pressure to adopt EDI will differ across industries. Finally, and independently from the other factors, firms will make different use of EDI for purchases of production parts and maintenance, repair and operating (MRO) purchases. The following discussion explains in more detail these relationships and develops formal hypotheses.

External pressure

The adoption of supply chain improvements such as EDI is very often triggered by macro-social factors such as trading partner pressures, especially from their customers (Jones & Beatty, 1998; Chen & Williams, 1998; Hendon et al., 1998; Senn, 1992; Webster, 1995; Holland et al., 1992; Rogers et al., 1996; Marcussen, 1996; Hart & Saunders, 1997), and, less frequently, from their suppliers (Chen & Williams, 1998; Sriram & Banerjee, 1994). Buyer power is the influence of buyers to impose trading terms or interorganizational technologies on their suppliers (Holland et al., 1992, Hart &

Saunders, 1997). Buyers use their buyer power to pressure their suppliers to implement EDI (Tuunainen, 1998).

Although the first applications of EDI in the U.S. transportation industry were an attempt to increase industry wide efficiency, during the 1980s firms considered the use of EDI as a source of competitive advantage, and tried to establish proprietary EDI systems to communicate with its business partners. Competitive adoptions were usually based on the perception that EDI adoption would improve the competitive position of the firm. Subsequently, cooperative industry based schemes appeared, with the intention of making individual supply chains more efficient and competitive. Such cooperative schemes are based on the realization that in order to take advantage of information and communication technologies common standards are required to reduce the costs and maximize the return on the adoption investment. When EDI is implemented on a supply chain basis, a dominating institution typically determines the standards, organizes the communication protocols, and establishes norms requiring all the other supply chain members to implement EDI (Clarke et al., 1992). This leading institution can be a member of the supply chain, a consortium formed by industry members, or an institution chartered by the industry leaders to set standards in order to organize the supply chain. Industry institutions can therefore influence the EDI adoption decision of individual firms with the objective of improving the performance of the supply chain (Tuunainen, 1998).

H_1: External pressure will have a positive effect on the adoption of EDI in maquila plants.

Perceived benefits and compatibility of EDI

Managerial understanding and attitude towards a new information technology are associated with the likelihood of its adoption (Lal, 1999). Given the efficiency gains derived from EDI analyzed in detail in the literature review, it is hypothesized that intra-organizational economic efficiency factors such as the manager's perception of EDI benefits are a factor contributing to EDI adoption (e.g. Iacovou et al, 1995; Jones & Beatty, 1998; O'Callaghan et al., 1992). Managers who understand the benefits of EDI adoption are more likely to allocate the managerial, financial, and technological resources needed for EDI adoption (Benbasat, Bergeron, & Dexter, 1993; Premkumar & Ramamurthy, 1995). Therefore,

H_2a: Perceived EDI benefits will have a positive effect on the adoption of EDI in maquila plants.

Compatibility is the level of consistency of a technology with organizational systems, procedures, and practices (O'Callaghan et al., 1992; Premkumar & Ramamurthy, 1995; Iacovou et al., 1995). As potential users of a technology perceive that the adoption will cause fewer disruptions in processes and will require lower investments and modifications to current systems and procedures, they will be more likely to implement it (Rogers, 1983).

H_2b: Perceived EDI compatibility will have a positive effect on the adoption of EDI in maquila plants.

Plant size

In general, size is related to the availability of both human and physical resources to facilitate the adoption of technology. Size is a determinant factor in the adoption of all

types of technology (Germain et al., 1994; Grover & Goslar, 1993; Lal, 1999; Fariselli et al., 1999; Damanpour, 1987). With particular relevance to this study and using production function estimates from Mexican data at the plant level, Grether (1999) found that plant size is a significant determinant of technological diffusion.

There is substantial evidence of the relationship between firm size and EDI adoption (Daugherty et al., 1995; Murphy et al., 1998; Murphy & Daley, 1996; Williams et al., 1998; Barua & Lee, 1997; McGowan, & Madey, 1998; Premkumar et al., 1997; Fariselli et al., 1999; Tuunainen, 1998; Chen & Williams, 1998; Germain & Droge, 1995). Size also has an impact on the way businesses benefit from EDI. Economies of scale allow larger organizations to make a higher return on their technology implementation investments (Clarke et al., 1992), while EDI becomes a "strategic necessity" to smaller suppliers competing against larger, technologically sophisticated suppliers (Barua & Lee, 1997). Although it has been reported that lack of flexibility could reduce the number of innovations in larger firms (Grover & Goslar, 1993), factors such as the availability of slack resources and economies of scale support the higher EDI adoption levels in larger plants.

H_3a: Plant size will have a positive effect on the adoption of EDI in maquila plants.

H_3b: Plant size will have a positive effect on the perceived benefits of EDI in maquila plants.

Purchases of production vs. MRO goods

Purchases of maintenance, repair, and operating supply (MRO) items have different characteristics from purchases of production items. Since purchases of MRO

and production parts have differing information needs and purchasers assign different priorities to various types of information (Monczka et al., 1992), firms are expected to use different forms of communication for production and MRO goods.

About 80 percent of the items purchased by manufacturing firms tend to be MRO, but they only account for a 20 percent of the total dollar value of the purchases (Ellram, 1993). This makes MRO items very transaction cost intensive relative to their price, and the cost reductions derived from EDI would have a strong relative impact on the cost of MRO purchases. In addition, MRO purchases tend to involve more simple and less critical items, and require less contact with the supplier beyond the routine purchasing transaction that is appropriate to be performed electronically (Marcussen, 1996).

Although these factors suggest that the use of EDI should be higher for MRO purchases, other factors determine that purchasing firms tend to build weaker relationships with suppliers of MRO goods than with suppliers of production goods (Hendrick & Ellram, 1993). Very frequently, in order to reduce the search and transaction costs, firms outsource the MRO purchasing function, that is, they purchase MRO goods from third party intermediaries (Ellram, 1993) or integrated suppliers (Lawrence & Varma, 1999), for which they pay a higher price than they would pay purchasing directly from individual MRO suppliers. In addition, and given the special characteristics of MRO purchases and the practice of major corporations, the popular press (e.g. Welty, 2000; Avery, 2000; Brack, 2000) is widely suggesting the use of electronic marketplaces instead of EDI for MRO purchases. These electronic marketplaces have the advantages of electronic purchasing discussed above, without the need to establish communications links with a large number of MRO suppliers.

Mexican maquiladora firms tend to buy a significant portion of their MRO goods and packaging materials from local suppliers, but virtually all production components come from distant suppliers in other countries (Fawcett et al., 1993; Fawcett, 1993). Also, the practice of single sourcing is more extended in production goods than in MRO (Carter & Narasimhan, 1994). The low dollar value of MRO purchases and the critical logistical importance of production parts for the reliability of the supply chain also contribute to a higher use of EDI in production parts than in MRO purchases.

H_4: The proportion of maquila plants using EDI for production parts will be higher than that of plants using EDI for MRO goods.

Decentralization of the purchasing function

A large body of literature has analyzed the relationship between technology adoption and organizational structure, obtaining conflicting results (e.g. Cohn & Turyn 1980 and 1984; Miller et al., 1991; Grover & Goslar, 1993; Gatignon & Robertson, 1986). Decentralization is an empowerment of particular business units at lower levels in an organization, enabling them to make decisions. Based on the idea that centralized firms are better suited to adopt innovations that require organizational standardization (Gatignon & Robertson, 1986), Williams et al. (1998) hypothesized a positive relationship between centralized organization structure and EDI range, but found no empirical support. Other research, however, has shown that the decentralization of innovation adoption decisions is positively related to the likelihood of adoption. For example, Germain (1996) found that the decentralization of logistic process innovation adoption decisions is a good predictor of low cost incremental innovation, but not of radical innovation. The positive relationship between decentralization and innovation

adoption is based on the fact that centralized firms reduce autonomy in the functional areas of application of the technology, and decision makers in headquarters are withdrawn from these functional areas, and have a bounded perspective. Employees in decentralized firms are empowered to suggest and implement technological innovations. Decentralization provides managers the freedom to be innovative. If the innovation under consideration involves a very large, complex, or expensive project, however, the resources needed might not be available at the local level, and plant employees might be unwilling to take the risks and personal responsibility associated with the innovation adoption decision.

Decentralization can also be a consequence of the availability of information technologies. The improvement of communications between headquarters and manufacturing plants and its impact on organizational coordination can be a determinant of decentralization (Bowersox & Daugherty, 1995). Information technology induced decentralization gives rise to what Drucker (1988) has called the "information-based organization". Germain et al. (1994) found that, although decentralized firms do adopt greater levels of all types of technologies, the effect of centralization on technology adoption is statistically nonsignificant. In the EDI literature, however, Daugherty et al. (1995) found a positive relationship between EDI adoption and decentralization of adoption decisions. Given the strong control of corporate headquarters over maquiladora plants, it seems reasonable to hypothesize that plants with more responsibility over the purchasing function will use more EDI than plants with no control of the purchasing function.

H_5: The level of decentralization of the purchasing function will have a positive effect on the adoption of EDI in maquila plants.

Industry differences

Plants in industries with EDI standards and requirements in place are more likely to use EDI. Since EDI lowers transaction costs and reduces the frequency of communication errors that impair coordination in the supply chain, EDI is used most intensively in highly structured industries that apply JIT, such as the automotive and electronics industries (Pfeiffer, 1992). These industries use supply chain practices more intensively and, thus, EDI use should also correlate with other supply chain initiatives that regulate the relationships between buyers and suppliers, such as quality certification.

Therefore,

H_6a: There are significant industry differences in the level of EDI perceived benefits.

H_6b: There are significant industry differences in the level of EDI external pressure.

H_6c: There are significant industry differences in the level of EDI adoption.

The model for EDI adoption and hypotheses tested are graphically represented in Figure 1.

Target Population

The target population in this dissertation is maquiladora plants in the Mexican state of Tamaulipas. The state of Tamaulipas was selected because the government agencies in this state were willing to support and collaborate in the study. The addresses, telephone, and fax numbers for the plants have been obtained from The Complete Twin

Plant Guide 2000, published by Solunet Info-Mex, Inc. from El Paso, Texas. This directory has been combined with other directories obtained from the Mexican Secretary of Commerce (SECOFI) and the Mexican statistical agency (INEGI) to obtain a census as complete as possible. Since it was suspected that the combined list of 453 plants contained a number of plants that no longer existed, nonrespondent plants were visited personally. These visits had the double purpose of delivering the questionnaire and identifying the plants that are not in operation or no longer exist.

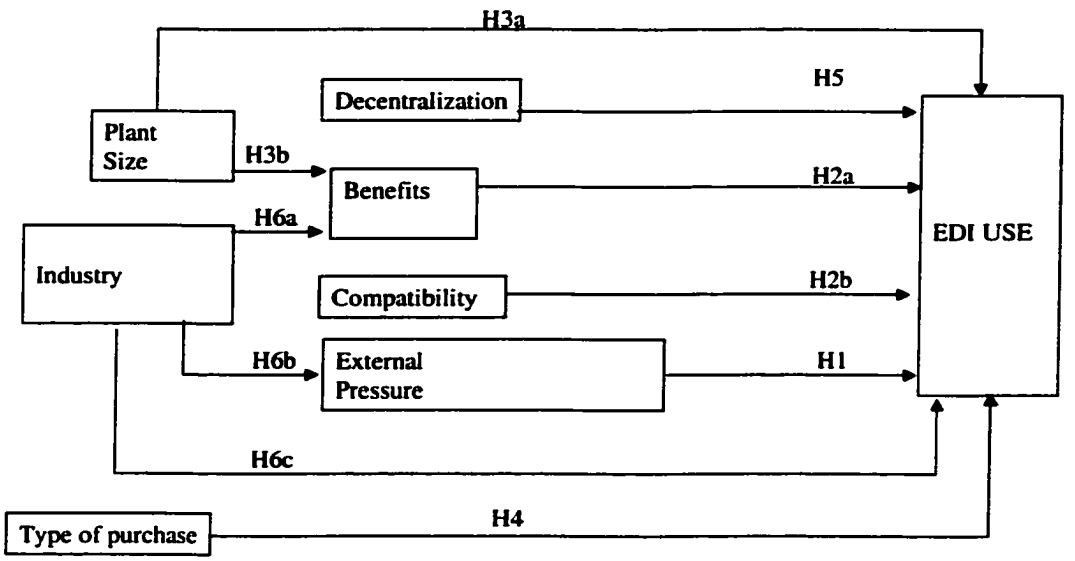

Figure 1. A model for EDI adoption

Case studies and interviews

The methodology to develop the questionnaire and test the proposed model is based on qualitative and quantitative empirical data. Qualitative data was collected

through preliminary case studies and interviews, and used to develop the questionnaire instrument, which was subsequently used to collect quantitative data.

During the initial stages of this research, a series of exploratory interviews was conducted in the maquiladora industry. There is a need for an equilibrium between quantitative and qualitative methodologies (Jick, 1979; Morgan & Smircich, 1980) and in particular for case studies that can be used to refine theoretical models in early stages of the research process (Bonoma, 1985; Eisenhardt, 1989). The interviews were conducted with plant personnel who were close to the purchasing processes involving buyer-supplier communications, and with the managers in charge of purchasing, supplier development, or logistics. Where EDI systems were in place, the system was reviewed and analyzed in more detail. These interviews helped to clarify the issues surrounding the adoption of EDI in the context of the maquiladora industry. Six manufacturing plants were visited in different industries such as electronics, electrical equipment, medical equipment, automotive, appliances, and telecommunications. All the plants visited were subsidiaries of U.S. firms with the exception of one subsidiary of a European multinational.

Respondents were asked open ended questions, such as the way they communicate with their suppliers for different purposes, and in particular, for purchasing transactions. They were allowed to answer in their own words, explaining the importance of buyer-supplier communications in their plant, its relationship to supply chain management, and the nature of the adoption decision process. The interviews were critical for the development of the model. For example, some of the firms were very proactive in the implementation of EDI and had a very active role in the adoption process

while others had less involvement in the decision to adopt this and other technological innovations. The importance given to EDI varied widely from one firm to the other, and the atmosphere was different in firms from different industries. Appendix B contains brief summaries of the interviews. These summaries provide the reader with information about industry practice and managerial perspectives, and were used for the development and refinement of the survey instrument.

