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APPLICATION OF TRANSACTION COSTS IN ANALYZING TRANSPORT CORRIDORS USING MULTI-AGENT-BASED SIMULATION

ABSTRACT

In analyzing the freight transportation systems, such as the transport of intermodal containers, often direct monetary costs associated with transportation are used to evaluate or determine the choice of transport corridor. In forming decisions on transport corridor choice, this paper proposes that transaction costs can be considered as an additional determinant in conducting transport corridor analysis. The application of transaction costs theory in analyzing the organizations and the transactions that occur, assists in indicating as to which governance structure results in higher efficiencies. Efficiency is seen as either the minimisation on costs or the maximisation of customer service levels. The use of multi-agent based simulation for modelling the organisational structure and mechanisms provides a novel approach in understanding the relationships in a regional transport corridor.

KEY WORDS

transaction cost economics, transport corridors, Multi-Agents Systems, simulation, terminals and short-sea shipping

1. INTRODUCTION

The goal of this paper is to apply the elements from transaction costs economic theory in building a computer simulation model for analysing the choice of the transport corridor. The simulation model adopts a multi-agent approach in coordinating the intelligent behaviour among a collection of autonomous agents. This technological approach implies that the agents would be modelled to represent both users and providers in a transport corridor for simulation and analysis. The agents would be seeking to satisfy their own goals rather than searching an optimal organisational solution. Contracts and negotiations could be simulated and organisational structures analyzed, i. e. market, vertical and contract. The application of transaction costs theory would assist in explaining or predicting the behaviour of other agents in the transport corridor. Additionally, multi-agent based simulation (MABS) could assist in analysing the simulations of decisions that are influenced by the different levels of transaction costs, such as whether shipping lines should purchase or build their own terminals as opposed to using terminals of others (make or buy). The research question that is studied is: "How can agent-based technology be used in analyzing the transaction costs and organisational structures in a transport corridor?"

The objective of the research presented in this paper is to analyze how the transaction costs influence the structure of the organisations in the transport corridor. This means that goods should be transferred through the entire transport chain, from origin to final destination, in the most efficient manner, i. e. cost- and time-effective. In particular emphasising the following:

- Improvement of transparency in seaport operations and costs.
- Improvement of the system design. It is important to identify the bottlenecks and suggest how these can be alleviated in order to prepare for a potential demand increase of shipments.
- Support of shipping in multimodal transport chains or networks. The possibility of integrating multimodal transport chain depends largely on the ability to link shipping to other transport modes. The use of a common standard, e. g. an ISO container, may create strong interconnectivity with other actors in the organisation of shipping.
- Improvement of the operations and utilization of resources. For instance, it is important that time tables meet customer requirements.
- Use of new technologies. Examples of new technologies are: fast ships, automatic handling systems, and regional IT cooperation which may help to bind firms closer, settle claims, and develop trust.

The paper is structured as follows: In section 2 a description of transaction cost theory is presented.

The components that are to be represented by agents in a generic transport corridor are described in section 3. The multi–agent perspective of analyzing the transaction costs and organisation structure in the transport corridor is presented in section 4. A conclusion and summary of the main ideas is presented in section 5, which also provides an outlook onto future work.

2. TRANSACTION COST ECONOMICS

In Ronald Coase´s book *"The Nature of the Firm"* [1], the author observed that market prices often govern the relationships between firms, known as transactions. Ronald Coase noted that if transactions are not governed by the price system then an organisational structure must exist. The transaction cost approach was developed by Ronald Coase to identify what the costs of providing for some transaction through the market are, rather than having it provided from within the firm [1] Some transaction cost types are: searching costs, negotiation costs, and monitoring or policing costs.

In further developing the transaction cost economics, Williamson [2-3] has studied the organization of transactions and "governance structures" that occur whenever or wherever goods or services are transferred from a provider to a user. As one transaction occurs when goods or services are transferred, a stage of activity is terminating and another is beginning [2]. The transaction costs economics focuses on the transactions between the stages of activity where the firm is one type of organisational structure. The transaction cost economics can be seen as the mapping of forms of organisations into transactions. The existence of low transaction costs in global trade has been a leading element in globalization.

