Redesigning Process Control Mechanisms Using EDI
An Agency-theoretic Perspective

Hans van der Heijden, René Wagenaar, Jo van Nunen and Frans van den Bosch
Erasmus University, Rotterdam School of Management
P.O. Box 1738, 3000 DR Rotterdam, The Netherlands

Abstract

In this paper we argue that the use of Electronic Data Interchange (EDI) allows organizations to redesign the control mechanisms that govern their processes. More specifically, we have looked at relationships between agencies and their principals and analyzed what the impact of EDI usage might be on the mechanisms to measure and evaluate the performances of the agents. The paper draws upon developments in agency theory.

The analysis is built around two propositions. It is proposed that since EDI allows to reveal more of the behavior of the agent than traditional communication, more behavior-based control can be implemented. Secondly, if EDI allows to improve the communication about the desired outcome of the agent’s process, more outcome-based control can be implemented.

Material from a case study about an inter-organizational information system for multi-modal, multi-country transportation is used to illustrate the propositions. The system has been developed to improve the communication between shippers, consignees and their forwarding agencies. Furthermore, after discussing each proposition, the relevance of the proposition for a process re-engineering team is outlined.

1. Introduction

Process re-engineering is widely recognized as a valuable managerial tool to improve the competitiveness of a company (e.g. [5], [12]). It can be defined as the deliberate analysis, redesign and change of a subset of organizational activities. Most organizations have been adapting their organizational structure to meet the limited human capabilities of structured information processing and to the limited storage capabilities of paper-based information (see for example [10]). As information technology is increasingly utilized to speed up structured information processing and to improve organizational data management, these organizational design concessions are gradually losing ground. The decreasing costs of information technology as well as the experiences with information technology that companies have gained during the last decades are two additional factors that have encouraged process re-engineering to emerge.

Process re-engineering is somewhat like developing a traditional information system. First, it includes an analysis of (a part of) the organization, a redesign of a subset thereof and a concluding implementation phase. Second, it is likely to encounter problems of user participation and miscommunication, which are known problems in information systems development. Third, to overcome these problems, diagramming techniques have been developed for both information system development and process re-engineering. A diagramming technique is a suitable tool to overcome miscommunication because it allows a group to specify a system or a process more unambiguously. This helps to improve group decision making, especially when the representatives of the group have different backgrounds (see e.g. [22]). Special diagramming techniques for process re-engineering have been introduced for example by [6]. These techniques express organizational design in a descriptive, graphical way.

On the other hand, process re-engineering is somewhat different from traditional information systems development in that it may benefit from organizational theories that explain why one redesign would be more effective than the other. Within a process re-engineering effort, normative
rules of thumb can provide "educated guesses" in
the generation of valuable process redesigns. To
formulate these "educated guesses", theories on
organizational design and organizational behavior
might provide valuable inputs. Hence, we envision
a research area of process re-engineering that
consists of two, complementary, streams. The first
stream is concerned with the description of process
designs. Researchers in this stream try to identify
what the necessary building blocks are and build
tools to support the drawing of those building
blocks in order to stimulate discussion among the
participants in a process re-engineering team. The
second stream, on the other hand, is concerned with
the generation of process redesigns. Researchers in
this stream try to identify what information
technology can do with a current process design and
what a future process design might consequently
look like.

This paper is meant as a contribution to the
second stream. We do not pursue a theory that
generates a good redesign from any arbitrary
organizational situation. This is far too ambitious
given the almost unconstrained possibilities of
formalizing organizational situations and the
indeterministic and significantly less rigid character
of the organizational theories that might be of help.
Therefore, we have significantly narrowed down the
scope of this paper in two respects. In the first
place, we will concentrate on one instance of
information technology only: Electronic Data
Interchange (EDI). EDI is a communication
technology that is often said to contribute to process
redesigns. Section two contains a discussion on
these contributions. In the second place, we will
focus on the redesign of process governance
mechanisms, more specifically, on those between
organizations and their agencies. By doing so, we
will draw upon advancements in an organizational
theory called agency theory. Section three contains
a discussion of this theory. Section four contains
empirical material from a case study with which
propositions will be illustrated. The propositions
that we can deduce from agency theory are outlined
in section five. Finally, section six completes the
paper with conclusions and recommendations for
further research.