In addition to the plant interviews, two focus groups were developed to collect additional feedback from individuals related to the industry and as a pre-test to validate the instrument. One session was held at the SECOFI offices in the border city of Reynosa, a major maquiladora location. The group included a moderator and five specialists on the maquiladora industry. A second focus group was held at the facilities of the city of Reynosa, and included the city's director of industrial development and members of the Reynosa maquiladora association. In both sessions, earlier versions of the questionnaire were discussed and refined. The presence of experts from the industry and government was highly synergetic, and provided insights that could not be collected from one-on-one plant interviews.

Participants were asked to identify any factors that they considered critical in their decision to use EDI which could had been omitted on the questionnaire. These discussions contributed to a complete sampling of the content domain of the variables involved in the study, which contributes to content validity. Focus group participants also clarified the terminology they use in their organizations for concepts, processes, and functions mentioned in the instrument, allowing to customize the instrument to the context of the maquiladora industry. Additionally, information collected from this group

complemented the values of the researcher and other researchers in the literature with values prevalent in the specific context of the maquiladora industry (Nunnally, 1978). Focus groups were also critical in improving questionnaire items in terms of clarity, and were very helpful in planning the questionnaire administration and data collection process. Critical information was collected regarding the acceptable length of the instrument, construct validity, question ambiguity, and the format of the scales. Regarding the length of the survey instrument, focus group participants warned that many maquiladoras have expressed concern regarding their reporting requirements, including reporting to government agencies such as SECOFI and INEGI. Given the traditionally low rates of response reported in the maquiladora industry (e.g. Dowlatshahi, 1998), it was imperative to adopt all practices that can increase the response level. The questionnaire had to be kept at minimum length, and unclear questions, as well as questions involving sensitive information or subject to social desirability were avoided.

Survey Development

The construction of sound measuring devices is crucial in any study and particularly when using a survey instrument to measure abstract constructs. External pressure to implement EDI was measured through four Likert scale questionnaire items, reflecting the level of agreement of the respondent with four sentences stating that the plant is required to implement EDI by customers, suppliers, headquarter policies, and the industry. To measure EDI use, dichotomous questions were used regarding EDI use with suppliers of production parts, suppliers of MRO goods, and customers, as well as the years of EDI experience with each of them. In order to capture the multidimensional

content of EDI use, the scale developed by Williams et al. (1998) was selected to measure the width, depth, and range dimensions described above.

As a measure of the perceived benefits and compatibility of EDI, the 16 item scale validated by Jones and Beatty (1998) is used. This scale assures content validity for both pre- and post-adoption perceptions, because the items have been generated from independent research studies on both groups, particularly Banerjee and Golhar (1994), Iacovou et al. (1995), Premkumar and Ramamurthy (1995), Scala and McGrath (1993), and O'Callaghan et al. (1992). The dimensionality of this scale was originally assessed using confirmatory factor analysis with oblique rotation and structural equation modeling indicated that two of the original items had to be eliminated.

The number of employees in the plant was used as a proxy for plant size. This measure was taken because it is considered public information, and has been previously published in other sources such as the SOLUNET directory. This suggests that few managers would object to respond to this question, and their answers could be validated with data published in SOLUNET. Firm size was transformed into natural logarithms to improve linearity.

Previous studies measuring corporate decentralization have used instruments developed from the hierarchical perspective, conceptualizing decentralization as the level of autonomy that subordinates are given to make decisions in general. For example, in a study of decision making in buying centers, Dawes, Lee, and Dowling (1998) measured hierarchical decentralization in purchasing decision making using the instrument developed by Bacharach and Aiken (1977). Their instrument was designed to measure hierarchical decentralization for a unit within the corporation, and refers to a wide

number of tasks, such as establishing the unit's budget, evaluating the performance of the unit, purchasing new equipment and supplies, and establishing new projects or programs. The specific interest of this study, however, is the level of autonomy of the plant versus the corporate headquarters for purchasing tasks. The list of basic purchasing functions provided by Heinritz et al. (1986) was considered appropriate to develop an instrument to measure the level of the plant-headquarter decentralization of the purchasing function. Accordingly, the survey prompts for the level of responsibility assigned to the plant for main purchasing tasks of selecting suppliers, generating purchasing orders, expediting outstanding orders, receiving and inspecting materials from the suppliers, checking the supplier invoices, sending requests for quotations, and inspecting for quality.

Survey Administration

The research questionnaire was developed in both Spanish and English. Some of the questionnaire items have been adapted from previous research in English. For example, items from the instrument validated by Jones and Beatty (1998) are used to measure perceived benefits and compatibility of EDI. The method of back translation (Brislin, 1983) is used to assure that the meaning of the questions has been retained. After the author translated the items into Spanish, five other bilingual translators independently translated the questions back to English, and no semantic differences in the translation were found. This process adds to our confidence that the translation conserves literal accuracy (Harpaz, 1996).

Mexico lacks a reliable postal service and addressing system, which is a prerequisite for mail survey administration (Oppenheim, 1996). Only some maquiladoras have a physical mailing address or P.O. box in the United States and collect their mail

periodically. All businesses in the population have, however, access to a telephone and a fax machine, and the preferred form of written communication in the maquiladora environment is the fax and, increasingly, electronic mail. For this reason, the main data collection method was the fax, instead of mail. Two days after the questionnaires were faxed, a follow up telephone call was carried out with all nonrespondents. Finally, nonrespondents which could not be reached through telephone were personally visited to determine if they were still in operation. This last step, although very costly, was necessary given the volatility of the population of maquiladoras in Tamaulipas. Maquiladoras not in operation were removed from the population and were not be counted in the calculation of the rate of response. In order to test for the presence of nonresponse bias, late respondents were compared with early respondents.

The data collection process was performed in cooperation with two Mexican government institutions: SECOFI, through its State delegation in Tamaulipas, and INEGI, through its office in Reynosa. We are very fortunate to count on the cooperation of these institutions, which provided the perfect infrastructure for this project. The Mexican Secretary of Commerce is the government organization in charge of administering the Mexican maquiladora program, including its supervision, administrative procedures, promotion, and support. Its personnel has privileged insight in the industry, and is permanently in contact with maquiladoras in the state. On the other hand, INEGI is the agency in charge of the generation of all statistical information in the country and the development of the information infrastructure. Their activities include the collection of all demographic, technological, and industrial census information in Mexico, and they are very experienced in data collection methodologies, questionnaire

construction, data coding, and analysis. For all these reasons, both agencies were particularly interested in this project, and were instrumental in the data collection process.

Given the participation of the government institutions in the state of Tamaulipas, it was decided to survey the total population of this state rather than a sample of the maquiladora industry at the national level. Collecting data from only one state can limit the generalizability of the results to the rest of the states, but will likely increase the rate of response to very high levels. Although the sampling frame was limited to the state of Tamaulipas, the generalizability problem is minimum because this state has a very significant share of the Maquiladora industry. As of April 2000, the state of Tamaulipas accounted for 14% of the 1.2 million employees and bought 19% of the total supplies in the maquiladora industry (INEGI, 2000).

Analytical Methods for Hypothesis Testing

Before testing the hypotheses in the model, EDI use was first operationalized as a dichotomous variable taking the value of 1 if the respondent uses EDI to communicate with suppliers, and 0 otherwise. Given the binary nature of the dependent variable, a multivariate logit model was used to test hypotheses H_1, H_2, H_3a, H_4, and H_5 simultaneously. Additionally, the same hypotheses were tested using the metric dimensions of EDI using the scales developed by Williams et al. (1998). Since all nonusers score zero in the EDI use scales, there is a lack of linearity in these variables, and a tobit model for truncated data was used for estimating coefficients and their statistical significance.

Descriptive statistics reveal additional information about buyer-supplier communications in the maquiladora industry, such as the types of technology used by

different types of firms, EDI message formats used in different industries, and barriers to EDI adoption.

CHAPTER 4.

RESULTS OF THE PLANT INTERVIEWS AND SURVEY

This chapter presents the results of the data collection. First, a brief description of the findings of the interviews with maquila managers is presented. These interviews produced valuable insight into the EDI adoption decision process in maquiladora plants, and they were used to test and refine the questionnaire instrument. Following the interview reports, the findings of the statistical analysis of the survey data are presented.

Plant interviews

Before the survey instrument was designed, six manufacturing plants in the Mexican city of Reynosa were visited and their managers were interviewed. Summarized reports of these interviews are included in appendix D. The interviews provide insight into how maquilas communicate with their supply chain partners, how they organize their logistic flows, and the attitudes of the purchasing department toward EDI use. The interviews also indicated that the adoption of EDI can be influenced by pressures from the corporate headquarters, the customer, or supply chain organizations. The manufacturing plants visited were in the industries of home appliances, automotive systems, electric motors, medical equipment, telecommunications, and automotive electronics. There are wide differences in the way these plants are organized, as well as

their relationship with the parent firms and other supply chain members and organizations.

The manufacturer of appliances is a technological innovator within its industry. Although the pressure from other supply chain organizations was low, this plant has established EDI links with its suppliers primarily motivated by the need to reduce inventories, and to support their just-in-time (JIT) system. The implementation of EDI took place together with supplier development programs, and with efforts to move suppliers to locations closer to the plant. Given the low level of success obtained with other initiatives directed at improving the relationship with suppliers, EDI has become a high priority in this company. After some suppliers refused to invest in standard EDI systems, the firm established a web-based EDI system which does not require any investment by the supplier. This system handles standard EDI transactions such as material releases, advanced shipping notices, receiving advices, text messages, and JIT shipping schedules. The managers at the plant are very aware of the benefits of EDI use, and are committed to further developing electronic communications with supply chain partners. The web-based EDI system is proprietary, and suppliers can use this system only to communicate with this customer. In addition, suppliers cannot integrate the information collected through EDI with their internal information systems, and they have to manually re-enter the information in each system. This lack of integration in the supplier's system contributes to the poor distribution of EDI benefits between buyer and supplier. While the buyer's EDI system is used to communicate with all its suppliers and is integrated with its internal systems, this is not true for suppliers, who need a different

EDI system to communicate with each customer, and cannot derive the full benefits of EDI.

The automotive systems manufacturer, however, is facing external pressure from the supply chain regulatory agency -the AIAG- to implement EDI. Local managers are also committed to the implementation of the system and are well aware of the benefits of EDI. The plant serves as an instrument to translate the pressure to adopt EDI to the suppliers, and EDI capability is used as a supplier selection factor.

The electrical equipment manufacturer has not adopted EDI primarily due to a lack of corporate management support. Plant managers, however, are well aware of the use and benefits of EDI and are exploring the possibility of adoption. Currently, purchasing agents spend a large proportion of their time exchanging fax documents and expensive telephone calls to communicate with suppliers. They also access supplier web sites to collect information about their products, inventories, and prices. Although the attitude toward EDI is proactive at the plant level, the centralization of the purchasing function and the lack of corporate support creates an obstacle to the adoption of EDI with suppliers.

The medical equipment manufacturer is owned by a firm with a highly centralized structure, and its management has a reactive attitude toward the adoption of new technologies. Low pressure and a lack of awareness of the use and benefits of EDI make this plant unlikely to adopt EDI in the near future. The purchasing manager shows resistance to the adoption of EDI, insisting that there is no need for it and that the purchasing personnel is too busy dealing with suppliers to worry about new technologies.

Similar to the manufacturer of appliances, the telecommunications equipment plant faces strong pressure from the corporate headquarters, and EDI implementation is under way, although only for production parts, while MRO purchases will continue in the traditional form. In this case, however, there is an important degree of centralization of the purchasing function and technology adoption decisions. Plant personnel are well aware of the benefits of EDI and actively support the adoption process.

The automotive electronics manufacturer, being a member of the automotive industry, faces supply chain pressure to adopt EDI with customers and suppliers. The attitude in this plant, however, is not as proactive as it was in the case of the automotive systems manufacturer. This lack of interest may be due to the fact that this company has already implemented a one-way electronic link with suppliers. Suppliers can consult the planned consumption for each component and deliver materials on a JIT basis. The supplier, however, is unable to send information such as production schedules, prices, or advanced shipping notices to the plant. There is a strong awareness of the EDI technology and its benefits, but there is a feeling that the existing system partially performs that function, and therefore there is not a sense of urgency to implement a full EDI system as required in the automotive industry. Table 5 summarizes the level of pressure to adopt EDI each plant faces from corporate headquarters, the corporation, and the supply chain. It also shows each plant's level of awareness of EDI systems and their benefits for the plant.

Table 5

Summary of Plant Interviews

	Appliances	Automotive systems	Electrical Equipment	Medical equipment	Telecommu nications	Automotive electronics
Pressure from Customer	Low	High	Low	Low	Low	High
Pressure from HQ	High	High	Low	Low	High	Moderate
Pressure from Supply Chain	Low	Very high	Low	Low	Low	High
Perceived Benefits	High	High	High	Low	High	Moderate
EDI Awareness	High	High	High	Low	High	Moderate

Statistical analysis

This section analyzes the survey data, according to the research hypotheses. Out of the 453 plants included in the master list, physical visits determined that 38 plants no longer existed and, thus, were not surveyed. Questionnaires were sent to the remaining 415 plants. Table 6 details the survey response statistics. Out of the 186 questionnaires received, 25 did not have enough information to be used. In total, 161 usable questionnaires were received, a 39% rate of response, which is extremely high in the context of the maquiladora industry.

Before doing any statistical analysis was performed, the randomness of the missing data was analyzed. Specifically, tests for significant correlations were performed in the matrix of dichotomous missing/not missing variables. No significant correlations were found, which suggests a random missing data pattern. Observations with some variables missing were also analyzed searching for significant differences in other variables between observations with and without missing data. The absence of any

significant differences provides additional evidence of the randomness of the missing data. Since the missing data are considered to be completely random, all pairwise available data was used for the correlation analysis, and all cases with missing data in any of the variables analyzed were omitted from the multivariate analysis. Although this approach has been criticized because it can sacrifice a large amount of data (e.g. Malhotra, 1987), the relatively small amount of missing data in this study minimizes the effect of this problem.

