DESIGNING ELECTRONIC INTERMEDIARIES

an agent-based approach for designing interorganizational coordination mechanisms

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Introduction

Internet-based technologies enable new ways of conducting business. The Internet facilitates the *globalization* of business relations. The relatively low costs of the use of electronic networks make it easier to trade with existing and new business partners and to use information systems to *customize* trading relations. Customization means that each customer can be treated in an individual, unique way.

Trading between buying and selling organizations can be supported by electronic intermediaries*. Electronic intermediaries* are independent organizations that support buyers and sellers to coordinate their activities using ICT in distribution networks. Electronic intermediaries are aimed at bridging the gap between the sellers' offers and the customers' wishes and requirements during the trading process. In the past electronic intermediaries, abbreviated as intermediaries, provided functions primarily based on Electronic Data Interchange (EDI) to exchange structured data between information systems of independent organizations. Internet-based technology enables to extent the functions traditionally provided by intermediaries. Electronic intermediaries play an increasingly important role in supporting the trading processes between buying and selling organizations. New roles performed by intermediaries are coming into existence; however, it is not clear which functions are viable or add value in a given situation. There is a continuing discussion about the viability and associated discussion about the disappearance of intermediaries in the literature. As a result we focussed our research on the development of a support environment to help decision-makers to identify opportunities provided by intermediaries and to evaluate the added value of these functions for buying and selling organizations. We, therefore, formulated the research objective as follows:

Develop a support environment based on the dynamic modeling approach that helps organizations in a distribution network to identify opportunities provided by electronic intermediaries and to evaluate the added value of electronic intermediaries

Shifting views on electronic intermediaries

We investigated a number of views and shifts within these views that are considered to be relevant for the design of intermediaries. The *technology* view enables a shift from the structured exchange of data between machines to the exchange of data between machines and humans. The *process* view shows that there are three main trading phases, the information, negotiation and settlement phase. In the past, intermediaries mainly supported the exchange of information in the settlement phase. New technologies facilitate the automation of the information and negotiation phase. Fulfilling the various trading phases requires that intermediaries manage the activities performed by independent buyers and sellers. The design problem can be associated with solving the *coordination problem*, as the essence of designing an intermediary is developing mechanisms that coordinate the activities of independent buying and selling organizations. From an *interorganizatonal* view our research we bound our research to distribution networks. Distribution networks can be defined as the temporary cooperation of three or more independent organizations having buying and selling relations that is aimed at making a product efficiently and effectively available for use or consumption. The *interorganizational* view shows that the rise of technology is enabling intermediaries to support the market mediation role, where in the past they were mainly focussed on supporting the physical roles. This view shows that organizations can be described using a number of *roles*. Roles are independent from technology and organizations performing the roles. The *relationship* view shows a shift to the support of bilateral relationship to relationships involving multiple buyers and sellers. The support of multiple relationships also has as a consequence that not only relationships based on cooperation can be supported by intermediaries, but that also relationships involving competition between organizations can be supported.

Dynamic modeling

Support environments based on dynamic modeling have been developed for the field of EDI. The philosophy behind dynamic modeling is to develop a dynamic 'as is' model of a problem situation, experiment with this model, and experiment with 'to be' models of possible solutions. An important aspect of dynamic modeling is generating one or more 'to be' models of possible solutions and selecting the 'to be' model that is better or best in either an efficient or effectiveness sense. Modeling and automated support are viewed as crucial to a support environment.

Based on the shifts in views and an overview of dynamic modeling we concluded that the dynamic modeling approach for EDI is only sufficient as a starting point, and a support approach had to be developed that incorporated the specific issues for our domain. Our support environment must allow decision-makers to focus on the relevant issues for designing electronic intermediaries. There is a need for a support environment that helps decision-makers to identify the possible roles of electronic intermediaries and evaluate the added value of electronic intermediaries. The dynamic modeling approaches based on EDI was taken as our initial theory of dynamic modeling.

Research approach

Our research objective was translated into three research questions.

1. Which factors are of influence on the design of electronic intermediaries in distribution networks?
2. What coordination mechanisms can be used by electronic intermediaries to support coordination between buying and selling organizations in a distribution network?
3. How can coordination mechanisms be conceptualized using building blocks?