Transaction can be either internal or external to organizations. The transactions that occur within the organization are internal and may include such costs as managing and monitoring staff, products, or services. The external transaction costs when buying from an external provider may consider the source selection, performance measurement, and managing the contract. Transaction cost economics is trying to answer such questions as: Shall we make or buy? Is the market structure the best method to organize purchasing? When is cooperation beneficial? In [4] examples are provided of transactions costs that are considered to be related to the trading partners located in a transport corridor:

- *Searching costs* – Caused by the search for transaction partners or alternative actions (examples are: the amount of time needed for the search at special organisations or institutions, costs which are caused by the use of telecommunications, online services or special publications or management consultants).
- *Information costs* – Due to lack of information in the process of interaction. This covers costs that are caused by the use of different languages (e. g. translation costs) or by technical problems that disturb the exchange of information (costs of technical equipment to overcome this disturbance).
- *Decision costs* – Arise from the participation of a group in the decision process. Due to different aims and motives of participants of decision groups, coming to a (shared) agreement is a very time-consuming process. Moreover, decision costs are caused by contracts that were not fulfilled in the way they had been negotiated or by contracts that were not closed in the intended meaning.
- *Bargaining costs* – Caused by the process of negotiation (examples: costs of lawyers and consultants, costs of the required resources like costs of travelling and travelling time).
- *Control costs* – Emerge from the adaptation and supervision of transaction results (examples: costs controlling payments or arranged technical standards or quality).
- *Handling costs* – Emerge from the management of converging action cooperation (examples: costs involving human resources, costs which are caused by the definition of business processes).
- *Adjustment costs* – Caused by the change of transaction conditions can be defined as costs of adjustment (examples: costs which are caused by the implementation of new laws or new IT-standards).
- *Disincentive costs* – Emerge from an opportunistic behaviour of the transaction partners or employees, i. e. every partner tries to interpret the contract to his own advantage (examples: unannounced high increase of prices by a supplier of products which have a very high level of specificity).
- *Execution costs* – Arise from the collection of overdue performances or payments. A possible example is the collection of proceedings.

In [5] Williamson lists six key elements of which two are assumptions, fixed factors and four are variables, used to characterise a transaction. According to the theory, the variables can determine whether the transaction costs will be the lowest in a market or in a hierarchy that can affect transaction costs *assumptions:*

- *Opportunism* – A situation in which one partner in a relationship exploits the dependence of another partner, i. e. increasing prices or reducing quality.
- *Bounded rationality* – Not possessing perfect information due to limited time or span of control. It is

difficult to locate the best solution or know what alternatives may exist.

Transaction cost *variables*:

- *Asset specificity* – These investments are made by the trading partners who are specific, such as the tools, routines, knowledge or machines to serve a certain trade partner.
- *Uncertainty* – The plethora of new technologies and the increasing complexity that characterizes many systems impacts the decisions that are made.
- *Information Asymmetry* – Information or quality is not disseminated among all partners evenly. Typically characterized in many transportation networks are the number of "islands of information" which generate, release or retrieve information that is useful for a specific trading partner.
- *Frequency* – The number or volume of orders.

The major concentration of transaction costs theory has been on *governance structures* that seek to maximize the value net of production and transaction costs. Most transactions are carried out through a market governance structure. There are three main types of governance structures: *market, contracts, and vertical integration*. Markets are seen as the most preferred solution to organize activities, when uncertainty, and knowledge is imperfect. Contracts provide protection for transaction specific assets by binding both the provider and the user together for a certain time period. Vertical integration is employed in order to internalize the values of transaction specific assets. Table 1 compares the advantages and disadvantages listed by [6] on the three main governance structures resulting from transaction costs.