In order to test for the presence of nonresponse bias, early respondents were compared to late respondents (Armstrong & Overton, 1977; Lambert & Harrington, 1990). The number of days that each plant took to respond was computed by subtracting the date when the questionnaire was delivered from the date when it was returned. Observations in the fourth quartile of this variable were considered late respondents and assumed to be similar to nonrespondents. Late respondents were compared to the rest of the observations using t-tests for mean differences in independent samples. The variables tested were plant size and square feet of the plant (both logarithmically transformed), perceived benefits, perceived compatibility, decentralization, and external pressure. None of the differences between the means of early and late respondents was significant at the $p<.05$ level, suggesting an absence of nonresponse bias.

Outliers were identified by computing the standard Z scores within each variable, and examining all observations with a score higher than 2.5 in absolute value. For the variables included in correlation analysis, outliers were identified also using bidimensional scatterplots. Finally, the Mahalanobis D^2 measure was computed to identify multidimensional outliers in the multiple regression analysis. The significance of

the D^2 statistic was evaluated at the $p<0.001$ level (Hair et al., 1998), and only one observation had a significant Mahalanobis distance and was excluded from further multivariate analysis.

For this study, industry categories are based on the Mexican Secretary of Commerce's categorization: Electric/electronic materials, excluding all materials destined to the automotive industry; automotive and/or auto-parts; textile and apparel, and other industries. These are the most common maquiladora plants, and given the size of our data set, four groups are appropriate to assure sufficient group size for statistical analysis. The industry of each plant was determined based on a description of the main activity of the plant included in the survey questionnaire. Table 7 shows the distribution of the respondents by industry.

Table 6

Survey Response Statistics

	Frequency	Percent
Total sampling frame	453	100.0
Plants closed	38	8.4
Questionnaires sent	415	91.6
Nonrespondents	229	50.6
Returned not usable	25	5.5
Returned usable questionnaires	161	35.6
Rate of response	161 /415	38.8

Table 7

Industry of the Respondents

Industry	Count	Percent
Electric/electronic materials (except automotive)	48	29.6
Automotive and/or auto-parts	35	21.6
Textile and apparel industry	24	14.8
Other	55	34.0

The average plant reported to have 574 employees. Table 8 shows the distribution of plant sizes, showing a clear balance between large and small plants.

Table 8

Number of Employees per Plant

Employees	Plants	Percent
0-100	40	24.69%
101-250	31	19.14%
251-500	34	20.99%
500+	53	32.72%

Of the 161 valid responses, 49 (29.5%) report using some form of EDI to communicate with their customers, their suppliers of production parts, or their suppliers of MRO products. Table 9 reports in more detail the composition of EDI use to communicate with each of these groups. While 27.95% of respondents report to be using EDI with their customers, only 16.15% of them report to be using it with their suppliers. Within this group, EDI is much more frequently used with suppliers of production parts than it is with suppliers of MRO goods.

Regarding the types of technologies maquiladora plants are using to communicate with their suppliers, firms are using mostly traditional forms of communication such as fax and telephone. Use of e-mail has grown considerably in the industry, while the use of traditional mail is relatively very low. This is an expected finding given the low reliability of the Mexican mail system, as revealed by our interviews and focus groups during the initial phases of the study. As shown in Figure 2, electronic data interchange, as well as web pages and XML are still used by a relatively small percentage of the plants.

Table 9

Use of EDI in the Maquiladora Industry

		Frequency	Percent
EDI with customers	Non-users	116	72.05
	EDI users	45	27.95
EDI with production part suppliers	Non-users	137	85.09
	EDI users	24	14.91
EDI with MRO suppliers	Non-users	148	91.93
	EDI users	13	8.07
EDI with suppliers	Non-users	135	83.85
	EDI users	26	16.15

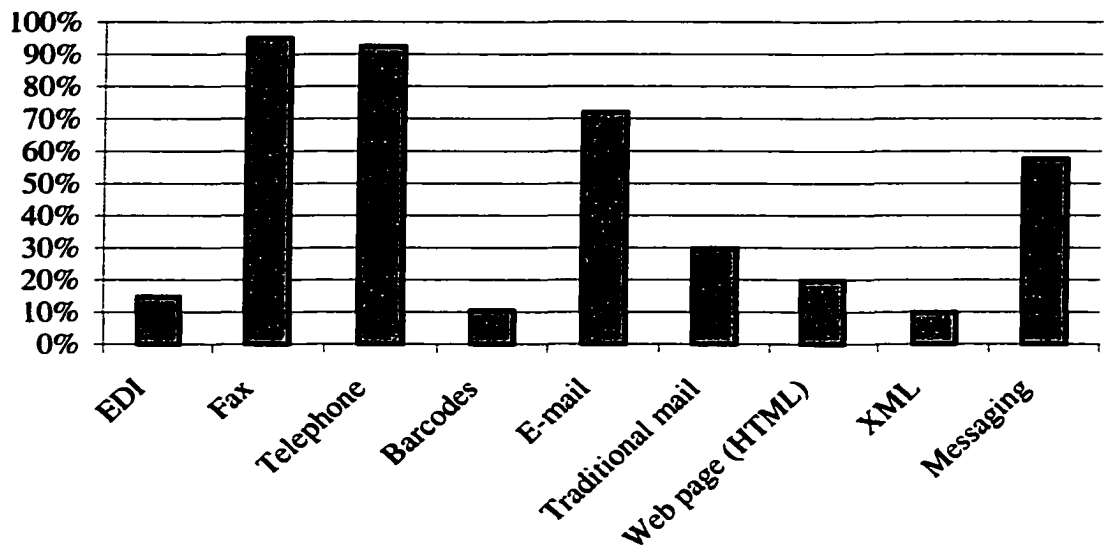

Figure 2. Communication modes between maquila plants and suppliers

A large percentage of maquiladora plants are using private EDI standards, and many are also using the EDIFACT and ANSI X.12 standards described in the literature review (Figure 3). Many plants report using more than one standard, probably in an attempt to satisfy requirements from different customers. As discussed in the literature

review, this lack of standardization of EDI formats increases the cost of implementation for maquiladora plants and also for their suppliers, who are forced to respond to different requirements from their customers.

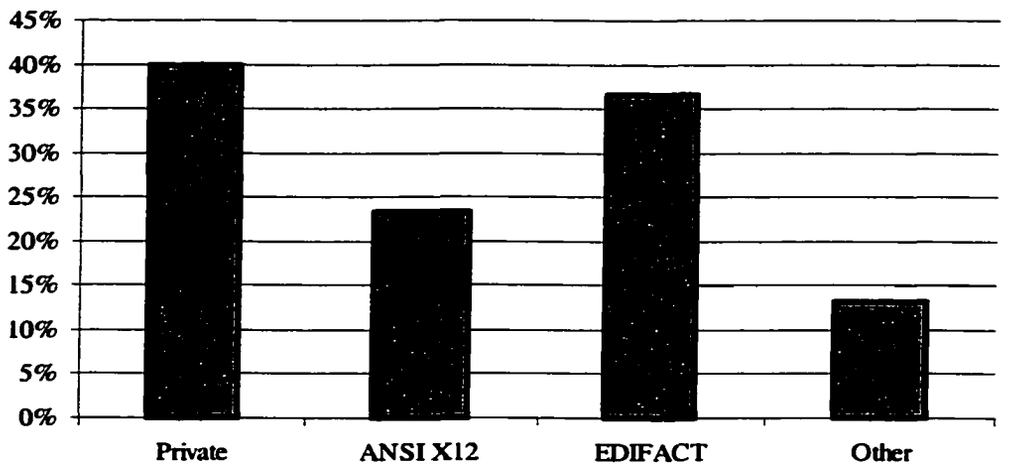

Figure 3. EDI standards in the maquiladora industry.

When analyzing EDI use by industry, it is evident that the automotive industry is the most advanced and proactive in the adoption of EDI, especially to communicate with customers. The electronics industry seems to be making more balanced progress in EDI use with customers, suppliers of production parts, and suppliers of MRO goods. The low use of EDI in the textile industry, however, reveals a lack of technological sophistication in this industry (Figure 4). Appendix E shows additional evidence of the differences across industries in the use of computers and computer-based communications.

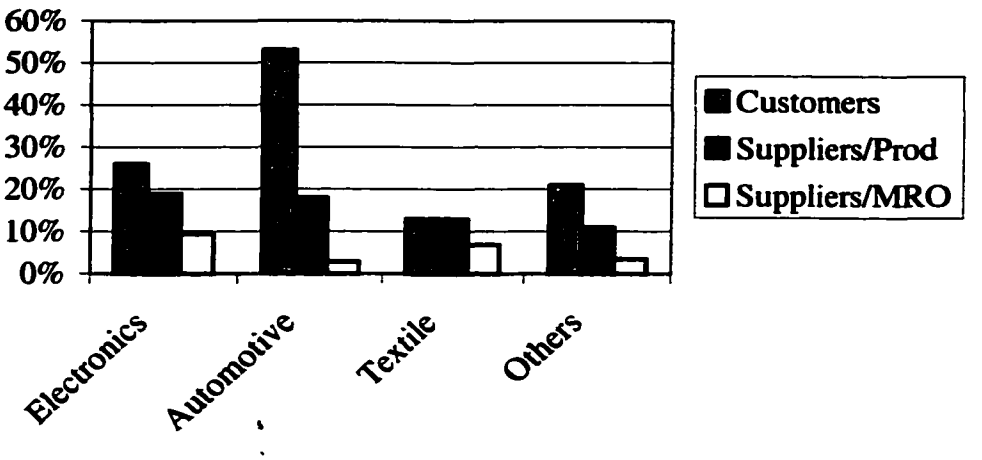

Figure 4. EDI use by industries

The decentralization of the purchasing function differs markedly by the type of material being purchased. In general, plants report to have much more control over their purchases of MRO goods than they have over production parts. In particular, supplier selection for production parts is largely controlled by the headquarters, while the responsibility for inspecting incoming materials relies mostly on the plant. Figure 5 illustrates the level of decentralization of the production function for both production parts and MRO goods, on a seven point Likert scale.

The main perceived benefit of EDI is the improvement of information quality, followed by improvements in customer service and the reduction of transaction costs (Figure 6). Benefits of EDI such as the improvement of cash flow and the reduction in inventory levels, although considered extremely important in the academic literature, are perceived by managers as less important.

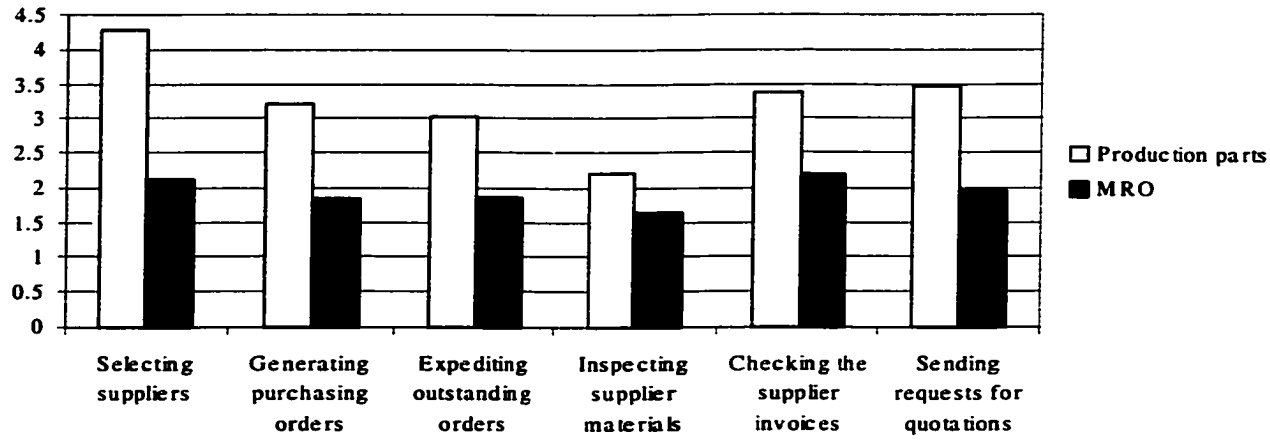

Figure 5. Decentralization of the purchasing function

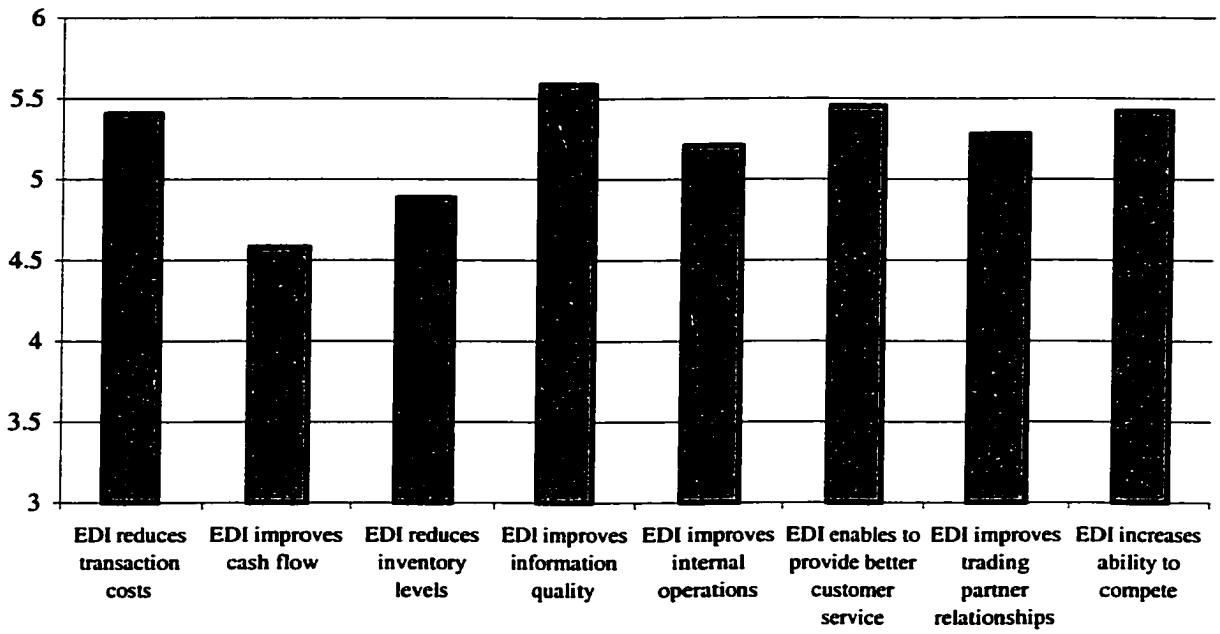

Figure 6. Perceived benefits of EDI

The main barrier to EDI adoption is lack of training (Figure 7). This finding reveals a lack of support from maquiladora parent firms when it comes to transferring technology to offshore plants. The second barrier to EDI adoption is the lack of

sufficient transaction volume with suppliers to justify the implementation costs. Some managers consider that they have a low level of interaction with their suppliers, in some cases because they receive their production parts and components directly from other locations of the parent firm, which drastically reduces their need to communicate with suppliers. Smaller plants also perform fewer transactions with suppliers, and lack the economies of scale necessary to justify the cost of EDI implementation.

