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EDI통제의 효율성 결정: DEA 방법론

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Determination of Control Efficiency in EDI : DEA Approach

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■ Abstract ■

Electronic Data Interchange (EDI) has a significant impact on business practices by eliminating paper related audit trails and enabling transactions to be processed at high speed without human intervention. Major advantages and benefits derived from EDI, however, depend upon the usage of EDI controls.

Management must determine whether their investment on EDI controls is appropriate, as the establishment of EDI controls demands much resources and high skills. This study proposes data envelopment analysis model to identify efficient and inefficient EDI control systems in various context of input (formal and automated EDI controls) and output (EDI implementation and performance). DEA can also determine the factors that are significantly different between efficient and inefficient groups. The model is tested using data collected from EDI adopters.

1. Introduction

Electronic Data Interchange (EDI) is an application of information technology that allows business partners exchange transaction documents in structured, machine-processable form over telecommunication networks. EDI is also one type of interorganizational electronic commerce. EDI integration indicates the degree of seamlessness achieved in incorporating electronic

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information received into business operations. EDI must be integrated with IS applications in order to be effective (Arunchalam, 1995; Stern and Kaufmann, 1985; Teo et al., 1995). The advantages of EDI can only be obtained when it is utilized and automated to the full extent. The firm must deal with a large number of transactions in order to reap benefits from EDI (Scala and McGrath, 1993). High speed and the lack of human intervention, however, may make the errors of one system rapidly propagate into other systems. The high value and degree of automation associated with EDI systems make the potential loss resulting from inappropriate planning and maintenance of controls even higher.

One of the other major impediments to the implementation of controls for sophisticated IS, however, is the lack of funds available for the adoption of controls. Controls like integrated test facilities and the concurrent audit technique are not implemented fully due to financial problems of EDI adopters. A substantial system enhancement is required to install an automated transaction log and authorization system into an existing system. Furthermore, the expertise required to install some of automated controls is very high (Lawrence, 1988). The full implementation of automated controls requires extensive expertise in order to manage diverse operating environments (e.g., protocols, line speed, standard, and hardware).

Hence, it is critical to adjust the appropriate usage level of controls in order to satisfy the efficiency objective. Lee et al. (1998) asserted that EDI controls are the critical factors for successful EDI implementation. The determination of the level of efficient IS controls, however, receives only limited attention in academic research as well as in business. There has not been a single investigation into the efficiency of controls for the implementation of EDI system. This study proposes that the efficiency of EDI controls, which can be broadly classified as *formal* and *automated*, can be empirically analyzed using data envelopment analysis (DEA). DEA model is used to identify efficient and inefficient EDI control systems in various context of input (formal and automated EDI controls), output (EDI implementation and performance), and organizational contexts. The factors that are significantly different between efficient and inefficient groups can be determined. DEA model is empirically tested using data collected from Korean firms adopting EDI. The results of study will help companies implement EDI controls efficiently in order to successfully integrate and utilize EDI systems. The usage level of EDI controls can be compared across EDI adopters and this will help them build the appropriate usage level of controls.

2. EDI Controls, EDI Implementation and Performance

The requirement of controls for each level of integration is different (Chan et al., 1993). Each progressive level of integration represents a higher level of complexity, dependency and vulnerability. The integration with internal systems increases vulnerability of system through a domino effect from the mishaps of trading partners or VAN. The dependence of trading partners lends itself to the possibility of sharing technology and databases. A mistake by just one trading partner would lead to a domino effect where every trading partner could suffer. All parties must protect themselves from possible disclosures or alterations of transmitted messages made by other partners or an unauthorized third party.

Further, as EDI is expanded to link diverse partners and VANs (Value Added Networks), it is necessary to require these trading partners or VAN service providers to establish appropriate controls to detect the disclosure of confidential information, the introduction of invalid or unauthorized transactions and errors in transmission, and provide appropriate corrective measures. Unless they are reduced to an acceptable level, there is a possibility of a serious loss of data, contaminated data or system breakdowns, thereby resulting in increasing implementation costs.