Table 1 - The three types of governance structures described in RAND (2002)

Governance Structure	Advantages	Disadvantages
Market	Incentive on maximizing net value	Cannot protect transaction-specific investments
Contracts	Some protection on investments	Not all possible contingencies can be contracted
Vertical Integration	Internalize values of transaction-specific investments	Cannot control costs nor markets

3. COMPONENTS OF A TRANSPORT CORRIDOR

The major goal of the European Union (EU) *Motorways of the Sea* initiative and especially in the *BalticGateway* project is the increase use of intermodal freight, seaports and terminals in order to take more freight traffic off the road and rail systems. The enlargement of the European Union, especially in the East Baltic region offers many tantalizing opportunities and uncertainties for policy makers regarding the choice of freight transportation systems and transport corridors. The investments and business decisions on seaports, rail networks, and roads in moving cargo between the new members states in the Baltic raises many questions that require further analysis. In particular, the terminals (seaports) require much attention and need to be studied since they are the "nodal point" between the land-based transport net works and marine transport networks. The terminals are often not explicitly taken into account when cargo transportation flows are analyzed at a regional level [7].

Shipping can be viewed as a network coupled with land-based transport networks (by trucks or railway), marine transport networks (ships) and seaports or terminals. As network organisations, *shipping* can be considered to be virtual organizations linked by supplier--customer relationships. Such relationships are often modelled as markets where goods are bought and sold between actors in the network. Transportation costs include physical movement costs and the non-monetary transaction costs between the organizations in the transport corridor. The use of market mechanisms in coordination or control has assisted in eliminating much of the administrative overheads, meaning that the fall in transaction costs significantly decreases the total transportation costs. The following entities can be modelled into a generic transport corridor:

3.1 Terminals

Terminals have an important position in transport corridors as the intermediaries in helping to reduce the number of transactions, which then leads to lower transport costs. Transaction costs in a transport corridor can be seen as handling costs at railroad stations, seaport and terminals. Seaports and terminals are used to reach the hinterlands or markets that they serve by access through transport corridors, which try to achieve overall transportation system performance by having lower costs and wider access to markets [8].

Modern seaport and terminals are no longer passive points of interface between sea and land transport, used by ships and cargo as the natural points of intermodal interchange [9]. They have become logistic centres acting as 'nodal points' in a global transport system. The emergence of integrated freight transport system leads to new challenges in the field of efficiency, equity and sustainability. In order to meet the new requirements, active forms of inter-governmental co-operation, on the sub-regional and even global level, are indispensable.

3.2 Freight forwarders

The business of transporting goods involves many various activities. The use of sales contracts between the exporter and importer are the starting phase, where intermediaries may intervene, e. g. *freight forwarders*. If the exporter or importer do not have their own shipping departments they will contact a freight forwarder. The freight forwarder will have contacts and contracts with various road haulers and steamship lines. The freight forwarder makes the necessary arrangements in overtaking the responsibility of transporting goods from place of origin to the destination. In practice, this means that the freight forwarder will check with the government-legal authorities (e. g. customs), insurance companies, and the banks to insure the transport activity is cleared.

3.3 Inland transportation providers: road and rail

Competition does not always come from other terminals. As road transport and rail cargo transport are becoming more and more effective competitors of sea transport, it is no longer possible to look at maritime transport, including port economics, separately from the total transport system. This explains why traditional modal split issues are reconsidered in the so-called system split model: "the choice will not primarily be a modal choice; it will really be a choice between different transport systems, some of which will contain a combination of several modes and some of which will depend on only one mode" [10]. Consequently, shippers do not necessarily choose a seaport, but they select a transport chain in which a seaport is merely a node.

With road and rail networks connecting many terminals to their shippers and with vessels calling at multiple terminals, the seaport or terminal is sensitive to freight variations and to competition. The seaport must develop a strategic plan and coordinate with the stakeholders on a path that will support the seaport and develop more mutual business in order to compete. The notion that a terminal will be competing with other terminals is now being redefined.