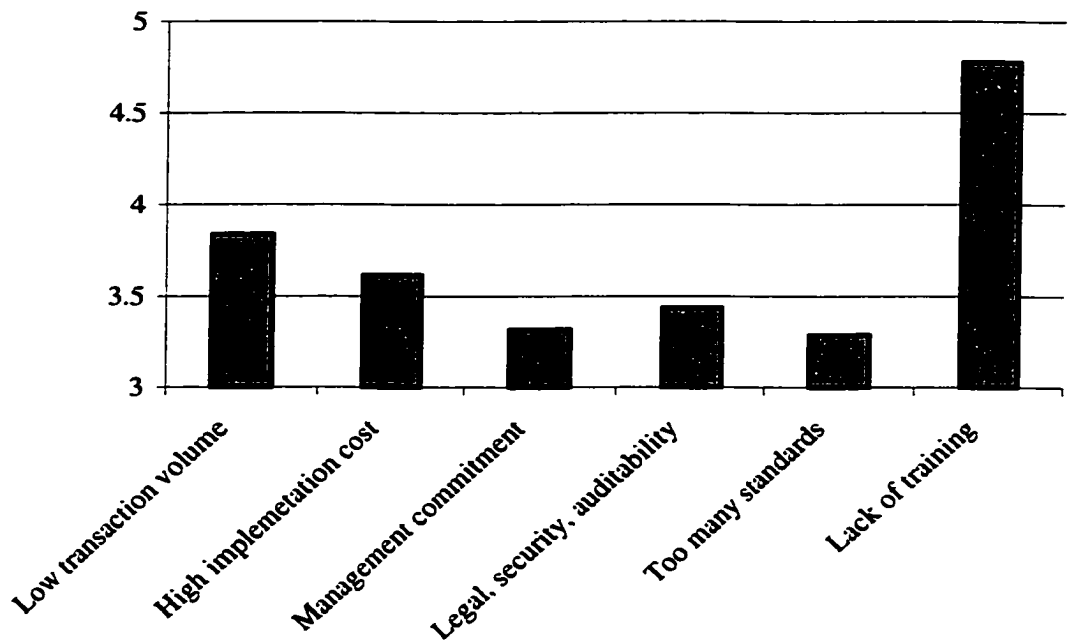

Figure 7. Barriers to EDI adoption.

Analytical research statistics

Cronbach's alpha statistics were computed to assess the internal consistency reliabilities of the multi-item measures. All multi-item measures meet the minimum alpha benchmark of 0.70 established by Nunnally (1978), suggesting a strong inter-item covariance (Table 10). Correlations between variables are shown in Table 11.

Table 10

Reliability Statistics

Construct	Number of items	Number of cases	Cronbach's alpha
External pressure	5	131	.9204
Benefits	8	127	.9438
Compatibility	7	126	.7807
Decentralization	6	153	.9136

Table 11

Bivariate Pearson Correlations

	LOGSIZE	DECEN	PRESS	PERBENE	PERCOMP
DECEN	0.08				
PRESS	0.26**	0.17			
PERBENE	0.10	-0.02	0.45**		
PERCOMP	0.04	-0.05	0.08	0.27**	
EDI	0.32**	0.05	0.51**	0.42**	-0.09

* p<.05
** p<.01

Although the correlation between perceived benefits and external pressure is significant, the correlation coefficient is well bellow the minimum benchmark of 0.8 to cause a harmful collinear relationship (Griffiths, Hill & Judge, 1992). Additionally, the variance inflation factors (VIF) of these variables are 1.249 and 1.284 respectively (tolerances of .800 and .779), also well within the acceptable VIF benchmark of 10 (Hair et al, 1998).

Factor Analysis

In order to establish the unidimensionality of the measures, a principal component factor analysis with varimax rotation was performed on all questionnaire items of multivariate measures. The factor loadings are presented in Table 12. The number of factors retained was determined by the underlying theory and the pilot testing of the

questionnaire with industry practitioners. All questionnaire items load clearly on the correct factors, with the only exception of one item from the compatibility construct regarding EDI disrupting the workplace (question 16.9) which does not load clearly on any latent variable. This item was eliminated from the construct for further analysis. All factor loadings meet the significance standard of 0.4 suggested by Ford, MacCallum and Tait (1986).

Tests for differences between EDI users and non-users

Table 13 shows the means and standard deviations for EDI users and for non-users. Table 14 reports significant differences in population means for all determinants of EDI adoption except for decentralization and compatibility. The group standard deviations were used to test the homogeneity of variance using the Hartley's Fmax test (Hartley, 1940, 1950), as well as a Levene's test for equality of variances. Both tests rejected the null hypothesis of equal population variances, and the t-tests reported in Table 14 do not assume equal population variances.

Table 12

Factor Analysis of Multivariate Measures

Construct	Name	Factor 1 Benefits	Factor 2 Decentralization	Factor 3 Ext. pressure	Factor 4 Compatibility
Ext. pressure	Q14_1	0.295	0.108	**0.826**	0.092
Ext. pressure	Q14_2	0.151	0.093	**0.845**	0.015
Ext. pressure	Q14_3	0.270	0.080	**0.750**	-0.021
Ext. pressure	Q14_4	0.200	0.039	**0.840**	-0.065
Ext. pressure	Q14_5	0.151	0.110	**0.869**	-0.015
Benefits	Q16_1	**0.806**	-0.039	0.213	0.085
Benefits	Q16_2	**0.697**	0.004	0.273	0.017
Benefits	Q16_3	**0.772**	0.007	0.213	0.065
Benefits	Q16_4	**0.831**	-0.096	0.199	0.211
Benefits	Q16_5	**0.861**	0.028	0.142	0.136
Benefits	Q16_6	**0.866**	-0.008	0.102	0.072
Benefits	Q16_7	**0.799**	-0.130	0.216	0.155
Benefits	Q16_8	**0.883**	-0.034	0.162	0.152
Compatibility	Q16_9	-0.298	-0.184	0.057	0.205
Compatibility	Q16_10	0.154	-0.160	0.016	**0.456**
Compatibility	Q16_11	-0.266	-0.111	-0.047	**0.653**
Compatibility	Q16_12	-0.129	-0.058	-0.075	**0.750**
Compatibility	Q16_13	0.392	0.050	-0.089	**0.564**
Compatibility	Q16_14	0.337	0.046	0.166	**0.568**
Compatibility	Q16_15	0.176	0.122	0.029	**0.735**
Compatibility	Q16_16	0.250	0.141	0.012	**0.651**
Decentralization	Q13_1	-0.059	**0.778**	0.159	0.002
Decentralization	Q13_2	0.030	**0.819**	0.138	-0.121
Decentralization	Q13_3	-0.110	**0.872**	0.061	0.020
Decentralization	Q13_4	0.092	**0.698**	-0.022	0.069
Decentralization	Q13_5	-0.038	**0.803**	-0.036	0.078
Decentralization	Q13_6	-0.042	**0.817**	0.146	-0.110

Table 13

Descriptive Statistics for Users and Non-Users

		N	Mean	Std. Deviation	Std. Error Mean
SIZE	Non-users	131	487.38	636.336	55.597
	Users	25	1031.64	888.147	177.629
DECEN	Non-users	128	3.211	2.197	0.194
	Users	25	3.513	2.070	0.414
PRESS	Non-users	106	3.288	1.749	0.170
	Users	26	5.731	1.149	0.225
PERBENE	Non-users	101	4.915	1.484	0.148
	Users	26	6.462	0.656	0.129
PERCOMP	Non-users	101	4.048	1.027	0.102
	Users	26	3.793	1.305	0.256

Table 14

Independent Samples T-tests

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
DECEN	-0.661	35.3	0.513	-0.302	0.457	-1.231	0.626
PRESS	-8.658	57.1	0.000	-2.443	0.282	-3.008	-1.878
PERBENE	-7.897	93.6	0.000	-1.547	0.196	-1.936	-1.158
PERCOMP	0.925	33. 4	0.362	0.255	0.276	-0.306	0.816
SIZE	-2.924	28.8	0.007	-544.26	186.127	-924.999	-163.518

Logistic regression

In order to test the hypotheses, a binary logistic regression was estimated with the dichotomous EDI use as dependent variable, and external pressure (H1), perceived benefits (H2a), perceived compatibility (H2b), plant size (H3a), and decentralization (H5), as independent variables.

The results (Table 15) show that plant size, external pressure, perceived benefits, and perceived compatibility have a statistically significant effect on EDI use, and all the coefficients have the expected signs. The coefficient for decentralization, however, is very small and statistically insignificant. There is, therefore, support for H1, H2a, H2b, and H3a, but not for H5.

Larger beta coefficients are associated with larger contributions to the probability that a plant will use EDI. Plant size has the largest beta coefficient, followed by perceived benefits, perceived compatibility and external pressure. These variables are, therefore, the best predictors of EDI use in maquiladora plants.

Table 15

Logistic Regression Coefficients

	B	S.E.	Wald	df	Sig.	Exp(B)
LOGSIZE	1.333*	0.592	5.061	1	0.024	3.791
DECEN	0.049	0.179	0.074	1	0.786	0.952
PRESS	0.849**	0.280	9.163	1	0.002	2.337
PERBENE	1.024*	0.449	5.206	1	0.023	2.784
PERCOMP	0.856**	0.327	6.850	1	0.009	0.425
Constant	-11.434	3.546	10.397	1	0.001	0.000

Overall model chi-square: 59.63 with 5 degrees of freedom.
* $p<.05$
** $p<.01$

A classification table for the logistic regression is presented in Table 16. The model was able to predict correctly 89.2 percent of the cases, versus a proportional chance criterion of 67.01%, which provides a highly significant classification accuracy ($p<.01$).

The relationship between plant size and perceived EDI benefits (H3b) was tested computing the bivariate correlation, resulting on a coefficient of .1 (p=.26). Hypothesis H3b is, therefore, not supported by the data.

Table 16

Logistic Regression Classification Table

	Predicted			
Observed	Non-EDI	EDI	Total	Percentage Correct
Non-EDI	91	4	95	95.8
EDI	9	16	25	64.0
Total			120	89.2

Proportional chance criterion: 67.01%
Classification accuracy t=10.70, significant p<0.01

Discriminant analysis

In order to validate the results of the logistic regression, a canonical discriminant analysis was performed to assess the power of each variable in differentiating EDI users and nonusers. A canonical discriminant analysis estimates a linear combination of independent variables that best discriminates between users and nonusers of EDI with suppliers (Hair et al., 1998). The discriminant function includes the variables of size, decentralization, external pressure, perceived benefits and perceived compatibility. The estimated function is highly significant, with a Wilks' Lambda of 0.61. Table 17 shows that the largest discriminant function coefficients (weights) are assigned to perceived benefits, external pressure, perceived compatibility, and plant size. Decentralization has the lowest discriminating power.

Discriminant loadings (variable-discriminant function correlations) are used to assess the significance of the variables. External pressure, size, perceived benefits, and perceived compatibility have significant discriminant loadings. Since decentralization does not reach the significant threshold of 0.30 suggested by Lambert and Durand (1975), it can be concluded that decentralization is unable to discriminate between users and nonusers of EDI. Perceived benefits and external pressure have the largest discriminant coefficients, closely followed by perceived compatibility. These findings largely confirm the results of the logistic regression.

Table 17

Discriminant Function Coefficients and Loadings

Wilks Lambda	.610	
Chi-Square	57.164	
Degrees of Freedom	5	
Significance	.000	
Variable	Weight	Loading
DECEN	0.017630	0.081944
PRESS	0.590315	0.734858
SIZE	0.347432	0.388540
PERBENE	0.594762	0.579505
PERCOMP	0.513510	-0.171350

In addition to analyzing the discriminant coefficients and loadings, it is important to assess the predictive power of the discriminant function. Table 18 shows that the function predicts accurately 106 out of 120 observations used in the analysis. This predictive accuracy yields a hit ratio of 88.3%, which exceeds the proportional chance criterion of 67%, and is highly significant ($p<.01$).