We chose an inductive-hypothetical research strategy to fulfill our research objective, because we needed to get a better understanding of the problems related to the design of electronic intermediaries and our research was aimed at theory development. This research strategy starts with the selection of a number of problem situations for an initial study based on a set of theories. A description of the relevant aspects of the problem situation is made using descriptive empirical models. In the second step, the descriptive empirical models are abstracted to form a descriptive conceptual model. This model is used to describe the problem situation with respect to the elements and aspects under study. A prescriptive conceptual model is built on the basis of a descriptive conceptual model and a literature review. This model is constructed by formulating a theory that solves the problems observed. The prescriptive model is a support environment that consists of an agent-based dynamic modeling approach, design guidelines, roles and tasks of intermediaries and an agent-based simulation environment. The prescriptive conceptual model is implemented in a number of practical problem situations. The use of the prescriptive conceptual model in a practical situation results in a set of alternatives, which provides solutions to the original problem and is described in a prescriptive empirical model. The formulated theory is evaluated by comparing the descriptive empirical model and the prescriptive empirical model. A prototype of a discrete-event agent-based simulation environment is developed to test the *feasibility* of information technology support for our theory. Our theory is tested on *usability* using the test case studies and the *valuation* of our theory was tested by gathering opinions.

Various research instruments were used in the inductive-hypothetical research strategy. We used literature research to get the initial starting points of our research, to compare our findings, to sharpen emergent ideas from case studies and to gain a better understanding of the results of the case studies. We used case study research to get a better understanding of the factors of influence on the design of electronic intermediaries. We used action research to test our support environment on usability and we used a survey and a group supported session to gain indications of how our support environment was valued.

Theoretical background

When looking at the shifting views it can be concluded that there is a need for an overview of coordination mechanisms that are enabled by technology developments and can be used by intermediaries to coordinate activities of buyers and sellers. We looked at coordination theory

and concluded that coordination of activities and the coordination of commitments based on relationships is of importance for our research. In the first coordination approach tasks are central, in the second coordination approach interactions are central.

Subsequently various coordination mechanisms and interorganizational structures were identified. We investigated coordination mechanisms used for interorganizational design, as we were interested in designing interorganizational networks and coordination mechanisms for multi-agent coordination, as we were interested in coordinating buying and selling organizations using ICT. Multi-agent coordination has a similar overall goal as that of a distribution network; to achieve coordination to make a product or service available for use or consumption. From the overview of coordination mechanisms it became clear that negotiation plays an important role. Negotiations are often categorized as distributive and integrative. In a distributive or competitive negotiation the outcome space is unidimensional; one organization's gain is another's loss. Win-win solutions exists on integrative negotiation or cooperative negotiation. One particular outcome can be better for both parties. Techniques based on multi-attributes and constraints are used for integrative negotiation in practice.

From the overview of the electronic intermediary literature it became apparent that much of the literature is focussed on the viability of electronic intermediaries and on the related discussion about the increase or decrease in the number of intermediaries. Research mainly founded in practice showed that intermediary roles and the added value of these roles are dependent on the characteristics of the situation and organizational strategies. From the literature overview of intermediary roles we concluded that the roles found in the literature are described relatively abstract and do not prescribe how roles can be performed using specific coordination mechanisms and what the added value of the roles would be in a specific situation.

Electronic intermediaries in practice

Two case studies are analyzed in the transport industry to get a better grip on factors of influence on the design process, possible roles performed and coordination mechanisms used by intermediaries. The Electronic Services Center (ESC) was chosen as the first inductive case study. The ESC is an intermediary that is focussed on the settlement phase and that has already proved itself. The ESC is a central and neutral hub that coordinates the flow of relatively large streams of information between a number of organizations. A second inductive case study was chosen to cover the information phase. At that time no case studies were found that covered the negotiation phase. The goal of the second case study was to develop an Internet-based intermediary, called Intermodel Explorer, to support shippers in identifying intermodal transport alternatives.

We identified a number of issues influencing the decision-making processes within the two case studies and clustered them into two main categories; coordination and change process management. The categories shown below are interdependent and should not be considered to be mutually exclusive.

Coordination categories	Change process management categories
• Information sharing • Information access • Central and decentral coordination • Cooperative and competitive coordination • Coordination of supply and demand • Coordination using a trusted role	• Complexity • Value assessment • Power and unequal advantages • Trust and resistance • Strategic conducts of electronic intermediaries

Our research objective is to develop a support environment based on the dynamic modeling approach that helps organizations to identify opportunities provided by electronic intermediaries and to evaluate the added value of electronic intermediaries. Consequently our support environment is mainly focussed on solving the issues described in the coordination categories. This does not mean that the change process management issues are less or not important. Based on the problems the following *starting points* for our support environment were identified.