2. Process re-engineering using EDI

It is commonly acknowledged that the increasing
usage of telecommunications can have profound
impacts on the way organizations work (see eg. [5],
[13], [14], [16]). While the "usage of
telecommunications" encompasses a broad range of
applications, they are generally focused upon the
transportation, rather than the enrichment of data.
An airline reservation system for example is
frequently mentioned as an application of
telecommunications technology, as it improves the
communication between airline carrier and the
various travel agencies by transporting reservation
data back and forth. In this paper, we will focus
upon a particular subset of telecommunications
applications: Electronic Data Interchange (EDI)
applications. EDI by itself can be defined as the
"inter-organizational, computer-to-computer
exchange of business documentation in a standard,
machine-processable format" ([9]). Whether the
adjectives "inter-organizational" and "business" are
necessary restrictions is debatable, but for our
purposes satisfactory. An obvious example of an
EDI application is the order-entry system, whereby
organizations send purchase orders to their suppliers
through EDI.

If we are to investigate the enabling capabilities
of EDI for process re-engineering, a closer look at
the basic advantages of EDI over traditional means
of communication seems appropriate. These
advantages are fourfold (see also [19]).

1. Speed. An EDI message is usually much
faster than a traditional mail message.
2. Reliability. EDI messages are usually being
transported over reliable third-party Value-
Added Networks (VANs).
3. Ease of data capture. As the data within an
EDI message is structured according to a
certain predefined syntax (commonly Edifact
or Ansi X.12), organizations can easily
integrate the contents of the message into
their own in-house applications.
4. Cost. The exchange of EDI messages is
usually quite cheap and currently competes
with stamp costs. Note that communication
costs are considered here, in stead of initial
investments costs.

From these EDI benefits, speed and ease of data
capture are generally the enabling capabilities to
realism process re-engineering. It should be noted
however that the utilization of those capabilities is
dependent on the degree to which EDI is integrated
with the internal applications of the organization.
This degree can be defined as the level of EDI
integration. Swatman and Swatman ([20]) have
introduced a model that distinguishes stages of integration. In this model, there are four stages:

1. **Stand-alone PC.** In this stage, the organization uses stand-alone PCs to print the incoming EDI messages. A printed EDI message gets the same status as an incoming document.

2. **EDI converter.** In this stage, the organization uses an EDI converter to transform incoming EDI messages into files that their own internal system can read and vice versa. There are no fundamental differences between files input from incoming documents and files created by the EDI converter.

3. **Software integration.** In this stage, the application possesses EDI conversion software itself and the intermediary step of creating in-house files has been eliminated. This usually enables organizations to send and receive EDI messages in (nearly) real-time, rather than batchwise.

4. **Structural integration.** This final stage "would result in EDI influencing the functional structure of the organization and the structure of the supportive information systems within the organization" ([20]:5).

For example, the speed advantage of EDI is better utilized in stage two than in stage one. The ease of data capture advantage of EDI is better utilized in stage three than in stage two. The benefits of EDI are likely to increase as the level of EDI integration increases. However, it should also be noted that the more an organization integrates EDI into its own applications, the more costly the necessary investments usually will be. Although the stage model suggests that process re-engineering is only viable when organizations are in stage four, processes can also be re-engineered while using EDI in stage one. An example would be the printing of EDI messages containing pre-information.

There are several different ways that EDI can help to create a process redesign. These various ways can be described along the framework of Davenport & Short [5]. They have listed nine information technology capabilities. Some of these have no direct relation with the basic capabilities of EDI - these are the transactional, analytical and knowledge management capabilities. However, six other capabilities remain. The geographical (1) capability suggests that processes should be reconsidered upon location. EDI can be utilized for example to transport a better quality of information to distant locations, making those locations more attractive to make decisions. The automation (2) capability suggests that processes can be reconsidered upon human involvement. EDI can be utilized in this redesign effort to reduce data entry costs. The informational (3) capability suggests that processes should be reconsidered upon availability of input information. EDI for example can bring more input information to the locus of decision making. The sequential (4) capability requires process re-engineering teams to reconsider the sequence of processes. EDI can be used to transform sequential processes in parallel ones by exchanging the information between those processes as soon as it becomes available. The tracking (5) capability says that processes can be more easily tracked with information technology. EDI can be used to exchange status messages about processes. Finally, the disintermediation (6) capability of information technology requires a closer look at information intermediaries and whether they are still required for the process. A process redesign in which intermediaries are excluded may use EDI to improve the communication between the not previously connected processes. As these six capabilities obviously have overlaps, we would encourage more theoretical research on the orthogonality of process redesign dimensions. Such dimensions would allow for a more straightforward mapping on the basic capabilities of IT and EDI.