Various stakeholders such as internal users, trading partners, and industrial associations may demand "control assurance" where adequate controls must be in place in terms of contractual obligations or agreements before the decisions regarding further implementation of the system can be made (Chan et al. 1993). If sufficient security is not provided in system use, some internal applications planned for computerization might have to be done manually (Parker 1981). An "adequate" usage level of controls, specified in trading partner agreements before connecting their system to trading partners' systems is requested among companies (Jamieson 1994, Mehta 1998). For example, the retailer is integrating their internal system with the manufacturer sharing its information with the manufacturer through EDI. The retailers make the contractual agreements with their manufacturers concerning, for instance, fail safe with logistical systems or bar coding practices. EDI controls are necessary to establish the belief that the system is safe and accurate to users and to increase the capability for implementation and adjustment before an organization decides to implement EDI.

Thus, a larger amount of EDI controls is associated with the higher potential for EDI implementation. As EDI implementation is related to EDI performance, EDI controls increase performance indirectly through their effect on IS implementation. As the growth of interconnection and dispersion of technology within or between organizations continue, it is critical to have sound IS security and integrity controls (Boockholdt 1989). It is difficult to determine the expected reduction of incidents from implementing controls. IS controls have invisible benefits, as they affect the extent of IS implementation success, which is related to IS performance.

3. Input: EDI Controls

The objective of EDI controls is to ensure that an organization achieves its goals through the implementation of EDI. They are the activities to safeguard assets, maintain data integrity, accomplish organizational goals effectively, and consume resources efficiently (Weber, 1988). EDI controls in this study focus on asset safeguarding, integrity, and confidentiality. When an EDI system is highly utilized, it is always prudent for management to focus on preventive controls rather than after-the-fact reporting of exceptions

〈Table 1〉 Research Variables

(a) Input Variables

Class	Subclass	Variables
internal formal controls	internal formal application controls	• system change control by authorization (FC1) • integrity check of the message before processing in the application (FC2) • transaction log for the possible errors and collapse (FC3) • appropriate system login procedures using password (FC4)
	internal formal communication controls	• integrity check after generating EDI messages (FC5) • authentication of trading partners after receiving EDI messages (FC6)
external formal controls	external formal VAN controls	• back up and recovery plan by VAN (FC7) • retransmission after correcting erratic messages by VAN (FC9) • dispute reconciliation procedures by VAN (FC11) • access control on network by VAN (FC13) • mailbox access control by VAN (FC15)
	external formal partner controls	• back up and recovery plan by trading partners (FC8) • retransmission after correcting erratic messages by trading partners (FC10) • dispute reconciliation procedures by trading partners (FC12) • access control on network by trading partners (FC14)
internal automated controls	internal automated application controls	• programmed integrity check before processing in application systems (AC1)
	internal automated communication controls	• automated data integrity check before transmission of EDI messages (AC2) • automated authentication of trading partners using message code (AC3)
external automated controls	external automated controls by VAN	• automated transaction log for EDI messages by VAN (AC4) • error message tracing and error reporting by VAN (AC6) • digital signatures(message authentication code) provided by VAN (AC8)
	external automated controls by trading partners	• automated transaction log for EDI messages by trading partners (AC5) • error message tracing and error reporting by trading partners (AC7) • digital signatures(message authentication code) provided by trading partners (AC9)

(b) Output Variables

Subclass	Variables	Items
implementation	integration	• integration of EDI in five application systems
	utilization	• utilization of EDI in five application systems
performance	improved relation	• Improved relationship by reducing response time (REL1, REL2) • improved trust by enhancing confidentiality of documents (REL3) • improved relationship by reducing errors (REL4. REL5)
	competitive advantage	• increase in efficiency of interdepartmental transaction processing (ADV1) • increase in accuracy by reduced paper work (ADV2) • reduction of transaction processing costs (ADV3)

and corrective procedures, as they might reduce the impact of system mishaps. EDI controls need to assist in timely identification and resolution of critical problems as they occur but also they need to check the compliance of transactions with accepted standards and prevent errors from reaching into other applications. Trading partners need to promptly identify and acknowledge each other of any alteration, omission, and duplication of messages encountered prior to further processing. The syntactic check of messages needs to be automated to check diverse forms of transactions from a number of trading partners.