- There is a need to provide a common background, so organizations can gain insight into the current situation and alternative coordination mechanisms provided by intermediaries.
- There is a need for guidance to identify opportunities provided by electronic intermediaries.
- The identification and thinking in *terms of independent* organizations seem to be essential during the problem solving process. Independent organizations design and develop their trading processes in the light of their own goals, interests and requirements. Modeling should support this way of thinking.
- Behavioral aspects need to be modeled, especially, the implications of matching mechanisms which can only be evaluated when modeling behavior, like buying and selling strategies.

A support environment for designing electronic intermediaries

Our modeling effort was aimed at the task of producing organization like entities to simulate realistically a trading situation. *Agent-based modeling* employs an implicit world-view that is very close to the perspective of a network of interdependent actors. The coordination problem in a system consisting of multiple agents is analogous to the coordination problem of a distribution network consisting of autonomous actors.

Object modeling was used for *conceptualizing* our agent-based approach. We needed diagramming techniques to visualize objects, describe coordination between activities and for communicating objects to persons. We chose to make use of *interaction* and *task* diagramming, as we wanted to give explicit attention to these two aspects, the tasks of organizations and the interaction between organizations.

An agent-based, discrete-event simulation environment to *specify* the conceptual model was developed. Agent-based simulation has the following characteristics that are in favor of an agent-based approach.

- *Factorization*: the identification of an agent with a particular entity.
- *Distribution*: decision-making capabilities are distributed over a number of autonomous actors.
- *Variable structure*: systems of agents can change during their life-cycle by adding and removing agents.
- *Dealing with changes*: suitable to deal with a number of different situations.

We developed an architecture for constructing autonomous agents that meets the characteristics of agents and supports the logical construction of agent-based discrete-event simulation models. Autonomous agents can be described by their percepts, their incoming messages, actions, their outgoing messages, their behavior, and their tasks. We adopted the explicit and separate representation of control and behavior, as an agent's control can be relatively generic and it's behavior should be relatively specific. Apart from this distinction visualization is necessary to show the contents of the control logic and behavior algorithms. Based on the above-described requirements, we construct an autonomous agent as an aggregate of three types of object classes: a Control, a Role and an Visualization object class. Each object class can be an aggregate of other object classes or can inherit characteristics from object classes. The *Control* object classes are an aggregate of object classes that are responsible for the handling of interactions with other agents by receiving and sending messages and for allocating tasks to the limited resources of an agent. These object classes provide the autonomy, reactive or deliberative behavior and communication properties of agents. The *Role* object class contains the tasks and decisions that make up a trading role. Behavior is used as a manifest of intelligence. We use the term *emulation of tasks* to refer to a situation that actual software is written to calculate the outcomes of a negotiation strategy and the term s*imulation of tasks* to refer to the modeling of time aspects of tasks. This object class can inherit roles and tasks of pre-defined object classes to enable quick building. The *Visualization* object class shows a window containing an animation of the time-ordered dynamics of objects, a static background, an overview of performance indicators and a user-interface.

We observed in our inductive case studies that there is a need for guiding the identification of opportunities for electronic intermediaries. The approaches based on EDI are aimed at evaluating possible solutions, not on finding these solutions. We introduced a set of *design guidelines* to organize our ideas for supporting the identification of opportunities.

The first design guideline can be used for diagnosing the problem situation and for checking the completeness of ‘to be’ models of possible solutions. This guideline prescribes capturing information only once at the source and the re-use of the information in other processes.

The second guideline was introduced to support delineation of the problem to keep the complexity limited, but also to ensure that all relevant dimensions are considered. This guideline prescribes considering all intermediary roles and trading phases explicitly to find

opportunities for improvements. The design, however, should be focussed on a limited number of roles and trading phases.

The third guideline was introduced due to the need for a customized approach for buyers and sellers, as they are interested in different aspects of the trading process. It prescribes the use of profiles and templates to customize interactions with buyers and sellers. Profiles can be used to store information about customized trading situations, templates can be used to re-use order information.

The fourth design guideline aims at bridging the gap between buyers and sellers by exchanging information. This guideline prescribes that the exchange of information should be aimed at supporting buyers and sellers, instead of trying to control the exchange. This guideline also prescribes that sensitive information should be kept confidential to avoid opportunistic behavior. An intermediary can keep information confidential by only providing the results of information processing without providing any reference to the source(s) of the information.