Table 18

Discriminant Function Classification Results

	Predicted			Percent Correct
Observed	Non-EDI	EDI	Total	
Non-EDI	90	5	95	94.7
EDI	9	16	25	64.0
Total	99	21	120	88.3

Tobit model for EDI use dimensions

As a measurement of the extent to which EDI is used in maquiladora plants, the metric dimensions of width, range, and depth provide much richer information than the dichotomous adoption / non adoption variable. Although with metric dependent variables least squares estimates of functions are best linear unbiased estimates, it is not appropriate to use least squares regression with this data because its distribution is truncated and not normal. Since a large percentage of plants do not use EDI, the EDI dimension variables take a value of zero in a large number of cases. In addition, negative values of EDI use dimensions are not possible. The dependent variables are, therefore, censored and not normal, and their least square estimates could be biased (Maddala, 1983). Under these circumstances, a Tobit model is robust to the presence of measurement error (censoring) and will produce unbiased parameter estimates (Greene, 1990; Maddala, 1983; Tobin, 1958). In order to estimate the Tobit model, the LIMDEP statistical software package (Greene, 1991) was used. Algebraically, the equations can be written as:

$$\text{Range} = \beta_0 + \beta_1 \text{ logsize} + \beta_2 \text{ decen} + \beta_3 \text{ perbene} + \beta_4 \text{ percomp} + \beta_5 \text{ press}$$

$$\text{Width} = \beta_0 + \beta_1 \text{ logsize} + \beta_2 \text{ decen} + \beta_3 \text{ perbene} + \beta_4 \text{ percomp} + \beta_5 \text{ press}$$

$$\text{Depth} = \beta_0 + \beta_1 \text{ logsize} + \beta_2 \text{ decen} + \beta_3 \text{ perbene} + \beta_4 \text{ percomp} + \beta_5 \text{ press}$$

The estimated beta coefficients of the Tobit model are presented in Table 19. Consistently, with the results of the Logit model, all coefficients have the hypothesized signs, and the coefficients for decentralization are not significant for any of the three dimension of EDI. In addition, plant size is not significant in the width model, and perceived compatibility is not significant in the depth model.

Table 19

Tobit Estimates for EDI Metric Dimensions

	RANGE	WIDTH	DEPTH
Constant	-364.04**	-30.88**	-459.43**
LOGSIZE	49.41*	2.65	56.79*
DECEN	5.86	0.27	6.86
PERBENE	30.51*	2.73*	34.22*
PERCOMP	20.10*	1.16	16.79
PRESS	21.60**	1.94**	29.73**

* $p<.05$ ** $p<.01$

Test for differences in EDI use across industries.

One-way analysis of variance was used to test hypotheses H6a and H6b regarding industry differences in perceived benefits and external pressure. As Table 20 shows, only external pressure showed a statistically significant difference across industries.

Table 20

One-way Anova for Industry Differences

		Sum of Squares	df	Mean Square	F	Sig.
PERBENE	Between Groups	12.650	3	4.217	1.937	.127
	Within Groups	267.790	123	2.177		
	Total	280.440	126			
PRESS	Between Groups	64.712	3	21.571	6.667	.000
	Within Groups	414.116	128	3.235		
	Total	478.828	131			

In order to detect an industry impact on EDI adoption (H_6c), a test was performed for significant differences between the proportions of EDI use in the industries with the largest (electronics) and the lowest (other) proportions of EDI use. Table 21 presents the proportions of EDI use with suppliers in each industry. The analysis yields a p value of .049, which provides some support for the hypothesis.

Table 21

Use of EDI with Suppliers by Industry

Industry	N	Sum	P
Electric/electronic materials (except automotive)	42	10	.24
Automotive and/or auto-parts	34	6	.18
Textile and apparel industry	24	3	.13
Other	61	7	.11
Total	161	26	.16

The type of product purchased is hypothesized to have a positive and statistically significant effect on the adoption of EDI in maquila plants (H4). In order to test this hypothesis, a test is performed for significant differences in the proportion of maquila plants that adopted EDI for purchases of production parts versus MRO materials. The percentage of maquila plants using EDI to communicate with their suppliers of

production parts is 14.91%, while only 8.07% of the plants use EDI to communicate with their suppliers of MRO materials. These proportions are found to be significantly different (p=0.027). Table 22 presents a summary of the results of statistical tests for each hypothesis.

Table 22

Summary of Statistical Tests

Hypothesis	Test variables Indep/dependent	Discriminant Weight	Logit coefficient	Correlation	Different proportions (z)	ANOVA (F)
H1	PRESS/EDI	0.590	0.849**			
H2a	PERBENE/EDI	0.595	1.024*			
H2b	PERCOMP/EDI	0.514	0.856**			
H3a	SIZE/EDI	0.347	1.333*			
H3b	SIZE/PERBENE			0.100		
H4	PURCHASE/EDI				1.92**	
H5	DECEN/EDI	0.018	0.049			
H6a	IND/PERBENE					1.937
H6b	IND/PRESS					6.667**
H6c	IND/EDI				1.65*	

* p< .05
** p< .01

The results of the statistical analysis support hypotheses H1, H2a, H2b, H3a, H4, H6b and H6c. Chapter 5 analyzes these results and their managerial implications, providing conclusions and future research suggestions.

CHAPTER 5.

FINDINGS AND CONCLUSIONS

This chapter analyzes the findings of the statistical analysis, and draws implications for firms and for policy making. Finally, directions for future research are discussed.

Findings

Understanding the process of information technology adoption is crucial for firms and supply chains to attain higher levels of adoption that allow them to benefit fully from information technology. The findings of this dissertation are useful for managers as they plan their buyer-supplier communication policies, and for economic development agencies in the US-Mexico border area as they attempt to develop a local supplier base for the maquiladora industry.

The results of this study show a link between external pressure and EDI adoption. Interorganizational ties such as those of maquiladora firms with their customers and suppliers serve both as a vehicle for diffusion of technology, and as a channel for institutional pressure and conformance monitoring. The role of inter-firm relationships is especially relevant in the case of interorganizational communication technologies, where the adoption of a common or compatible communication standard is a technical necessity. The diffusion of technology and the pressure to adopt it, therefore, will be

transmitted from customers to maquiladora firms, and, subsequently, to their suppliers. Exerting pressure on business partners will lead to faster adoption of interorganizational information technologies, and therefore to the improvement of logistic performance. The pressure to adopt should be accompanied by training and support, making sure that the implementation does not just attempt to conform to the requirement, but it also maximizes efficiency for both buyer and supplier, and along the supply chain. Industry organizations can contribute to this process by taking advantage of economies of scale in the provision of support and training, and by providing standards and implementation guidelines that make EDI systems less relationship specific, encouraging the creation of new interorganizational information links.

Efficiency advantage

This study also found that perceived efficiency advantage is a strong predictor of EDI adoption. The adoption of EDI is, therefore, subject to a managerial understanding of the economic gains derived from the use of this technology. Perception of benefits of a technology can be gained through formal training or through informal processes such as social or vicarious learning (Bandura, 1977; Rogers, 1983). Business partners can, therefore, have an impact on perceived benefits of EDI, and this relationship is reflected in the significant correlation found between perceived benefits and external pressure.

From a dynamic perspective, institutional factors can be expected to have a larger impact on the future implementation of EDI. Most empirical studies on adoption of technological and administrative innovations show that early adopters are more likely to respond to technical or economic efficiency arguments, while late adopters are motivated by the need to conform to network requirements (Tolbert & Zucker, 1983; Baron,

Dobbin, and Jennings, 1986; Westphal, Gulati & Shortell, 1997; Scott, 1987). Accordingly, maquiladoras perceiving clear opportunities to improve performance with EDI systems would be the first to adopt, as is found in this study, but institutional factors will be the critical determinants of later adoption. Supply chain leaders and organizations, as well as other governmental and industry related institutions will play a critical role in future development of EDI in the maquiladora industry.

Perceived compatibility

Perceived compatibility is also a strong predictor of EDI adoption. The perceptions that EDI implementation will be costly, will require the modification of plant processes, and will be difficult to learn affect the decision to adopt EDI. Regarding this variable, it is important to note that when the metric EDI use dimensions are used as dependent variables, perceived compatibility is significant only in the range model, but not in width and depth. The same variable that is highly significant explaining categorical EDI adoption (p=.009), is a weak predictor of the metric EDI use variable. This indicates that incompatibility with present systems is an obstacle to implementation with individual business partners, but compatibility is not a driver for expanding EDI use to other types of documents, or for a larger percentage of transactions. When a firm perceives higher compatibility of EDI, it is more likely to adopt the technology with business partners that require electronic transaction capability, but the decision to expand EDI use to other types of documents will be dictated by perceived benefits and, most importantly, by external pressure.

The ability and willingness to adopt new technologies in a plant is related to technology specific skills and training, as well as the cost/benefit relationship. Larger

plants have the resources to train and hire more specialized personnel who possess the necessary skills to implement new technologies, and have a larger transaction volume, which will increase the cost efficiency of the implementation. Larger investments can be justified when EDI use with multiple partners generates a large volume of electronic transactions. According to this logic and hypothesis H3a tested in this study, plant size is a strong predictor of EDI adoption. When using the EDI metric dimensions, however, the relationship is only weakly supported for EDI range and depth, and not supported for width. The main advantage of larger plants is availability of resources and economies of scale. The decision to expand EDI use to a wider range of documents is made jointly by both business partners, and depends on what types of transactions are commonly performed electronically in the industry or by individual suppliers. The use of EDI for additional purposes is more related to the level of interorganizational coordination than it is to cost/benefit considerations.

The hypothesized relationship between plant size and perceived benefits of EDI (H3b) is not supported by the data. This finding suggests that, although the literature finds extensive evidence of economies of scale in technology adoption, the size of individual plants does not affect managerial perceptions about the benefits of EDI implementation. There seem to be other factors affecting the perceived benefits of EDI. A careful examination of the data collected in this study shows a highly significant correlation between external pressure and perceived benefits (see Table 11). This correlation could be due to the direct influence of external pressure on perceived benefits. It is intuitive to recognize that, when other components of the supply chain or the parent

organization itself exert pressure on the implementation of a technology, local managers perceive higher benefits derived from that technology.

The use of EDI is more frequent for purchases of production parts than it is for MRO goods. The data supports hypothesis H4, and plant interviews provide an explanation for this. The adoption of information technologies between buyers and suppliers depends strongly on the strength and criticality of the interorganizational relationship, both at the dyadic and at the supply chain levels. At the dyadic level, switching costs for MRO goods are lower than they are for production parts, and their production tends to involve shorter term commitment and fewer relationship specific assets. For this reason, MRO buyer-supplier relations take a form that is closer to the market than to the hierarchy (Williamson, 1975; Malone et al., 1987, 1989), and the opposite is true for production part buyer-supplier dyads. From the supply chain perspective, MRO goods are not physically assembled in the product that is delivered to the next customer in the channel. MRO goods, therefore, are not part of supply chain material flows, and their coordination is less critical for supply chains. In fact, supply chain regulatory institutions require EDI implementation only for production parts, and not for MRO goods. Use of less structured and more flexible information technologies such as electronic marketplaces is more common for MRO goods, and fewer plants report plans to implement EDI with MRO suppliers in the near future.

The level of decentralization of the purchasing function does not have a significant impact on adoption of EDI between maquilas and their suppliers. This finding suggests that opposite mechanisms are in conflict in the relationship between decentralization and technology adoption. While decentralization provides the flexibility

and autonomy for individual plants to acquire the resources necessary to adopt information links with suppliers, centralization can also facilitate the adoption of common standards and provide the managerial support needed to implement the new technology. The opposing impacts of these mechanisms can explain the lack of significant results.

The data does not support hypothesis H6a regarding industry differences in perceived benefits. The fact of belonging to an industry does not affect managerial perceptions about a technology. The correlation between external pressure and perceived benefits, along with the significant differences in external pressures across industries (hypothesis H6b) tends to suggest that industries differ in pressure to adopt, and pressure, in turn, affects perceived benefits.

The level of pressure to adopt EDI differs very strongly across industries. As discussed in Chapter 2, while some industries have established formal requirements to adopt EDI, other industries lack that level of organization and supply chain coordination. The relatively low statistical significance of industry differences on EDI adoption ($p=0.049$) is only due to the small number of adopters in general, especially in the industry with the lowest proportion, with only 3 adopters in the textile industry. The differences in proportions, however, seem practically significant, ranging from 11% in other to 24% in electronics.

EDI is in the process of transition of telecommunication technology from private and public telephone networks to the Internet (Segev, Porra, & Roldan, 1997). Firms that have included EDI in their communications strategy must have the skills to handle internet technologies and to perform the tasks that have traditionally been performed by

VANs (Baer, 1998). Such tasks include translation to the standard used by each partner, maintenance and security issues. This study found that lack of training is a major barrier to the adoption of EDI systems in the maquiladora industry. This finding is consistent with EDI studies in other locations as documented in the literature (Iacovou et al., 1995; Lal, 1999; Crum, Premkumar, & Ramamurthy, 1996; Johnson, Allen & Crum, 1992; Crum, Johnson & Allen, 1998). The literature also identifies lack of awareness as a factor leading to the slow adoption of EDI (McGowan & Madey, 1998). In particular, businesses in Mexico have been reported to lack a good understanding of EDI and E-commerce, and multinational firms play an important role in international technology transfer, which explains why most EDI users in Mexico are subsidiaries of large multinational corporations (Mireles, 1998). As the use of EDI expands in the maquiladora industry, the supply of managers and employees that are familiar with EDI will increase, and lack of training and awareness can be expected to gradually lose importance as a barrier to EDI adoption. Likewise, as generally accepted standards emerge, the marginal cost of implementing EDI with additional partners will decrease, and lack of standards can be expected to gradually lose importance as EDI adoption barrier.

Implications for firms

The case studies indicate that such factors as pressure from customers, generalized use of EDI in the industry, the level of managerial training, and the size and technological sophistication of the plant affect the general attitude toward EDI. In order to take advantage of the efficiency gains associated with the use of EDI with suppliers,

firms should include supplier EDI training and support among their supplier development efforts (Stank et al., 1996).

The case studies suggest that there is a relationship between the main driver for implementing EDI and the success of the implementation. If the plant belongs to an initiator firm, the technology is transferred from the HQ to the plant, and the plant will pressure its suppliers to adopt EDI. If the initiator firm is the customer, the customer will pressure the plant to adopt EDI to communicate with it, but not with other customers or the plant's suppliers. If there is a well defined communications strategy at the supply chain level, however, the technology transfer takes place at multiple levels of the supply chain, and under a single set of standards, which facilitates the expansion of EDI links with other supply chain partners without the need for additional investments in EDI software or programming. In addition, when EDI is initiated as a supply chain strategy, it is perceived by followers as a long-term policy, and they tend to invest in an integrated EDI system that automatically shares information with the internal system, rather than running an EDI application in a stand-alone PC.