The listing of capabilities suggests that the process re-engineer wanting to use EDI has two strategies at his disposal. The first strategy is to consider one process at a time and see whether EDI can change its location (1), help to automate the process (2), or improve the information availability (3). The second approach is not to consider one process and see whether it can be improved but to consider the control of a number of processes and see whether the control mechanism can be improved. As the tracking, sequential and disintermediation capabilities suggest, it is not the process itself that is re-engineered, it is rather the way it is controlled. Can the process be better managed when more information becomes available? (3 and 4) Can two processes be better coordinated when more information is being exchanged between them? (5) Can the process be better organized as intermediaries are eliminated? (6) Obviously, a process re-engineer needs to
pursue both strategies interactively. In this paper however we focus upon governance mechanisms only.

Moreover, this paper will focus upon the redesign of governance mechanisms between organizations and their agencies. Agencies are organizations that in their operations make decisions on behalf of other organizations. It would be useful to investigate whether governance mechanisms between these organizations would change as a consequence of EDI. The use of EDI for example would allow organizations to monitor their agents more closely.

3. Agency theory

Agency theory is a theory about the governance of agency relationships. An agency relationship can be defined as a relationship "between two (or more) parties when one, designated as the agent, acts for, on behalf of, or as representative for the other, designated the principal, in a particular domain of decision problems" ([18]:134). Agency relationships are ubiquitous. Examples are shareholders and managers (managers run the firm on behalf of the shareholders) and patients and physicians (physicians operate on patients on their behalf). Agency theory is most commonly used to denote intra-organizational relationships (see eg. [7]), but the concepts of principal and agent can be equally well applied to denote inter-organizational relationships. Examples of these relationships include insurance companies and insurance agents, tour operators and travel agencies, government and governmental agencies, shippers and liner agencies etc.

Agency relationships need to be governed because of the possible existence of agency problems. An agency problem can best be stated as the risk, or danger, that the agent will not make the best decision from a principal's point of view. The risk can be caused by several factors, including divergence of interests between principal and agent and uncertainty about the decision outcome that the principal requires. An example of an agency problem in an inter-organizational relationship would be the following situation. Suppose a liner agency has two principals (shippers): both have cargo in a particular vessel. Principal A wants the cargo to be discharged in Port X, whereas principal B wants the cargo to be discharged in Port Y. The vessel's route is first to discharge in port X, and then in port Y. It may now occur that principal B, who is commercially more important to the liner agency than principal A, demands the cargo to be delivered on time in Port Y. This might cause the liner agency to decide to postpone Port X and navigate to Port Y first. Obviously, this manoeuvre is not at all in the interest of principal A.

As Eisenhardt ([8]), after a review, has concluded, agency theory is particularly concerned with the question whether the control of the agent's performance should be behavior-oriented or outcome-oriented. Figure 1 depicts both control mechanisms.

Figure 1 represents the decision making process of the agent as a decision tree, squares being decisions and uncertain events being circles. The upper horizontal arrows represent the moment when the principal authorizes the agent to make a decision on his or her behalf. The lower horizontal arrows represent the moment when the agent reports the outcomes to the principal. This might be either the result of the decision or it might be the event that the implementation of the decision has influenced. The middle horizontal arrow in the right decision tree represents a feedback loop from the agent to the principal, in which the agent reports certain aspects of his behavior with regard to the decision. This might be either a particular subdecision or a particular event that has occurred in between. Behavior-based control can be defined as the degree to which the governance of the relationship is dependent on the behavior of the agent. The degree of behavior-based control may be observed in the evaluation or reward mechanism specified in a formal contract. A reward that is independent on behavior, but fully dependent on outcome is called outcome-based. Both behavior-based control and outcome-based control are extremes on a continuum of control mechanisms.