Various control dimensions can be used to make a framework of EDI control modes (Lee et al., 1998). In this study, internal and external controls can be classified according to two important control dimensions: formality and automation. The descriptions of the measures of EDI controls are suggested in Table 1. Formal controls are established by management and based on written procedures to be formally abided by. Automated controls indicate the degree of using automated control procedures and methods.

Measures for EDI controls were newly developed, for which various sources (Chan et al., 1993; ISACA, 1990; Jamieson, 1994; Marcella and Chan, 1993) were referred to <Table 1>. They were measured on seven-point Likert-type scales. There exist 15 and 9 modes of controls for formal and automated controls respectively. As it is difficult to measure the use of EDI controls in a quantitative manner (e.g., investment cost of security software, labor cost of security staffs), only qualitative measures were used.

4. Output: EDI Implementation and Performance

The causality between EDI controls and implementation has been hypothesized on the basis of EDI implementation studies and IS control literature (Lee et al., 1998). EDI implementation has two dimensions, *integration* and *utilization*. Integration is measured by the level of integration of five application systems which respondents believe to be very closely connected with EDI. Although they have many organizational tasks, the scope of applications that are related to EDI is mostly limited. The five tasks - some companies have less than five tasks - are believed to be most closely connected with EDI and can represent the characteristics of EDI applications of EDI adopters at the organizational level. Integration is defined by the extent to which EDI data can be directly processed within applications without human intervention. This is measured using a seven point Likert-type scale.

EDI has to be extensively utilized while being integrated with internal applications such as payment systems, payable/receivable systems, and production planning systems in order to cover the large cost of installation. The measure of *utilization* indicates the proportion that a company used EDI in the five applications that can be processed through other means. It is the proportion of a firm's information exchange and processing that are handled through EDI. Electronic links and exchanged transaction sets/documents should be expanded to derive full benefits from EDI (Premkumar et al., 1994). Firms may realize a significant cost-efficiency by using

EDI with diverse partners. This requires the development of EDI documents tailored to individual partners who have different business requirements.

Mere measurement of the state of implementation may not be sufficient indicators of success until EDI adopters perceive high benefits from the implementation of technology. Installed systems may fail to provide the intended benefits to firms. The measures for EDI performance were based on various EDI survey results (Arunachalam, 1995; Banerjee and Golhar, 1994; Hansen and Hill, 1989). The measures of perceived EDI performance were sought from the objectives of EDI usage. There are two facets of EDI performance; improved relation and competitive advantage. The former is related to the reinforcement of ties with a business partner and improved customer service, while the latter describes cost reduction and increased productivity of work processes.

Hence, there are four output variables (two variables for EDI implementation and performance, respectively) in this study; integration, utilization, improved relation, and competitive advantage. The measures for the implementation and performance are summarized in <Table 1>.

5. Methodology

A key feature of this study is the use of Data Envelopment Analysis (DEA). The present study adopted radial improvement and constant returns to scale DEA model. The personal computer version of the DEA model was coded using Warwic-DEA software by Thanassoulis and Emrouznejad (1996). DEA is a methodology that evaluates the relative efficiency of Decision Making Units (DMU) (Charnes et al., 1990, 1994). DEA does not impose any functional form relating the independent variables to the dependent variables. The parametric approach, however, requires specific assumptions about the functional form (e.g., regression equation) and the distribution of error terms (e.g., independently and identically normally distributed). DMU requires only that each DMU lie on or below the extremal frontier. The ratio of a weighted sum of outputs to a weighted sum of inputs of each DMU is constrained not to exceed unity and this indicates the relative technical efficiency of any DMU.

The inefficiency of the DMUs that lie below the frontier is calculated for each of the inputs and outputs. It is determined after they are compared with a single referent DMU (or a convex combination of other referent DMUs) that lies on the frontier and has the same level of inputs and make a greater level of outputs. The potential improvements of the inefficient DMUs represent the amount of increase in outputs (or decrease in some inputs) without worsening the other inputs or outputs.