3.4 Governmental-legal authorities

Customs and governmental agencies from regional, national, and international make policies that effect shipping across borders. The inspections and clearance of goods and the way this activity is carried out can influence the transportation of goods and choice of transport corridor. The importance of fast clearance and transparency of the process is paramount as can be seen from the example of many shippers choosing Finnish ports over Russian ports in moving cargo to Russia [11]. The choice of transport corridor is influenced by such policies.

3.5 Shippers

They are persons or organisations that have initially decided to transport goods. They are either the exporter or the importer and depending on the contract, responsible for the transport activity. The shipper can be a manufacturer shipping the parts to its factories - in this case it takes an importer role. When a manufacturer ships the finished autos to its markets - it takes an exporter role. In both examples the manufacturer took a shipping role. In other situations, a shipper may represent a large group of small firms, e. g. the Swedish log industry. By having such an organisation representing thousands of small log companies, it can assist in negotiating better rates and contracts with shipping lines and terminals.

3.6 Shipping lines

Shipping lines are often associated with transporting goods between ports on ships. The emergence of logistics has propelled many shipping lines, such as Maersk or DFDS, to develop integrated systems where the ships are one component of a total transport system. In many cases shipping lines can take competing or cooperating roles. The "foot-loose" characteristics of the shipping lines influence the decisions on which transport corridors should be taken. The example of TEAM lines moving its container operations from Karlshamn, Sweden to Ĺhus, Sweden has severely influenced the flow of containers in Karlshamn.

4. SIMULATION OF TRANSPORT CORRIDOR CHOICES

A computer based simulator, representing two types of actors involved in the transport corridor are studied from the bottom up. The first group of trading partners are represented by agents that are considered to be the *users* of the transport system. The second group is represented by agents that are considered the *providers*, which are selling their services. The model will actively distribute the economic activities across various organisational forms represented by autonomous agents. The agents are considered to be bounded rationally and through their interactions with other agents emerges a pattern that can be used for further decision making by the agents. The representation of terminals and other partners found in short-sea shipping corridor will be rather detailed, which enables the processes and their implication on

the costs of the transport corridor to be analyzed rather thoroughly. In order to handle the complexity of the system, advanced simulator techniques using MABS would be developed.

The use of MABS allows for a realistic representation of the operations and actors in the system. For instance, the actors (agents) can be allowed to act pro-actively, which is particularly important when human decision-makers affect the system. Furthermore, the use of MABS supports a straightforward definition of decision-makers since they can be defined through their goals and intentions. Economic models incorporating MABS have been developed in investigating the theory of transactions cost economics. In [12] they have developed an agent-based model for simulating and analyzing transaction costs economics. In the model, agents decide autonomously on the "make or buy" decisions. The agents develop different preferences for other agents representing trading partners. These decisions are incorporated in the model. The actual agents and the actual transactions are incorporated in the model and the agents adaptively search suitable structural forms for organizing their transactions.

MABS differs from other kinds of computer-based simulation in that (some of) the simulated entities are modelled and implemented in terms of agents. As MABS, and other micro simulation techniques, explicitly attempts to model specific behaviours of specific individuals, it may be contrasted to macro simulation techniques that are typically based on mathematical models where the characteristics of a population are averaged together and the model attempts to simulate changes in these averaged characteristics for the whole population. Thus, in macro simulations, the set of individuals is viewed as a structure that can be characterized by a number of variables, whereas in micro simulations the structure is viewed as emergent from the interactions between the individuals. The MABS approach has been applied to other areas of policy-making [13].

Different polices and strategies for integrating terminal, shipping and logistics operations in transport corridor will be analyzed and compared using the simulator. In particular, different forms of organisation will be investigated. Scenarios representing different levels of transactions costs and various forms of organisation will also be generated and analyzed. These analyses will help to assess the factors influencing performance in the systems perspective and give indication of proper organisational strategies. In order to achieve an objective such as intermodality, intensive cooperation and coordination among trading partners in the transport corridor are essential.