In order to reduce the level of incompatibility with present systems and procedures, supply chain partners must cooperate closely when planning the implementation of a new EDI link. The implementation plan must consider issues such as technical compatibility of hardware and software, consistency with current procedures of both organizations, support and maintenance costs, and the loss of time and productivity during the implementation and adaptation periods. Flexibility must be exercised on both sides to guarantee a smooth and mutually beneficial transition to the new system.

Implications for policy making

Institutions play a key role in the process of technology transfer and adoption (King et al., 1994; Bessant, 1999). The role of institutions is particularly critical in the transfer of information technology innovations to less developed countries (Montealegre, 1999; McKenney, 1994). The findings of this study support the notion that institutions can stimulate the adoption of information technologies by establishing diffusion and training programs directed at plant management and their existing or potential suppliers.

First, since lack of training has been identified as a barrier to EDI adoption, institutions can help by providing training and awareness programs to both maquiladora managers and their suppliers. The availability of technical skills, together with an awareness of the importance of business-to-business communications, are critical factors for the development of successful suppliers for the maquiladora industry. The coordinated actions of economic development institutions, universities and maquiladora firms can lead to an efficient supply chain integration between maquiladora buyers and their suppliers. Examples of specific institutional actions include the promotion of basic and applied research, education, training of specific target groups, promotional and awareness campaigns, establishment of technology standards, or the provision of shared infrastructure. The establishment of supplier networks can allow maquiladoras to share infrastructure and training costs and make the implementation of EDI more cost effective for smaller suppliers (Oughton & Whittam, 1997). Interestingly, a public policy directed to creating supplier networks to implement EDI will be reinforced by the use of the communication technology itself, since it will improve the communication among suppliers as well as between suppliers and manufacturers (Fariselli et al., 1999). Second,

institutions can work with industry by establishing communication standards that can maximize the cost effectiveness of EDI implementation efforts. Third, the institutional intervention can affect the perceived benefits of technology adoption, making maquiladora managers more proactive in their adoption efforts. Fourth, by bringing together corporate buyers and local suppliers, institutions can stimulate the process of technological transfer beyond its historically low levels in the Mexican context (Grether, 1999).

Local supplier development and training in telecommunication readiness, as well as physical telecommunication infrastructure, are necessary factors for regional economic development. The cooperation of maquiladora firms with government institutions and universities is critical to achieve these goals and increase the efficiency and competitiveness of the maquiladora industry.

Research directions

While the model tested in this dissertation analyzes the determinants of EDI adoption, future research might focus on the extent of implementation. For instance, researchers could measure the extent to which firms have integrated EDI with their internal information systems, and really automated, simplified or reengineered their processes. The relationship between the process of adoption, the extent of implementation, and the impact on performance of international logistics needs to be analyzed.

EDI is more widely used in industries that have higher levels of supply chain integration. Further research should look specifically into the relationship between EDI adoption and other supply chain initiatives such as supplier base reduction, just in time

purchasing, and quality management. All of these initiatives involve inter-firm coordination and require efficient exchange of information.

Larger plants tend to have larger transaction volumes, and derive larger economies of scale from the adoption of EDI. At the same time, if EDI capability is among a buyer's supplier selection criteria, it may have fewer suppliers to choose from, which will contribute to a reduction in the number of suppliers used. Further, since supplier reduction implies greater order volumes for the remaining suppliers, EDI may become even more cost efficient for both the buyer and the suppliers. It would be interesting to investigate the relationship between EDI use with suppliers and supplier reduction. Future research should also study the role of EDI in the process of integration of information. This includes analyzing to what degree firms are integrating their inter-organizational information systems with their internal information systems, consequences of such integration such as the interrelation between EDI and integrated Enterprise Resource Planning (ERP) systems, its impact on internal processes, and its possibilities to further increase efficiency and create value for the customer.

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APPENDIX A: SPANISH SURVEY QUESTIONNAIRE

SECOFI

SECRETARIA DE COMERCIO Y FOMENTO INDUSTRIAL

CUESTIONARIO DE LA INDUSTRIA MAQUILADORA DE EXPORTACION

DATOS DE IDENTIFICACION DEL ESTABLECIMIENTO

1. Planta: (en caso de tener mas de una planta, favor de anexar la información al final del cuestionario)

Nombre de la empresa titular del permiso de maquiladora:_____

Dirección (calle, colonia o parque industrial, ciudad, código postal):_____

_____

Teléfono (s) _____ Fax _____ E-mail _____

2. Compañía fronteriza: **(oficinas, dirección, o P.O. Box en Texas):**

Nombre de la compañía: _____

Dirección o P.O. Box:_____

Teléfono (s) _____ Fax _____ E-mail _____

3. Corporativo:

Nombre de la compañía:_____ País de origen:_____

Dirección_____

Teléfono (s) _____ Fax _____ E-mail _____

4. Indique los nombres y apellidos de los gerentes:

	Nombre	Teléfono y Extensión	Fax	E-mail
Gerente de Planta				
Gerente de Relac. Industriales				
Gerente de Compras				
Gerente de Import/Export				
Gerente de Sistemas				
Gerente de Calidad				

5. Describa la actividad y/o producto principal de la planta:_____

_____

6. A que sector industrial pertenece esta planta?

☐Eléctrico/electrónico (excepto automotriz) 1 ☐Automotriz y/o autopartes 2

☐Textil y de la confección 3 ☐Otros(especifique) _____

_____ 4

7. Número de empleados en la planta: _____ 1 **Tamaño de la planta en pies cuadrados:** _____ 2

8. Indique sus principales insumos, si existen proveedores locales para este producto, y si desea desarrollar proveedores locales: (de necesitar más espacio, favor de anexar información)

Insumo (describa):	Existen proveedores locales? *(marque así: ☒)*	Desea desarrollarlos?
1.	Si ☐ No ☐	Si ☐ No ☐
2.	Si ☐ No ☐	Si ☐ No ☐
3.	Si ☐ No ☐	Si ☐ No ☐
4.	Si ☐ No ☐	Si ☐ No ☐
5.	Si ☐ No ☐	Si ☐ No ☐

9. Por valor de compra, de dónde proceden sus compras habituales de *material productivo*? (total 100%)

De Tamaulipas ___% 1
De México-otros estados ___% 2
Del Sur de Texas ___% 3
Del interior de los Estados Unidos ___% 4
De otros países ___% 5

10. Por valor de compra, de dónde proceden sus compras habituales de *material no productivo*? (total 100%)

De Tamaulipas ___% 1
De México-otros estados ___% 2
Del Sur de Texas ___% 3
Del interior de los Estados Unidos ___% 4
De otros países ___% 5

11. Indique si esta planta cuenta con alguna *certificación de calidad (marque así: ☒)*

Ninguna ☐1 ISO 9000 ☐2 QS 9000 ☐3 TL 9000 ☐4 Otra: _____ 5

12. Indique si *a los proveedores de esta planta* se les exige alguna *certificación de calidad*:

Ninguna ☐ 1 ISO 9000 ☐ 2 QS 9000 ☐ 3 TL 9000 ☐ 4 Otra: _____ 5

13. Quién tiene la responsabilidad sobre las siguientes funciones de compras, la planta o el corporativo? Responda independientemente para compras de material productivo, y para material no productivo, utilizando la siguiente escala del 1 al 7:

1 2 3 4 5 La planta
6 7 El corporativo

	Material productivo	Material no productivo
Seleccionar proveedores	____ 1	____ 7
Generar ordenes de compra	____ 2	____ 8
Expeditar ordenes pendientes	____ 3	____ 9
Inspeccionar materiales recibidos	____ 4	____ 10
Comprobar las facturas del proveedor	____ 5	____ 11
Enviar peticiones de cotización	____ 6	____ 12

14. Para cada una de las siguientes frases, indique si esta de acuerdo o en desacuerdo, relativo al uso de EDI con proveedores de material productivo, y proveedores de material no productivo, utilizando la siguiente escala del 1 al 7:

1 2 3 4 5 6 7
Completamente en desacuerdo — Ni de acuerdo ni en desacuerdo — Completamente de acuerdo

El uso de EDI con nuestros proveedores:	Material productivo	Material no productivo
Es un requisito de nuestro cliente	____ 1	____ 6
Es un requisito de nuestro proveedor	____ 2	____ 7
Es un requisito de nuestra compañía (política del corporativo)	____ 3	____ 8
Es un requisito en nuestra industria	____ 4	____ 9
Es un requisito para la selección del proveedor	____ 5	____ 10

15. Cuántas microcomputadoras hay en la planta en cada una de las siguientes categorías:

Numero de microcomputadoras con las que cuenta esta planta	_____ 1
Numero de microcomputadoras que están conectadas a una red local	_____ 2
Esta la red local conectada con el corporativo?	☐Si ☐No 3
Numero de microcomputadoras que están conectadas con Internet	_____ 4

16. Beneficios del Intercambio Electrónico de Datos (EDI)
Responda cada pregunta relativa al intercambio electrónico de datos CON LOS PROVEEDORES, según su opinión con un número del 1 al 7 utilizando la siguiente escala:

1 2 3 4 5 6 7
Completamente en desacuerdo — Ni de acuerdo ni en desacuerdo — Completamente de acuerdo

EDI reduce los costos de transacción	____ 1
EDI mejora el flujo de caja (cash flow)	____ 2
EDI reduce el nivel de inventario	____ 3
EDI mejora la calidad de la información	____ 4
EDI mejora las operaciones internas	____ 5
EDI permite mejorar el servicio al cliente	____ 6
EDI mejora las relaciones con nuestros socios comerciales	____ 7
EDI mejora nuestra capacidad competitiva	____ 8
EDI perturba el lugar de trabajo	____ 9
EDI requiere (o requirió) cambios en los procedimientos de operación	____ 10
EDI reduce la productividad por el tiempo que requiere aprenderlo	____ 11
EDI requiere un tiempo sustancial para aprender a usarlo	____ 12
EDI requiere inversiones en hardware/software	____ 13
EDI aumenta las necesidades de apoyo de computación	____ 14
EDI requiere una preparación sustancial de la planta	____ 15
EDI requiere modificaciones en el sistema de computación	____ 16

17. Por qué medio(s) de comunicación intercambian información con sus proveedores en esta planta? (marque todos los que corresponda):

EDI	☐ 1	Página Web (HTML)	☐ 7
Fax	☐ 2	Página Web (XML)	☐ 8
Teléfono	☐ 3	Servicio de mensajería	☐ 9
Códigos de barras	☐ 4		
Correo electrónico	☐ 5		
Correo tradicional	☐ 6		

18. Usan en esta planta EDI con sus *clientes*?

1 ☐No ☐ Si, desde hace ___ años. 2

Si no lo usan, planean implementarlo?

3 ☐No ☐ Si, en los próximos ___ años. 4

19. Usan en esta planta EDI con sus *proveedores de material productivo?*

1 ☐No ☐ Si, desde hace ___ años. 2

Si no lo usan, planean implementarlo?

3 ☐No ☐ Si, en los próximos ___ años. 4

20. Usan en esta planta EDI con sus *proveedores de material no productivo?*

1 ☐No ☐ Si, desde hace ___ años. 2

Si no lo usan, planean implementarlo?

3 ☐No ☐ Si, en los próximos ___ años. 4

SI RESPONDIO QUE UTILIZA EDI CON SUS PROVEEDORES (19 ó 20), CONTINUE CON LA PREGUNTA 21. SI NO UTILIZA EDI CON SUS PROVEEDORES, PASE A LA PREGUNTA 26 EN LA ULTIMA PAGINA.

21. Cuál es el *estándar* de EDI que se utiliza en esta planta? (marque todos los que corresponda).

Un estándar privado ☐ 1 ANSI X12 ☐ 2 EDIFACT ☐ 3

Otro estándar (especifique) _____ 4

22. Aproximadamente, cuál es el porcentaje de proveedores con los que esta planta intercambia información vía EDI?

Proveedores de material productivo ____% 1 Proveedores de material no productivo ____% 2

23. Por favor, indique si usted transmite y/o recibe los siguientes documentos de sus proveedores vía EDI. Marque los que proceda, para proveedores de material productivo, y para proveedores de material no productivo.

	Material productivo	Material no productivo
Ordenes de compra	☐ 1	☐ 11
Acuse de recibo de ordenes de compra	☐ 2	☐ 12
Liberaciones (releases) de material	☐ 3	☐ 13
Avisos de envío por adelantado	☐ 4	☐ 14
Facturas de compra	☐ 5	☐ 15
Conocimiento de embarque	☐ 6	☐ 16
Seguimiento de envío	☐ 7	☐ 17
Facturas de transporte	☐ 8	☐ 18
Avisos de envío de pago	☐ 9	☐ 19
Acuse de recibo de pago	☐ 10	☐ 20

24. Para cada uno de estos documentos, qué proporción de ellos se transmite al proveedor vía EDI? (0-100%)

	Material productivo	Material no productivo
Ordenes de compra	____ % 1	____ % 11
Acuse de recibo de órdenes de compra	____ % 2	____ % 12
Liberaciones (releases) de material	____ % 3	____ % 13
Avisos de envío por adelantado	____ % 4	____ % 14
Facturas de compra	____ % 5	____ % 15
Conocimiento de embarque	____ % 6	____ % 16
Seguimiento de envío	____ % 7	____ % 17
Facturas de transporte	____ % 8	____ % 18
Avisos de envío de pago	____ % 9	____ % 19
Acuse de recibo de pago	____ % 10	____ % 20

25. Para cada una de las siguientes frases, indique si esta de acuerdo o en desacuerdo, referente al uso de EDI, con proveedores de material productivo, y proveedores de material no productivo, utilizando la siguiente escala del 1 al 7:

1 2 3 4 5 6 7
Completamente en desacuerdo — Ni de acuerdo ni en desacuerdo — Completamente de acuerdo

	Material productivo	Material no productivo
Nuestro sistema EDI esta integrado con nuestros sistemas internos.....	____ 1	____ 7
Nuestras transacciones EDI con proveedores no precisan intervención manual.....	____ 2	____ 8
Necesitamos capturar datos para enviar un mensaje EDI.....	____ 3	____ 9
Al recibir un mensaje EDI, tenemos que capturarlo manualmente en nuestro sistema.....	____ 4	____ 10
Nuestros proveedores tienen que capturar datos de EDI en su sistema.....	____ 5	____ 11
Nuestros proveedores tienen que capturar datos para enviarnos un mensaje EDI.....	____ 6	____ 12

Por favor, continúe cuestionario en la pregunta 27.