Our fifth and final design guideline is aimed at guiding the design of matching mechanisms. It prescribes that when designing matching mechanisms one should aim at understandable mechanisms that minimize human processing time and take into account the interests of both buyers and sellers.

Analysis of intermediary roles and tasks

The analysis of intermediary roles and tasks has two goals. The first goal was to transfer knowledge about possible roles and tasks of electronic intermediaries. The second goal was to provide the basis for constructing building blocks. Building blocks make it possible to model a situation quickly.

Three types of generic roles are essential for the design of electronic intermediaries; buying, selling and intermediary roles. Roles can be described using a number of tasks. Roles cannot be described without considering accompanying roles, e.g. there should also be one or more buyers and sellers that trade using the intermediary and messages to enable communication between the intermediary and the sellers and buyers. Intermediary roles are identified in the information and negotiation phase based on the routing variants for searching potential trading partners and orders. Intermediary roles are identified for exchanging status and financial information in the settlement phase. Apart from intermediary roles, buying, selling and a number of supporting roles are worked out.

The roles and tasks are not prescriptive in the sense that all roles must be carried out in specific ways. The design of roles or tasks is dependent on the goals, interests, requirements and strategies of the organizations involved. Ideal roles and tasks applicable to all situations do not exist. The exact application of an intermediary role and accompanying tasks depends on the particular situation in which it is applied. The added value of the roles comes from identifying opportunities and from modeling situations quickly.

Technology feasibility: a supporting tool

An agent-based, discrete-event simulation environment to specify the conceptual model was developed. The supporting tool consists of autonomous agents interacting with each other. Developing a supporting tool has the advantage that it can be used to demonstrate the agent-based simulation approach, to provide better insight into the benefits and disadvantages of this approach, and to evaluate the feasibility of technology support.

We required the expression power and flexibility of general-purpose programming facilities, as we wanted to emulate trading behavior. We selected *Java* as the general-purpose language as we wanted our tool to be web-based. Given our choice of Java, we chose *Silk* to support the construction of a simulation environment as it provides Java class libraries for general-purpose simulation, queuing systems and animation. The agent architecture was implemented using Java and Silk object classes. Some trading mechanisms were selected to be emulated and were implemented using object classes. When constructing a simulation model the object classes can inherit from the general trading tasks to use the trading behavior.

The developed supporting tool showed that our agent architecture proved to be suitable for constructing autonomous agents with their own reactive and deliberative trading behavior. The use of an agent architecture enables the construction of a simulation model using building blocks. It also showed that it is feasible to integrate emulated and simulated tasks. It was possible to evaluate the added value of 'to be' situations of possible solutions using the results of process simulation and to evaluate the behavior of 'to be' situations of possible solutions using emulated mechanisms.

Usability test: two case studies

Two case studies were conducted to test our support environment on usability. The first case study was conducted at *LogiGo.com*, a start-up organization aimed at becoming an electronic intermediary bridging the gap between the demand of shippers and supply of carriers in the transport industry. The second case study was performed to test our concepts outside the transport industry. This allowed us to test our support environment independently of an industry sector. The second case study was conducted at *Tulip Computers*, an already existing brick-and-mortar intermediary that is highly interested in becoming a dotcom. In both case studies we developed conceptual and empirical models of the problem situation, diagnosed the problems, identified a number of 'to be' situations and evaluated the added value of 'to be' situations using our support environment.

The case studies demonstrated that our support environment, founded in the dynamic modeling approach, could be used to identify opportunities for electronic intermediaries and to evaluate the added value. Both case studies showed that an *agent-based approach* is suitable for reducing the complexity of a system to a number of autonomous agents that are used to model independent organizations. The task models provided a clear insight into the tasks performed within independent organizations modeled as autonomous agents and the interaction model provided a clear insight into the communication between organizations. Our

agent-based simulation environment is suitable for modeling a system of independent organizations having their own trading logic. The agent-based simulation models can be used to assess the difference in performance between empirical model of the 'as is' situation and 'to be' models of possible solutions. The simulation models can also be used to provide insight into modeled trading behavior by letting persons interact with a 'to be' model of possible solutions.

The *design guidelines* were used to guide the process of designing coordination mechanisms in a distribution network. The design guidelines were translated into case-specific design guidelines and used to diagnose the problem situation and identify ‘to be’ situations of possible solutions. The elements prescribed in our design guidelines were found back in the 'to be' models of possible solutions.