DEA relates efficiency outcomes to features of organizational (EDI controls in this study) design (Lewin and Minton, 1986). The organizations whose efficiency to be examined are 45 control systems. DEA analysis can help EDI managers and auditors to identify sources of relative inefficiency. Reducing employment of some of inefficient controls and selecting the resource-minimizing mix of controls would increase efficiency of EDI systems.

6. Data Collection

The data were collected using structured interviews with EDI practitioners. The data used in validating the research model were gathered as part of a larger investigation concerning the EDI controls (Lee et al., 1998). One or two EDI managers simultaneously participated in the interview. They were believed to have sufficient knowledge about EDI implementation. If some questions could not be answered, they took those questions to their colleagues who had sufficient knowledge of the subject area. The unit of analysis is individual EDI adopting company. The total number of firms in the sample is 45. DMU is an individual EDI adopter that has implemented EDI successfully in the population of more than 5,000 companies that adopted EDI in Korea.

7. Results and Discussion

Separate efficiency analyses were performed for the cases of different input and output variables. DEA found efficient and inefficient EDI adopters for each pair of input and output. The descriptive statistics of efficiency score for every 45 EDI adopter are suggested in <Table 2>. Formal controls are more efficiently used than automated controls except when output is utilization according to the mean of efficiency score.

The relatively high average efficiency is found when integration and two performance variables are used as output. The number of efficient firms is higher when output class is performance rather than implementation. This simply indicates that, regardless of the input, the efficient EDI control systems outperform the inefficient control systems in two important performance measures.

Korean companies have recognized the risks of the domino effects resulting from the propagation of errors in a highly integrated environment and have designed appropriate application controls for EDI integration. They understand that cost becomes proportional to the risk of integration unless adequate compensating controls and contingency plans are implemented along with EDI. As more Korean companies use EDI as a viable way of communication with trading partners, they recognize the need for a high level of formalized procedures and technical controls to manage the various types of transactions and connections

〈Table 2〉 Descriptive Statistics of Efficiency of firms (%)

input class	output variable	Mean	s.d.	Range	Min	Max
formal controls	integration	69.64	26.46	71.45	28.55	100
	utilization	37.62	33.74	98.67	1.33	100
	improved relationship	75.54	23.49	73.68	26.32	100
	competitive advantage	77.91	21.44	74.84	25.16	100
automated controls	integration	61.73	24.24	72.32	27.68	100
	utilization	47.55	35.94	98.67	1.33	100
	improved relationship	73.35	20.90	78.26	21.74	100
	competitive advantage	70.75	24.01	78.59	21.41	100

with different partners.

The low efficiency in the case of utilization as output can be partially explained by the trust that Korean companies have for VAN service providers. Korean companies depend mainly on VAN service providers to provide communication controls rather than on themselves. This trust tends to increase as they increase the extent of utilization (e.g., expansion of network connection), further demanding less technical controls. Their reliance on trust weakens the importance of efficiency management for EDI controls.

The appropriate efficient level of various controls should be determined in view of organizational contingencies. Different organizational environments can be considered to affect the sensitivity and vulnerability of the system and the desirable levels of various controls. The relationships between environmental variables and EDI controls can be deduced from organizational control and EDI literature.

Task routineness, for example, is related to the use of internal formal and automated controls. Routine tasks are amenable to standard operating procedures, formal rules and clear performance standards. Managers stress efficiency where activities can be measured quantitatively and are well-defined (Daft and Steers, 1986); this leads to the formalization of work processes. For example, in production departments and assembly lines where such routine processes are typical, the processes linking these departments are usually formalized.

The efficiency of processing can be improved by automating such easily measured and quantitative routine tasks (Daft and Steers, 1986; Hickson et al., 1969). The speed of repetitive transactions and the lack of human intervention in EDI systems demand prompt detection and correction of errors. Integrated test modules and automated edit checks need to be embedded in internal applications to prevent errors from spreading into other systems. Hence, automated controls are appropriate to cope with routine tasks.