26. BARRERAS PARA EL USO DE EDI:
Valore las siguientes razones para por las que la planta no utiliza EDI para comunicarse con sus proveedores utilizando la siguiente escala del 1 al 7:

1 2 3 4 5 6 7
Completamente en desacuerdo — Ni de acuerdo ni en desacuerdo — Completamente de acuerdo

No tenemos suficiente volumen de transacciones para beneficiarnos de EDI	____1
El costo de implementación de EDI es demasiado alto	____2
No tenemos suficiente apoyo de la alta dirección	____3
Nos preocupan los problemas legales, de seguridad, o auditoria	____4
Existen demasiados estándares de mensajes EDI	____5
Falta de conocimiento o entrenamiento sobre EDI	____6

Otra (explique) _____

27. OBSERVACIONES:

_____
_____
_____
_____

28. Nombre y firma de la persona que proporcionó la información:

Nombre: _____ *Firma:* _____ *Fecha:* _____

Teléfono de contacto: _____ *E-mail:*_____

APPENDIX B: ENGLISH SURVEY QUESTIONNAIRE

SECOFI

SECRETARY OF COMMERCE AND INDUSTRIAL DEVELOPMENT

SURVEY OF THE EXPORT MAQUILADORA INDUSTRY

PLANT IDENTIFICATION DATA

1. Plant: (In case of having more than one plant, please append information at the end of the questionnaire)

Name of the business holding the maquila permit:_____

Address (street, district or industrial park, city, postal code):_____

_____

Telephone (s) _____ Fax _____ E-mail _____

2. Border company: (offices, address, or P.O. Box in Texas):

Name of the company: _____

Address or P.O. Box:_____

Telephone (s) _____ Fax _____ E-mail _____

3. Parent Company:

Name of the company:_____ Country of origin:_____

Address_____

Telephone (s) _____ Fax _____ E-mail _____

4. Provide first and last names of the managers:

	Name	Phone and Extension	Fax	E-mail
Plant Manager				
Industrial Relations Manager				
Purchasing Manager				
Import/Export Manager				
Systems Manager				
Quality Manager				

5. Describe main activity or product of the plant:_____

_____

6. To which industrial sector does this plant belong?

☐Electric/electronic materials (except automotive) 1 ☐Automotive and/or auto-parts 2

☐Textile and apparel industry 3 ☐Other (specify) _____

_____ 4

7. Number of employees in the plant: _____ 1 **Size of the plant in square feet:** _____ 2

8. List your main supplies, whether local suppliers exist for these supplies, and whether you would like to develop local suppliers: (if you need more space, please append information)

Supply (describe):	**Do local suppliers exist?** *(mark like this: ☒)*	**Would you like to develop them?**
1.	Yes ☐ No ☐	Yes ☐ No ☐
2.	Yes ☐ No ☐	Yes ☐ No ☐
3.	Yes ☐ No ☐	Yes ☐ No ☐
4.	Yes ☐ No ☐	Yes ☐ No ☐
5.	Yes ☐ No ☐	Yes ☐ No ☐

9. By purchase value, where do your usual *production parts* supplies come from? (total 100%)

From Tamaulipas ___% 1
From Mexico-other states ___% 2
From South Texas ___% 3
From the interior of the U.S. ___% 4
From other countries ___% 5

10. By purchase value, where do your usual *MRO* supplies come from? (total 100%)

From Tamaulipas ___% 1
From Mexico-other states ___% 2
From South Texas ___% 3
From the interior of the U.S. ___% 4
From other countries ___% 5

11. Please indicate whether this plant has any *quality certification* *(mark like this: ☒)*

None ☐1 QS 9000 ☐3 Other: _____ 5
ISO 9000 ☐2 TL 9000 ☐4

12. Please indicate whether suppliers to this plant are required any *quality certification*:

None ☐1 QS 9000 ☐3 Other: _____ 5
ISO 9000 ☐2 TL 9000 ☐4

13. Who has responsibility over the following purchasing functions, the plant or the headquarters?

Respond independently for purchases of production parts, and for MRO purchases, using the following scale from 1 to 7:

1 2 3 4 5 6 7
The plant Headquarters

	Production Parts	MRO
1. Selecting suppliers	____ 1	____ 7
2. Generating purchasing orders	____ 2	____ 8
3. Expediting outstanding orders	____ 3	____ 9
4. Inspecting supplier materials	____ 4	____ 10
5. Checking the supplier invoices	____ 5	____ 11
6. Sending requests for quotations	____ 6	____ 12

14. For each of the following sentences, indicate whether you agree or disagree, regarding to the use of EDI with suppliers of production parts and suppliers of MRO, using the following scale from 1 to 7:

1 Absolutely disagree — 2 — 3 — 4 Neither agree nor disagree — 5 — 6 — 7 Absolutely Agree

The use of EDI with our suppliers :	Production parts	MRO
Is a requirement of our customer	____ 1	____ 6
Is a requirement of our supplier	____ 2	____ 7
Is a requirement of our company (corporate policy)	____ 3	____ 8
Is a requirement in our industry	____ 4	____ 9
Is a requirement for supplier selection	____ 5	____ 10

15. How many microcomputers are there in the plant in each of the following categories?

Number of microcomputers in the plant		_____ 1
Number of microcomputers connected to a local network		_____ 2
Is this network connected to headquarters?	☐Yes	☐No 3
Number of microcomputers connected to the Internet		_____ 4

16. Benefits of Electronic Data Interchange (EDI)
Respond to each question regarding EDI WITH YOUR SUPPLIERS, according to your opinion, with a number from 1 to 7 using the following scale:

1 Absolutely disagree — 2 — 3 — 4 Neither agree nor disagree — 5 — 6 — 7 Absolutely Agree

EDI reduces transaction costs	____ 1
EDI improves cash flow	____ 2
EDI reduces inventory levels	____ 3
EDI improves information quality	____ 4
EDI improves internal operations	____ 5
EDI enables to provide better customer service	____ 6
EDI improves trading partner relationships	____ 7
EDI increases ability to compete	____ 8
EDI disrupts the workplace, at first	____ 9
EDI requires changes in operating procedures	____ 10
EDI decreases productivity because of time required to learn it, at first	____ 11
EDI requires substantial time to learn to use	____ 12
EDI requires investment in hardware/software	____ 13
EDI increases computer support needs	____ 14
EDI requires substantial site preparation	____ 15
EDI requires modifications to your computer system	____ 16

17. Through which communication modes do you exchange information with your suppliers in this plant? (mark all that apply):

EDI	☐ 1	Web page (HTML)	☐ 7
Fax	☐ 2	Web page (XML)	☐ 8
Telephone	☐ 3	Messaging service	☐ 9
Barcodes	☐ 4		
E-mail	☐ 5		
Traditional mail	☐ 6		

18. Does this plant use EDI with its customers??

1 ☐No ☐ Yes, since ___ years ago. 2

If you don't use, do you plan to implement it?

3 ☐No ☐ Yes, within the next ___ years. 4

19. Does this plant use EDI with its *suppliers of production parts?*

1 ☐No ☐ Yes, since ___ years ago. 2

If you don't use, do you plan to implement it?

3 ☐No ☐ Yes, within the next ___ years. 4

20. Does this plant use EDI with its *suppliers of MRO parts?*

1 ☐No ☐ Yes, since ___ years ago. 2

If you don't use, do you plan to implement it?

3 ☐No ☐ Yes, within the next ___ years. 4

IF YOU ANSWERED THAT YOU USE EDI WITH YOUR SUPPLIERS (19 OR 20), CONTINUE WITH QUESTION 21. IF YOUR PLANT DOES NOT UTILIZE EDIWITH ITS SUPPLIER, PLEASE GO TO QUESTION 26 IN THE LAST PAGE.

21. Which EDI standard does this plant use? (mark all that apply).

A private standard ☐ 1 ANSI X12 ☐ 2 EDIFACT ☐ 3

Another standard (specify) _____ 4

22. Approximately, what is the percentage of suppliers with which this plant exchanges information via EDI?

Suppliers of production parts ____% 1 Suppliers of MRO parts ____% 2

23. Please indicate whether you send and/or receive the following documents to or from you suppliers via EDI. Mark all that apply, for suppliers of production parts, and for suppliers of MRO parts.

	Production parts	MRO
Purchase orders	☐ 1	☐ 11
Purchase order acknowledgments	☐ 2	☐ 12
Material releases	☐ 3	☐ 13
Advance shipment notices	☐ 4	☐ 14
Purchasing invoices	☐ 5	☐ 15
Bills of lading	☐ 6	☐ 16
Shipment tracking	☐ 7	☐ 17
Freight invoices	☐ 8	☐ 18
Payment/remittance advice	☐ 9	☐ 19
Receipt acknowledgments	☐ 10	☐ 20

24. For each of those documents that you transmit via EDI, what proportion of all documents are transmitted via EDI versus manual systems (0-100%)

	Production parts	MRO
Purchase orders	____ % 1	____ % 11
Purchase order acknowledgments	____ % 2	____ % 12
Material releases	____ % 3	____ % 13
Advance shipment notices	____ % 4	____ % 14
Purchasing invoices	____ % 5	____ % 15
Bills of lading	____ % 6	____ % 16
Shipment tracking	____ % 7	____ % 17
Freight invoices	____ % 8	____ % 18
Payment/remittance advice	____ % 9	____ % 19
Receipt acknowledgments	____ % 10	____ % 20

25. For each of the following sentences, indicate whether you agree or disagree, regarding the use of EDI, with suppliers of production parts and MRO, using the following scale from 1 to 7:

1	2	3	4	5	6	7
Absolutely disagree		Neither agree nor disagree			Absolutely Agree	

	Production Parts	MRO
Our EDI system is integrated with our internal systems.....	____ 1	____ 7
Our EDI transactions with suppliers do not require manual intervention.....	____ 2	____ 8
We need to key in data to send an EDI message.....	____ 3	____ 9
When we receive an EDI message, we need to manually rekey it into our system.....	____ 4	____ 10
Our suppliers must rekey received EDI data into their system.....	____ 5	____ 11
Our suppliers must rekey data in order to send us an EDI message.....	____ 6	____ 12

Please, continue the in question 27.

26. BARRIERS FOR EDI USE:

Value the following reasons why the plant does not use EDI to communicate with its suppliers using the following scale from 1 to 7:

1	2	3	4	5	6	7
Absolutely disagree		Neither agree nor disagree			Absolutely Agree	

We don't have enough volume of transactions to benefit from EDI	____1
The EDI implementation costs are too high	____2
We lack top level management commitment	____3
We are worried about legal, security, and auditability problems	____4
There are too many EDI message standards	____5
We lack the knowledge or training about EDI	____6

Other (explain) _____

27. OBSERVATIONS:

_____

_____

_____

_____

28. Name and signature of the person who provided the information:

Name: _____ *Signature:* _____ *Date:* _____

Contact telephone: _____ *E-mail:* _____

APPENDIX C: SURVEY COVER LETTER

SECRETARIA DE
COMERCIO Y
FOMENTO INDUSTRIAL

DELEGACION FEDERAL EN TAMAULIPAS
SUBDIRECCION DE PROMOCION ECONOMICA

OFICIO No. 720/28/B.2.1/5.1.1/00/0985

ASUNTO: Se solicita información.

Ciudad Victoria, Tam., Agosto 02 del 2000

Controles Temex, S.A. de C.V. (185)
RESPONSABLE DE IMPORT/EXPORT
PRESENTE

Con la finalidad de poder prestar un mejor servicio a los usuarios del Programa de Industria Maquiladora de Exportación, la Secretaría de Comercio y Fomento Industrial próximamente incorporará al **Sistema de Integración de Comercio Exterior "SICEX"**, los nuevos registros y ampliaciones de Programa de Maquiladora.

En ese sentido, y con la finalidad de programar con toda anticipación el ingreso de los nuevos registros y ampliaciones del programa de maquiladora al SICEX y que una vez incorporados, no se incurra en desfases en los tiempos de resolución de sus trámites, me permito solicitarle de la manera más atenta y de no mediar inconveniente de su parte se sirva requisitar el cuestionario anexo al presente, el cual deberá remitir a más tardar el próximo miércoles 9 de agosto del presente año, a la Subdirección de Promoción Económica de la Subdelegación Federal de SECOFI en Reynosa, Tam., vía fax (89) 26 31 28 Unidad Administrativa donde se concentrará la información Estatal.

Por otro lado, la información antes mencionada les servirá para fortalecer su infraestructura en redes de telecomunicaciones y para la identificación de nuevos proveedores nacionales de insumos, productos y servicios que demandan, mediante "EDI" (Intercambio Electrónico de Datos) se harán más competitivos sus procesos productivos. EDI es cualquier intercambio de datos entre organizaciones, en formato electrónico, y estructurado de forma que puede ser comunicado directamente de computadora a computadora.

Sin otro particular, y esperando contar con su apoyo incondicional como siempre, aprovecho el conducto para reiterar a Usted la seguridad de mi atenta y distinguida consideración.