The intermediary *roles and tasks* are suitable for modeling intermediaries in distribution networks. The testing case studies, however, showed that the model building using building blocks of the 'as is' and 'to be' situations of possible solutions took more effort than expected. The customization of the roles and tasks implemented as building blocks was time intensive, because case-specific variables needed to be added. Consequently, the processing of messages needed to be changed and messages were extended to include all attributes.

Valuation of the support environment

The *goal* of the valuation was to make plausible that using our support environment is ‘better’ than not doing so by collecting the opinions of stakeholders regarding our support environment. We were not able to compare our support environment with other support environments, as yet there are no others found.

The first valuation instrument developed was a *survey*, which was performed using structured interviews. Interviewees involved in the design process in our testing case studies were interviewed. A *quantile test* was used to support the interpretation of the interview results. The answers of the interviewees in the two case studies had the same tenor. In both case studies we gained indications that our support environment was valued positively. Our support environment contributed to the understanding and insight into the problem situations, and supported decision-making. The agent-based approach and the emulation of trading mechanisms were valued positively.

Group sessions were used as the second valuation instrument. Participants not involved in the design process generated and scored criteria before and after a walkthrough of our support environment applied to one of our test case studies. A *Wilcoxon signed ranks test* for a matched-pairs experiment was used to test if there was a significant difference in scores. We found support for a positive valuation of our support environment in two group sessions, as the score before and after the walkthrough increased significantly on most of the criteria.

Conclusions and recommendations

Our support environment helps to design electronic intermediaries and evaluates the added value for buying and selling organizations. Our first contribution comes from providing insight into the discussion about the viability and roles of electronic intermediaries as found in the literature. We conclude from our case studies that literature that proposed the disappearance of electronic intermediaries overlooked the reality that coordination of activities involves the solving of the issues described in the coordination and change process management categories. Our second contribution comes from expanding the dynamic modeling approach with an agent-based 'Weltanschauung'. We developed a prototype of a discrete-event, agent-based simulation environment and demonstrated the usability of an agent-based approach in two case studies. Our third contribution comes from developing a support environment that helps organizations to identify opportunities provided by electronic intermediaries and helps to evaluate the effects of electronic intermediaries. We introduced a set of design guidelines and developed roles and tasks of intermediaries.

The generated 'to be' models of possible solutions in the testing case studies show that the design of mechanisms to coordinate the activities of buyers and sellers is an *organizational problem*. Our support environment was used to evaluate the added value quantitatively as well as qualitatively. Tulip Computers rejected the idea to auction superfluous computer systems as it would take too much effort and they would become involved in the physical functions. Tulip Computers did not want to bypass their distributor due to channel conflicts, involvement in the physical functions and many orders they would need to process. Tulip Computers and Ingram Micro rejected the contracting scenario because they wanted to avoid conflicts over the use of production capacity. Tulip Computers accepted the dealer support and negotiation scenario as this scenario has quantitative advantages, avoids channel conflict and creates win-win situations. The models of LogiGo.com showed the coordination of shippers and carriers requires persons to handle messages that are not supported by the system. Shippers and carriers preferred a private market place instead a public market place where everybody can meet. The Transaction Company turns the invoicing process around the TC sends invoices to carriers (sellers) and shippers (buyers). For large organizations integrating of it's IS with LogiGo.com has more advantage than using a web-browser.

Five recommendations are made for further research. The participants in our case studies found that the added value of running simulation models in a web-browser without having communication facilities and support for the understanding of models was too limited. Therefore our first recommendation is to research the possibilities of communication over the Internet to support the design process.

Our agent-based simulation prototype provides the opportunity for only one person to interact with the prototype. Our second recommendation is to expand the prototype to a distributed environment as multiple participants could then interact with the simulation environment at the same time. This might lead to an increase in insight into the problem situation by participants.

During the test case studies it became clear that the customization of our building blocks took more effort than expected. As a result the benefits of building blocks might be less than expected. Our third recommendation is to research the added value of building blocks.

Agent-based modeling is suitable for modeling a situation from a coordination view, but has also the potential to model goals, requirements and political considerations of organizations. Our fourth recommendation is to research the suitability of an agent-based approach to incorporate a political *and* coordination view.

It should be noted that our research is time sensitive. The mechanisms that were emulated in this research were limited to the current status of practice. Based on practice we limited our research to matching mechanism based on constraints and multi-attributes. When organizations are willing to share information about their planning, forecasts and cost, an optimization mechanism might be used to coordinate activities of buying and selling organizations that can benefit buying and selling organizations better. Our last recommendation is to research these kinds of mechanisms.