Economic and industry environments may also affect the causal relation between controls and implementation. For instance, the EDI system in Korea is rapidly growing and the results of this study may reflect unique characteristics of Korean companies. The implementation of EDI in some industries in Korea has been supported by a government agency that monopolizes the provision of services associated with international trade. Their implementation of EDI relies substantially on a VAN that is managed by the government. Korean companies rely on the VAN to provide these controls. In addition, there is generally less computer abuse and disputes between partners so it is difficult to justify the investment of controls in order to reduce computer abuse.

In this context, a series of Mann-Whitney tests were conducted in order to investigate the factors associated with the efficiency ratings. The variables that affect EDI controls are selected (see Lee and Han (1999) for theoretical association between environments and controls). <Table 3> displays the test results of the factors (i.e., environmental variables) that exhibit significant difference between efficient and inefficient firms. For example, for the efficient versus inefficient

〈Table 3〉 Tests of Differences Between Efficient and Inefficient Firms

Input Class-Output Variable	Variable	Group	Mean	M-W U	p-value
formal control-integration	professionalism	efficient	3.2667	-2.5505	0.0605
		inefficient	4.0333		
	decentralization	efficient	2.6444	-2.2774	0.0114
		inefficient	3.4389		
	communication openness	efficient	3.2667	2.6807	0.0037
		inefficient	4.4000		
	partner interdependence*	efficient	4.7000	-1.7991	0.0360
		inefficient	4.0167		
formal controls-utilization	size*	efficient	1.4021	-1.5530	0.0602
		inefficient	1.0331		
	managerial attitude	efficient	3.9333	-1.2883	0.0988
		inefficient	4.6667		
	IS sophistication*	efficient	0.3044	1.9503	0.0256
		inefficient	-0.1254		
	task interdependence*	efficient	5.6733	-1.8651	0.0311
		inefficient	4.5857		
	task routineness*	efficient	5.9067	-1.3848	0.0831
		inefficient	5.4238		
formal controls-improved relationship	communication openness	efficient	3.4375	2.2000	0.0139
		inefficient	4.3448		
	partner interdependence*	efficient	4.6250	-1.5789	0.0572
		inefficient	4.0345		
formal controls-competitive advantage	decentralization	efficient	2.8854	-1.3481	0.0888
		inefficient	3.3333		
	communication openness	efficient	3.6875	-1.6133	0.0534
		inefficient	4.2069		
	partner interdependence*	efficient	4.5938	-1.4463	0.0741
		inefficient	4.0517		
	partner commitment*	efficient	5.3438	-1.2895	0.0986
		inefficient	5.0345		
automated controls-integration	decentralization	efficient	2.1429	-2.8046	0.0025
		inefficient	3.3640		
	managerial attitude	efficient	3.5714	-2.2185	0.0133
		inefficient	4.7719		
	role of IS	efficient	4.5238	-1.7756	0.0379
		inefficient	5.0548		
	communication openness	efficient	3.4286	-1.5012	0.0667
		inefficient	4.1316		
	partner commitment	efficient	4.7143	-1.4139	0.0787
		inefficient	5.2237		
automated controls-utilization	decentralization	efficient	2.6667	1.6430	0.0502
		inefficient	3.4649		
	task interdependence*	efficient	5.3875	-1.3896	0.0824
		inefficient	4.5552		
automated controls-improved relationship	external pressure*	efficient	4.7879	-1.3844	0.0831
		inefficient	4.1765		
	decentralization	efficient	2.6970	-1.7008	0.0445
		inefficient	3.3284		
	communication openness	efficient	3.5455	1.4294	0.0765
		inefficient	4.1765		
	partner commitment*	efficient	5.5455	-1.7344	0.0415
		inefficient	5.0147		
automated controls-competitive advantage	decentralization	efficient	2.8333	-1.3043	0.0961
		inefficient	3.2980		
	communication openness	efficient	3.5000	-1.7067	0.0440
		inefficient	4.2121		
	partner commitment*	efficient	5.5000	1.5802	0.0571
		inefficient	5.0152		

(M-W U: Mann-Whitney U Test, * : factor that is greater in efficient group) firms when input class is formal controls and output is integration, there is significant difference in professionalism, decentralization, communication openness, and partner interdependence.