Implementing behavior- and outcome-based
control is costly. Jensen and Meckling ([15]) have separated these agency costs in monitoring costs, bonding costs, and residual loss. The costs that the prinicpal has to make to implement behavior-based control are called monitoring costs. The costs that the agent has to make to interact with the principal are called bonding costs. Finally, residual loss refers to those opportunity costs that the principal will inevitably make because of the agency problem, and which cannot be compensated by monitoring and bonding mechanisms.

What determines whether a governance mechanism will be outcome based or behavior based? According to classical agency theory, the prime determinants are the various ways that information asymmetry occurs between the principal and the agent (see eg. [1]). Information asymmetry can be defined as the degree to which the agent is better informed about the decision problem than the principal. For example, if the structure of the decision tree is too difficult to grasp for the principal, it would be quite pointless to try to control the process by observing the agent’s behavior. On the other hand, if the behavior of the agent is known to the principal and if it can be stated in advance, the principal can very well coordinate his processes by interacting with the agent. Bakos and Kemerer ([2]) have noted that the information asymmetry concept needs to be operationalized in order to stimulate agency theory research in the information systems discipline. Eisenhardt ([9]) gives a number a variables to do so, for instance by pointing to outcome uncertainty, behavior uncertainty, and a number of others. To formulate our propositions, we will build upon Eisenhardt’s work.

For the purposes of this paper, it suffices to distinguish between two types of uncertainty in an agency relationship. The first type of uncertainty is the uncertainty about the behavior of the agent. This can be defined as the degree to which the principal can prespecify the agent’s behavior. If the principal knows exactly what the principal wants, this uncertainty is low. If the principal is not at all clear about the outcome of the agent’s process, this uncertainty is high. It can be argued that uncertainty about the outcome the principal desires and degree of behavior-based control are positively correlated. The more the agent is uncertain about the outcome that the principal desires, the more likely it is that behavior-based control is used. This is because the principal will have a need to monitor the agent’s decision process as it is likely that agents, left to their own devices, will not come up with the best possible outcome in the view of the principal.

Agency theory has been used by other IS researchers as well. Beath and Straub ([13]) have applied agency theory to the management of information resources. Gurbaxani and Kemerer ([11]), as well as Klepper ([17]) have applied agency theory to the relationship between the information center (the agent) and the computer-users in the organization (the principal). They argue, among other things, that the information asymmetry between the users and the information centers causes agency problems and point out behavior that can be interpreted as bonding and monitoring. There are some interesting differences however, between these applications of agency theory and ours. The aforementioned researchers apply agency theory to individuals only. However, we apply it to inter-organizational relationships. In the second place, in our application the governance mechanism is the dependent variable, not the locus of responsibility or the behavior of the information center vs. its users. Finally, primary attention has been paid to the opportunistic behavior of agents vs.
their principals. We soften this assumption and regard the relationship between principal and agent as primarily cooperative, rather than competitive.

We have now arrived at the point where we can formulate propositions about the influences that EDI will have on the governance mechanisms of principal and agent. To illustrate these propositions, we will use material from a case study in the area of multi-modal transport.

4. Case study

This case study is about an inter-organizational information system that provides information services to shippers, consignees, forwarders and carriers. The system is being sold commercially by a specially created joint venture and applied in various settings. We will discuss a typical setting in which the system can, and is, currently used.

The arrangement of multi-modal, multiple country transport can include up to 20 organizations and more than 100 documents to get cargo transported from one particular location to another. Ignoring for the moment specialist warehouses, financial companies, and governmental agencies, such as customs and port authorities, four different groups of organizations can be characterized in the entire process. The first group is the group of shippers: they are the suppliers of the goods. The second group is the group of cargo receivers, called the consignees. Usually shipper and consignee have completed a commercial transaction before the actual transport starts. Carriers are responsible for the physical transportation of the goods. A transportation may involve different modes of transport, such as air transportation, sea transportation and road transportation. All three groups of organizations can arrange transport in certain settings, but in complex situations this is usually done by specialists, a fourth and final group called the forwarders.

The situation ex ante of a typical setting in which the system is currently used can be depicted as in Figure 2.