SUFRAGIO EFECTIVO. NO REELECCION

DELEGADO FEDERAL

APPENDIX D: REPORTS OF INTERVIEWS WITH MAQUILA MANAGERS

Manufacturer of Appliances

This plant manufactures wiring systems and other subassemblies for electric appliances, and does not ship production directly to the customer, but to another assembly plant of the same firm for further processing in the U.S. Their largest customer does not require any quality certification, and does not require the plant to use EDI with their suppliers. The customer exercises, therefore, little influence over the supply chain. The plant just started making efforts to develop local suppliers. When they find local suppliers, they are usually not sufficiently prepared. The purchasing manager complains that "local suppliers have not yet developed a sense of urgency".

The use of information systems to communicate with suppliers started from the need to reduce inventory costs. This company has a large number of manufacturing plants concentrated primarily in the U. S. Midwest area. Suppliers are concentrated around the same area, most often within 100 miles from the plant they supply. Traditionally, plant warehouses were keeping one month of inventory of parts and components. In order to reduce the level of inventories, they implemented a JIT system in most plants of the company, but because of logistic and transportation problems, JIT was implemented only partially at this plant in Mexico. The company also requested suppliers to maintain an inventory of parts and supplies on consignment. Many suppliers refused to take the cost of inventory held at the buyer's facilities. In order to convince suppliers to keep inventory on consignment, the firm argued that suppliers would save the air freight costs when they suffer a delay in their planned deliveries. The cost of a shipment by air is often in excess of $10,000. By keeping a buffer inventory at the buyer's facility, the supplier protects itself from such expenses.

An effort was then made to convince suppliers from the U.S. Midwest to move to the South Texas/North Mexico area. Some suppliers considered the possibility of opening facilities in Mexico, based on the request of this firm and other customers. Some suppliers opened new facilities or moved to Mexican locations, primarily Monterrey, Guadalajara, El Paso, or Laredo.

When a supplier moves to Mexico, a new set of problems appears. The same suppliers who were performing satisfactorily from the U.S., started showing problems of quality and delivery reliability upon moving into Mexico. Our interviewee attributes the problem to the supplier's HQ not wanting to lose the business in the U.S. location, and being forced by their customers to move into Mexico. Then, they fail to provide adequate support, training, qualified expatriate transfers, and other resources. For example, they transfer the oldest equipment and machinery to Mexico, and this machinery is not able to produce with the same level of quality as the U.S. based facility was delivering.

In addition to the quality and reliability problems associated with suppliers who move to Mexico, plant management notes that it is more expensive to move materials from Monterrey to the plant, located in Reynosa, than it was from Indiana. There is no common carrier service in Mexico, and the carriers that are available, have excessive market power and charge higher prices. If there is no common carrier to consolidate truckloads from Monterrey to the U.S. border cities where the maquiladora industry is concentrated, the plant must charter a full truck in order to ship less than a truckload of material. Other maquilas refused to share truck charters from Monterrey.

The company outsourced inbound logistics with a specialized, nationwide firm, who designed a plan. An advance shipment notice system was implemented, where the suppliers are required to send an advance shipment notice with each shipment. The plant sends release orders to the suppliers, initially via fax, or by traditional mail. These releases were sent weekly, and daily to selected suppliers, and include daily release information for the next four weeks, and weekly demand forecasts for the next 25 weeks. At that point, it became obvious that there was a need to implement EDI links with their suppliers.

The first attempt of the firm was to request suppliers to purchase and implement a complete EDI system. This process would require implementing a software package which, for many suppliers, would be used exclusively to communicate with the plant. Most suppliers refused to implement such system because it would be too costly to them, and they did not expect to draw any benefits. At this point, the firm contracted a software company to develop a proprietary web-based EDI system to be implemented worldwide. The software, called EZ-ISM (Integrated Supplier Management), includes five transactions: the 830 Material Release, the 856 Advanced Ship Notice, 861 Receiving Advice, 864 Text message, and the 862 JIT shipping schedule. All these transactions are sent from the plant to the supplier, except the advanced shipment notice, which is generated by the supplier. The supplier logs on to the system every morning after 8 a.m. and check the new material releases. Material releases can be printed by the supplier, creating a paper record and assuring auditability. Suppliers that are located close to a buyer's facility also receive a JIT shipping schedule, although this is not the case with this plant, where the JIT system has not been implemented due to the long distance

between the plant and its suppliers. The suppliers can fill in an advanced shipping notice each time they ship material to the plant. The software prints a barcode label that is placed on the boxes, so that shipments can be easily identified upon arrival. At this point, the plant does not have a barcode scanner, and the labels have to be read by the receiving inspection employees. As soon as the supplier has sent the advanced shipping notice, the plant responds with an acknowledgement. If the buyer identifies an error in the advanced shipping notice, they respond with a text message, also called a discrepancy report. Finally, when the material physically arrives to the plant, a receiving advice is sent to the supplier. In order to access the data, the supplier must be connected to the Internet, through an internet service provider. In the future, the company plans to implement also an electronic payment system.

Technology adoption decisions are done usually at the corporate headquarters, with the participation and involvement of maquiladora managers. All materials managers participate in meetings where they expose the needs at individual plants, and decide whether or not EDI or other technologies should be implemented in a plant.

Automotive Systems Manufacturer

This plant manufactures automotive systems for cars, trucks, and vans. The plant employs over 2500 employees, and its parent company is a world leader in automotive seat belts. QS 9000 certified, the plant ships finished product to the United States by truck on a JIT basis. This plant has a well developed EDI implementation strategy. Among the programs the plant uses dealing with suppliers is the SUCCESS program, which includes value analysis/value engineering (VA/VE) and supplier development with

emphasis on lean manufacturing, quality management, and improvement of supplier delivery reliability. In support of this program, the firm places emphasis on improving communication with suppliers. The use of EDI is required by the customers and the industry regulating agency, the Automotive Industry Action Group (AIAG).

EDI capability is a supplier selection factor, although the system has not yet been implemented in this particular plant. The implementation is expected to take place within one year. The decision to implement EDI is made at the corporate headquarters, but the purchasing activities and control are performed at the plant, and the purchasing manager is a key player in the EDI adoption decision making. The local managers are convinced that using EDI to communicate with suppliers will reduce errors, save purchasing agents' time, and help lower inventories. They insist that electronic communications must also be extended to other functional areas, particularly quality management.

In summary, this is a company that actively promotes the use of EDI to communicate with suppliers, where local purchasing managers exert a strong influence on adoption decisions, and are well aware of the potential benefits of EDI use. The firm also acts as a diffusion agent with its suppliers, making EDI capability an important factor in supplier selection.

Electrical Equipment Manufacturer

This plant belongs to a large global multinational that manufactures electrical equipment, and employs over 500 people. It was certified ISO 9002 in 1999. The plant ships its product directly to its customers, mostly to air conditioner manufacturers, on a JIT basis. The purchasing process is very traditional: First, a purchasing agent contacts

the supplier by telephone to check if they have inventory, the price is negotiated, and then a formal order is sent via fax.

The purchasing agents spend most of their time communicating with suppliers. Purchasing agents feel that there is a need to automate the purchasing process, because it would reduce the scheduling problems they have with their suppliers, and would allow them more time to solve problems. There are no plans, however, to implement EDI in this plant. The purchasing function is performed locally, although the selection and approval of suppliers and material tests are done at the corporate headquarters.

The managers of the purchasing and systems departments are very interested in EDI, but until now the plan only has general access to the internet, and the purchasing department is using only some e-commerce tools such as supplier web sites to check order status and inventory. The customers are not promoting the adoption of EDI along the supply chain, and corporate headquarters do not support the investment necessary for implementation. In this case a proactive attitude is detected at the plant level, but a reactive attitude at the headquarters, which are facing little or no pressure from customers or supply chain organizations.

Medical Equipment Manufacturer.

This plant manufactures medical equipment, and is a subsidiary of a U.S. based multinational company. The plant employs 600 people, and is ISO 9000 certified. The purchasing department uses traditional purchasing methods, communicating mostly through telephone and fax. If the firm is planning to implement EDI, the plant is not informed. Such decision would be made at the headquarters.

The purchasing manager does not see a major advantage in the use of EDI in the plant, and there is no plan to implement an EDI system in the near future. They have not been pressured or required to implement EDI with their suppliers. When asked about the activities of the purchasing personnel, however, the manager claimed that they are extremely busy, and that they spend the vast majority of their time "talking to suppliers". In spite of this statement, the manager does not see EDI use with suppliers as an important issue.

The purchasing function in this plant, and management in general, are highly centralized and most decisions are adopted by headquarters, with little communication with the plant. Local managers are not aware of the important of communication technologies, and have a passive attitude toward technology adoption. They seem to resist technological change and insist that they are extremely busy dealing with day-to-day operations, communicating with suppliers mostly via fax.

Telecommunication Equipment Manufacturer

This plant manufactures batteries for cellular phones, employs 1400 workers, is certified ISO 9002, and its parent company is incorporated in Finland. The firm is running an ERP system located in the headquarters. This system maintains the master data for each component, and the plant has access to the data in real time using a software package independent of the ERP system. The master data includes supplier, inventory, and price information for each component. Although the parts are ordered from the plant, the sourcing department at headquarters selects and manages worldwide suppliers. Suppliers for this plant are located in Japan, Korea, Germany, Italy, and other countries.

The plant uses a modified JIT system, where suppliers are required to keep inventory in consignment, at the plant warehouse. This warehouse serves as a buffer for delivery disruptions, and materials are served on a JIT basis from it. The plant sends a production schedule to the supplier each week, to enhance the visibility of the material requirements. Some suppliers have personnel in the plant to control the inventory and address quality issues. In order to meet the production schedule, it is the responsibility of the supplier to maintain inventory at the supplier's expense.

The corporate purchasing department is highly centralized, and is using EDI integrated with the corporate ERP system. Although the plant does not directly receive EDI data from suppliers, the firm has scheduled to implement EDI in this location within the next few months. In the meantime, the purchasing process is traditional, and purchasers at the plant communicate with suppliers using telephone and fax. EDI will be implemented only for production parts, and MRO purchasing will remain traditional.

The EDI adoption initiative comes from a corporate strategy, and customer or supply chain pressures are low. This firm is a true leader and innovator in its market, and management, both at the plant and at the corporate level, is committed to technological innovation.

Automotive Electronics Firm

This plant belongs to a tier one automotive supplier of electric and electronic equipment. Electronic communications with suppliers are used only for production parts. For non-production parts, most communication is done through paper mail, fax, and

telephone. The system that communicates with suppliers is installed in a computer terminal located on the manufacturing floor.

Each part number has a master record where all the related information is stored. The supplier information is part of the master for each part number. There is only one supplier for each part. The level of inventory on hand is measured in days of supply.

The name of the system is "MPS", which stands for "manufacturing pull system". This system was designed to support JIT and is accessible to suppliers, who have authorization to read the records, but cannot enter information into the system. When the user logs on, the system prompts for a part number, and shows the planned consumption or "pulls" for each day of the week.

The purchasing manager believes that the system significantly reduces costs, and the production process reacts more quickly to variations in demand. Another benefit is that the purchasing agents save time, since they don't need to communicate demand or place orders with suppliers. Suppliers are responsible for consulting the MPS system and maintaining a safe level of inventory at all times. The ability of a supplier to operate in this way is a definite requirement for supplier selection.

The main weakness of this system is that it allows only one-way communication with suppliers. The supplier cannot communicate their own production and shipping schedules to the customer. In the future, the plant will implement EDI to communicate with its suppliers, in compliance with AIAG guidelines. The EDI adoption decision is, again, dominated by the supply chain, and local managers are moderately supportive of the implementation.

APPENDIX E: USE OF COMPUTER COMMUNICATIONS IN THE MAQUILADORA INDUSTRY

The differences in technological sophistication across industries are evident when the use of computers in the maquiladora industry are analyzed. Figure 8 shows the percentage of plants using communication technologies such as local area networks (LAN), internet connections, and connection between the plant LAN and the headquarters computer system. A lower use of electronic communication technologies can be observed in the textile industry, particularly in internet connection, while more sophisticated industries like automotive and electronics lead in the use of these technologies. These differences in sophistication across industries, as seen in this study, also extend to the use of EDI.

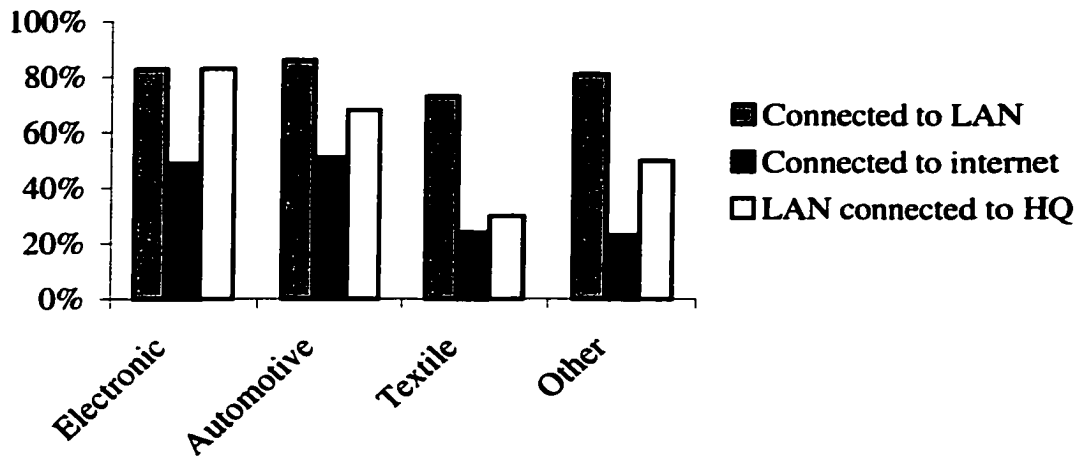

Figure 8. Use of communication technologies

VITA

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5/94 - 5/96	The University of Texas – Pan American, Edinburg, Texas **Master in Business Administration**
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TEACHING EXPERIENCE

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WORK EXPERIENCE

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7/96 - 1/97	ITT Automotive, Rio Bravo, Mexico **Quality Engineer**
5/94 - 5/96	The University of Texas – Pan American, Edinburg, Texas **Economic Analyst**
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December, 2001