In developing the simulator, a methodology known as MAS-CommonKADS is used by Henesey et al. in [8] in evaluating Stakeholder Relations Management (SRM) and is suggested to be used in modelling and simulating the transactions. The methodology is useful in eliciting domain knowledge for non-experts in the area of logistics, such as programmers, to develop software for simulation. The simulator is expected to generate results that would offer decision makers the ability to view the structure of a transport corridor system and the functions that the stakeholders have under various "what if" analyses. Different types of questions to be analyzed include:

- How can seaports, transport operators (land and sea based) and terminals improve performance?
  - Can better planning of operations improve performance?
  - Is there scope for improvement by sharing information?
  - Is there scope for improvement by joint planning of for instance loading and unloading strategies; and ship timetable planning?
- How does transportation using unaccompanied and accompanied driver transports compare with respect to cost and service?
  - Can road legs of transport be minimized?
  - Are we able to "bridge" the missing links?
- Where are the bottlenecks found in the system?
  - Are there bottlenecks in infrastructure (e. g. railways and roads)?
  - Are there bottlenecks in terminals (and what parts/operations of the terminal are bottlenecks, e. g. cranes, customs or berths)?
  - Are there bottlenecks in shipping capacity?
  - Are there different bottlenecks during different periods of time of the day of the week?

5. SIMULATION ARCHITECTURE, DESIGN, AND MODEL

In designing the simulator, the study of rational agency would be employed, e. g. the Beliefs, Desires, and Intentions (BDI) model. The BDI architecture is able to capture some of the characteristics of an individual since the agents in the system would have incomplete beliefs – bounded rationality. The desires of the agents could be considered the goals that could be achieved by individual agents. Intentions are the plans required to be executed in order to achieve the desired goal. Another factor for choosing the BDI model is that transaction cost economics includes a rational analysis component that searches for the best organisational structure for various types of transactions, given when bounded rationality exists and opportunism exists. The proposed agent methodology is attrac-