In this simplified model of a transportation process (extended models can be found in eg. [24]), shipper and consignee have agreed upon a particular transport. Freight conditions determine who will be responsible for what particular subroute in the movement of the goods. For example, "franco domicile" means that the shipper, and not the consignee, will arrange and be responsible for the entire transport to the consignee. In this case, a shipper communicates with a particular forwarder and books the transportation of particular shipments. Prices and release dates are exchanged. These are usually fairly fixed and specified in advance. The forwarder then takes over and communicates with the various carriers to pick up the shipment and deliver it to the consignee. It is also possible that the forwarder has a fleet of trucks of his own. In case various modes of transport are involved, and consequently various carriers, the forwarder takes care of the appropriate coordination, eg. the loading and unloading of the cargo in the various in-transit locations. The forwarder remains the contact person for both shipper and consignee during transport. It is his responsibility what arrangements to make with which carriers and how to organize the transport.

The main functionality of the inter-organizational system under study is to allow shippers to plan shipments, book them at forwarders, and trace them during transportation. The heart of the system is a database. This database is able to contain shipment data. In our stylized case example, shippers enter data about the shipments they would like to ship in this database through remote terminal access. After specifying the details, they can send an EDI booking message to

Figure 3 Situation ex post I
the forwarder of their choice. Note that the system is not an electronic market with various forwarders offering their rates, and the shipper selecting the best ones. Shipper and forwarder both have agreed in advance to use the system. The booking functionality is depicted in Figure 3.

As the forwarder has received the EDI booking, he will start to arrange the transport. While doing so, he is able to supply EDI status messages to the database. The system takes these EDI messages and matches their reference numbers with the shipment data that were already in the database. Through such cross-referencing, it is now possible to provide a full status report of the shipment, such as on what location the cargo currently resides and how many days are still left before the goods will arrive at their final destination. Other information may include the names of the carriers involved. As this information becomes available, not only the shipper may benefit from retrieving this information, but also the consignee. This functionality is depicted in Figure 4.

![Figure 4 Situation ex post II](image)

Note that the system is not substituting any previous communication lines, it is rather complementary in that it extracts information from various points in the transportation chain and combines these data to provide full visibility of the entire process.

5. Propositions

We will now proceed with propositions on changes in governance mechanisms between principal and agent and use the transportation system as an illustration. In our examples, the forwarder is the agent and the shipper and consignee are the principals. In stating the propositions, we assume the *ceteris paribus* condition, i.e. all other things are being held equal.

The first proposition is the influence of EDI on the uncertainty of the outcome that the principal most desires. A number of variables may influence this variable, such as the expertise of the agent and the degree to which the principal is able to express his or her wishes. It can be hypothesized that EDI reduces this uncertainty, as it is able to allow a better quality of data to be exchanged from the principal to the agent. With EDI, the principal will be able to better express the type of decision, or the decision outcome. The structure of the EDI message also helps: it forces principals to group data into the appropriate segments. The system described in the previous section for example allows better quality booking messages to be sent from a shipper (the principal) to a forwarder (an agent). As detailed information about the shipments to book has been entered in the database first, this information is more easily incorporated in the booking messages. As a result, the EDI booking message is generally of better quality than a traditional booking message and results in less errors and backtracking.

Agency theory argues that the less uncertainty there is about the desired outcome, the more agent and principal will be willing to engage in outcome-based control. As EDI, among other things, reduces this uncertainty it might be possible to change the governance mechanism of agency processes into one that is more outcome-based. For example, the better the forwarder is informed about the shipments of the shipper and the better he is informed about the destination of the consignee, the less additional information the forwarder will need during the transportation process and the more independent he will be able to work from the shipper. The more he is able to work independently, the more he might be willing to be controlled and rewarded upon the outcome of the process. Hence, we propose:

**Proposition 1**

If EDI decreases outcome uncertainty, then the use of EDI enables a shift to control mechanisms that are more outcome-based.

A process re-engineer investigating processes in an agency relationship might benefit from this proposition by inferring that the more information a principal sends to the agent (through EDI), the less the agent will have to be controlled on his behavior. This might result in a redesign where additional communication lines are eliminated and rewards are more outcome-based. For example, the shipper and the forwarder might arrange to start the
process when the EDI booking has been received, rather than first confirming and rechecking the booking by telephone.