Four variables, external pressure, size, task interdependence, and partner interdependence turn out to affect significantly the efficiency of EDI control systems, as they are significantly and consistently higher in efficient groups.

Firms under high external pressure and partner interdependence may lead to the implementation of efficient controls as they seek operational and marketing benefits available through EDI controls. The implementation of EDI is encouraged to maintain competitive advantage in these environments. As more trading partners implement EDI in the industry, other firms in the same industry will be more likely to adopt EDI in order to maintain their competitive position. Companies may be pressured to implement EDI from fear of losing business. They need to evaluate advances in technology and implement them out of strategic necessity.

When two firms establish an EDI links, the implementation of efficient EDI controls is affected by support strategy from VAN or government association. Given the fact that companies have uncertainty about the implementation of EDI, the promotion from trading partners or industry association (including government) may reduce their anxiety about the low return from their investment or make them realize the necessity of the implementation. For instance, government support policy to spread EDI in the industry is an important factor for EDI implementation in Korea. The pressures of government make firms to follow EDI standards through KTNET (Korea Telecommunication Networks) by communicating required documents whenever goods are imported or exported. They are faced with lengthy manual procedures if they do not exchange EDI messages via this network; hence, they are encouraged to follow the EDI controls of this network.

Large organizations and firms with highly interdependent task environments have better conditions to develop efficient EDI controls. As organizations increase in size, it is necessary to institute more formal planning process to ensure the development of an integrated vision for the IS function. In that case, formal controls can provide a consistent set of rules to control large and complex application systems integrated with EDI. Further, the full implementation of automated controls requires extensive expertise and expense and larger firms have more trading partners with diverse operating environments (protocols, line speed, standard, hardware) and higher transaction volumes than small companies. Automated controls are cost-efficient for large organizations with high communication complexity due to high transaction volumes and numerous trading partners. Large organizations are more likely to be able to afford the costs for automated controls and possess greater technical expertise than smaller organizations.

As the level of technological interdependence increases, the organizational structure becomes more complex. If the implementation of EDI affects a number of interdependent functional areas within an organization including accounting, purchasing, transportation, and marketing simultaneously, the problems of controls are compounded. It is difficult to control the EDI process where the activities of one department affect other departments almost simultaneously. In order to monitor interdependent task processes, more systematic controls are likely to be required. Mistakes should be detected as promptly as possible before they affect the workflow of other departments. The cross-vulnerability of these departments will make the efficiency of investment for EDI controls higher.

8. Implications

The main assumption of this study is that EDI controls affect EDI implementation and performance and the installation of them demands much resource. Although it is important that management can be convinced of effect of the security and integrity controls and devote much resources to make the control systems effective, it is equally critical to develop the controls in a cost-efficient way.

Companies which are about to adopt EDI can decide whether their EDI control system is appropriate for the implementation of EDI. The control structure may be enhanced to pave the way for EDI implementation. The tasks of designing control systems, as performed by EDI auditors, however, are difficult and unstructured, as there exists no normative model for EDI controls. Many alternative forms of controls may exist, and many environmental factors affect the design of controls. Many organizational factors, such as volume and complexity of transactions, and the speed of processing, affect the efficiency of controls. The first step in the design of EDI controls is a preliminary review of the existing formal and automated control procedures. Management should consider giving a great deal of efforts in adjusting the level of the specific mode of controls during system development. EDI managers and auditors should decide whether formal or automated controls have been installed efficiently.

9. Conclusion

The study examines the application of DEA on the efficiency analysis of EDI. Input is EDI controls and output is EDI implementation and performance. The control-implementation efficiency framework of this study may be modified to suggest control types for general IS controls or interorganizational systems such as an e-mail system. DEA enabled a series of analyses of the difference in the efficiency in various combinations of inputs and outputs, and the impact of environmental factors on the efficiency of control system. Although EDI controls have been considered as important by practitioners, few studies verify their efficiency. The application of DEA describes the decision support procedures when EDI auditors and managers have to determine the mode and usage level of controls in the process of EDI implementation for overall high efficiency of the control systems in various context of input and output.

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