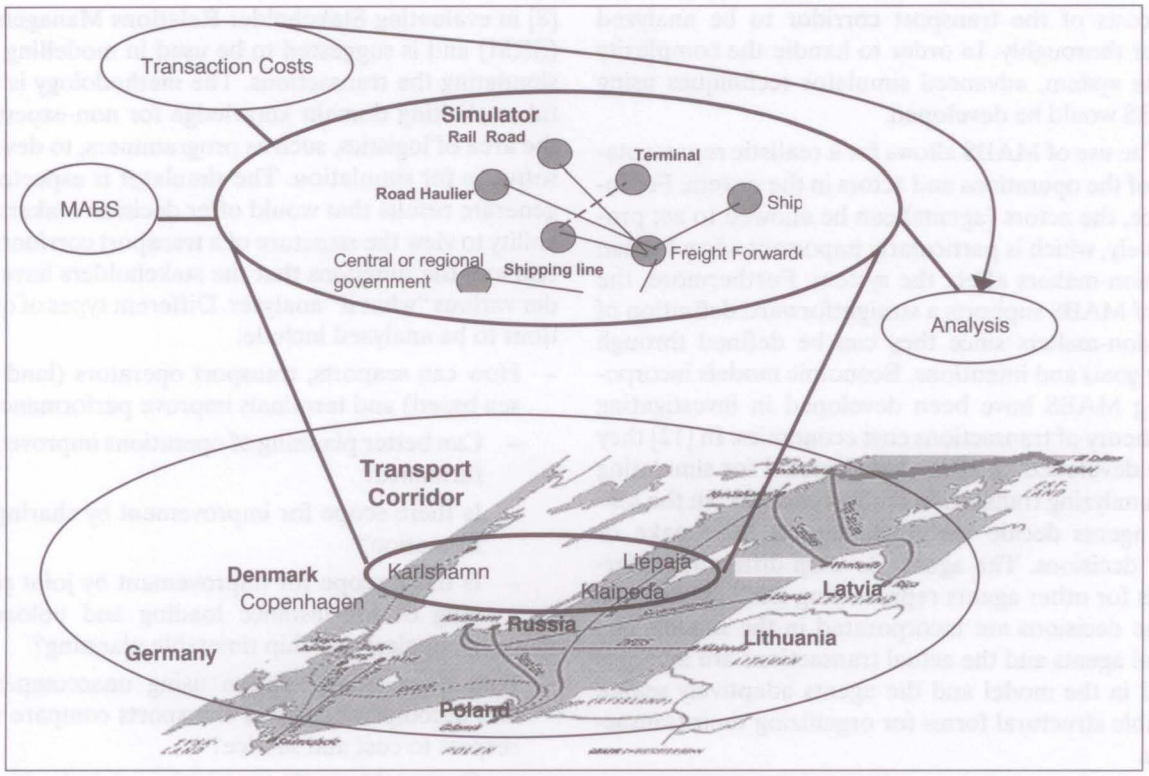

Figure 1 - Illustration of the transport corridor simulation

tive because it deals with the complexity in modelling the interactions between actors in the system.

The considered software is the trade network game (TNG) which combines evolutionary game play with preferential partner selection and can be used to study alternative specifications for market structure, trade partner matching, trading, expectation formation, and trade strategy evolution [14]. The evolutionary implications of these specifications can later be studied at three different levels: individual trader attributes; trade network formation; and social welfare available from the agent-based computational economics website (ACE) [14].

The design of the TNG platform would facilitate in simulating the real world transport corridor which would be mapped by agents in the simulator. Theories on transaction cost economics and the MABS approach would be used in the development of the simulation. In the analysis of the results from the simulator, transaction cost economics provides a background in determining the best organisational forms and indicators for improving efficiency. Figure 2 shows an illustration of the simulation.

6. CONCLUSION AND FUTURE WORK

In this paper a conceptual model for simulating transaction costs in analyzing a transport corridor is introduced and described using MABS. MABS provides an additional tool for analyzing decisions on choice of transport corridor as well as other decisions effecting freight movements. By providing a framework model integrating transactions (physical and information) flows between organizations, micro-simulation techniques such as MABS may assist in maximizing customer satisfaction whilst minimizing transaction costs.

Economic theory has provided many contributions to resource sharing and decision making, such as the use of multi-objective optimization techniques to identify and compute optimum allocation introduced through economic models. The use of computer simulation utilizing MABS introduces a novel approach to analyzing transport corridors and transportation systems. This paper has conceptually demonstrated how transaction cost theory could provide a useful base for models and tools to be further developed in assisting the choice of transport corridors.

Further work with the TNG software is required before MABS can be employed. Additional information and data collection from companies, i. e. questionnaires or interviews, would benefit the development of the agents in the transport corridor. A couple of situations that could be experimented are: opportunism with the agents in the system and/or the organisation structure that is best fitted, i. e. vertical integration, market, or contract. The switching costs of one agent to another, e. g. the use of a road hauler to a rail road can be measured. The coordination practices of the agents in the system could be analyzed. The devel-

opment of the suggested simulator in studying the transport corridor in the *BalticGateway* project is attractive. However, such a simulator is a vision to be applicable to other geographical areas.

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ABSTRAKT

MULTIAGENTBASERAD SIMULATION FÖR TRANSAKTIONSKOSTNADSANALYS I TRANSPORTKORRIDORER

För att analysera frakttransportsystem, som t. ex. transport av intermodal containers, används ofta direkta monetärkostnader associerade med transporten för att evaluera eller bestämma val av transportkorridor. I beslutsprocessen kring val av transportkorridor förselär vi att transaktionkostnaden används som ytterligare en faktor för att genomfära analys av transportkorridorer. Transaktionkostnadsteori används för att analysera organisationer och deras transaktioner vilket hjälper att avgöra vilken styrstruktur som är mest effektiv. Effektiviteten i rapporten är mättat genom att antingen minimera transportkostnader eller att maximera nivln pl kundservice. Användningen av multiagentbaserad simulation för modelering av organisationer struktur och metodik ger en ny metod för att förstl relationer i en regionala transportkorridorer.

NYCKELORD

Transaktionkostnadsekonomi, Transportkorridorer, Multiagentsystem, Simulation, Terminalar och Short-Sea Shipping

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