A second variable in agency theory is the uncertainty of the behavior of the agent. This uncertainty is determined by a number of factors. Eisenhardt ([9]) indicates several characteristics of the process, for example task programmability and outcome measurability. But whatever these process dimensions are, it is likely that the use of EDI will reduce the uncertainty with regard to the agent's behavior. The use of EDI generally allows for better quality of data, as it can be more timely and provide more information. This is nicely illustrated by the forwarder in our case study who provides status messages with EDI. These messages provide information on the status of the shipments, but by doing so, they also provide information about the behavior of the agent. For example, the status of a shipment can be that it is being loaded in a particular port. EDI messages are sent more regularly and provide a wealth of information when they are cross-referenced with the shipment data in the database.

Agency theory argues that the more is known about the behavior of the agent, the more the principal will be willing to reward and control the agent on a behavioral basis. As EDI is able to improve this knowledge significantly, there may consequently be a shift towards more behavior-based control. For example, the consignee might benefit from the information that the forwarder provides by anticipating on incoming inventory. As the goods in-transit are clearly more visible than in the situation ex ante, inventory can even be managed while it is in-transit. Of course, this is only possible if the consignee can absolutely rely on the information that the forwarder provides. The improved reliability of EDI messages is therefore an essential element. Furthermore, the more is known about the behavior of the agent, the more the principal will be able to evaluate and reward the agent on the basis of this behavior. This might cause compliance problems from the side of the agents, as the agents will sometimes be reluctant to show their behavior, especially when the divergence of interests is clearly evident. For example, the forwarder might not be willing to supply status messages if it reveals opportunistic behavior. We conclude by stating:

Proposition 2
If EDI decreases behavioral uncertainty, then the use of EDI enables a shift to control mechanisms that are more behavior-based.

Process re-engineers might benefit from this proposition when examining the processes of agents. Perhaps it is worth considering whether agents can supply information about their behavior to the principals. This can eventually lead to a more behavior-based control. In inter-organizational settings however, process re-engineers have to realize that willingness to move to behavior-based control can be a significant problem.

6. Conclusions and recommendations

In this paper we have shown how process control mechanisms can be redesigned with EDI. We have taken a look at uncertainty in agency relationships and concluded that different types of uncertainty enable different types of control mechanisms. We have described with examples from a case study how EDI has an impact on these types of uncertainty. This has allowed us to formulate two propositions in which EDI was linked to the control and evaluation of processes between principal and agent.

We can draw a number of conclusions from this analysis. A first conclusion is that the effort can be useful, as it provides the process re-engineers some guidelines to redesign. For example, we have concluded that compliance of an agency sending EDI messages might be encouraged by evaluating and rewarding him upon the correctness of the EDI messages. This is obviously not a rule in the sense that it has to be followed at all times. To process re-engineers, it is merely a suggestion to incorporate a different governance mechanism in the redesign when EDI is introduced. It allows the process re-engineer to generate new designs, albeit in an informal and non-deterministic way. A first recommendation for further research would be to verify and strengthen the propositions with additional empirical material.

A second conclusion is that this analysis is considerably less formal than the modelling languages process re-engineers tend to use. Obviously, as we already anticipated in the introduction, there is a large gap between expressing old and new designs (with diagramming techniques) and inferring new designs from old ones (as we have done, with agency theory). Clearly, further research on the formalization of governance mechanisms and the consequent inference of new
ones using EDI is of great practical and scientific importance. Furthermore, it can be concluded that EDI is an important enabler for process re-engineering. It carries many enabling capabilities of information technology to business process redesign. Other new technologies however have been starting to appear and gain success: interactive EDI, multimedia messages over ISDN networks, individualized mass communication etc. These technologies promise to have a huge impact on businesses and society in general. A recommendation for further research would be to investigate how these technologies can be used for process re-engineering. We would encourage a focus upon the crucial dimensions of information processing and communication exchange that these technologies offer.

Finally, governance mechanisms are just a part, albeit an important one, of process re-engineering. As different forms of process re-engineering may coincide with different organizational theories, an obvious recommendation to proceed in this research area would be to look at other organizational theories and see what guidelines they can give for process re-engineering. Transaction cost theory (the governance of transactions, see eg. [23]) and the information processing approaches to organizational design ([10] and [21]) seem to be obvious other fruitful areas to explore, as both take the availability of information as an independent variable. Process re-engineering will be a richer field if researchers both try to formalize organizations in a variety of ways, as well as try to generate new process designs with a theoretical backing. In the long run, we expect the research area to benefit from these complementary approaches and yield successful results.

References


