EAST WEST TRANSPORT CORRIDOR

REPORT

Performance Metrics and Micro-level Simulation Model Scenarios

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1 Introduction

This report addresses tasks 5.11 and 5.14 in the East West Transport Corridor project "Development of a Sustainable, Efficient and Attractive Intermodal Transport Corridor". The activities have the following specifications:

5.11 Identification of the activity:
Defining performance metrics relevant for the corridor
Purpose
Define performance metrics at operational level e.g. cost, time, reliability, environmental impact.

5.14 Identification of the activity:
Development of micro-level corridor simulator model scenarios
Purpose
Define the architecture of simulator model. Decide the level of detail including characteristics of objects to be micro simulated. Refine simulation scenarios for micro based simulation

We start by identifying the performance metrics relevant for the East West Transport Corridor. We then sketch the architecture of the micro-level simulation model by describing the different stakeholders involved and how they are modelled.

The purpose of the simulation experiments may be to analyse the consequences of, e.g., transport infrastructure investments, or application of governmental control policies.

2 Relevant Performance Metrics

In order to evaluate different types of improvements of the East West Transport Corridor, a number of performance metrics were identified based on literature studies, interviews, etc. They were categorised in three different types: economical, transport quality, and environmental. These metrics have been validated at several occasions, e.g., at WP4 stakeholder meetings and workshops.

The economical performance metrics identified were:

- costs for different actors: e.g.:
    - variable: labour, fuel, maintenance, taxes, fees etc.,
    - fixed: capital costs for transportation resources etc.,
- revenues to public authorities: tax income, etc.,

the transport quality metrics:

- reliability (deviation from schedule, estimated/promised time of arrival and shortage of products for customers),
- lead time,
- relation between transport work and traffic work,

and finally we have the environmental performance metrics:

- emissions (e.g., CO_2, SO_2),
- energy usage.

3 Micro Simulator Model Architecture

3.1 General stakeholders

There are a number of relevant stakeholders affected by and influencing the transport corridor. Activity 6 of WP 5 identified the following stakeholders:

- state and regional authorities;
- port terminals;
- warehouse operators;
- carriers: railway, haulers, shipping companies;
- forwarders, agents;
- controlling institutions;
- 3PL – supply chain managers;
- 4PL – integrators of several supply chains.

In a micro-level simulation model the focus is on the decisions affecting the transport choices including, route choice, mode choice and consignment size. It is complicated to define the exact roles of the actors in a transport chain as well as in a corridor. One reason being that industrial organisation differs significantly between different types of transport services depending on the character of the demand, traffic modes involved, level of vertical and horizontal integration etc. However, it is easier to define what decisions need to be made and also in which order they must be made (some concurrent and others in parallel).

When modelling transport chains, the definition of categories of actors and the applied terminology depend on the purpose of the modelling, and which perspective is taken, e.g., a Logistics Service Buyer (LSB) or a Logistics Service Provider (LSP), and the level of detail and abstraction. Functions within companies are treated as roles and an actor can play several roles and the same role can be played by several actors. For a more thorough discussion on transport actors and their roles see Ramstedt (2005) and Ramstedt and Woxenius (2006). Some material from Ramstedt and Woxenius (2006) has been used in this report.

The generic LSB and LSP are used here for denoting the *roles* at the demand and supply sides of the market for logistics services. The consignor, the consignee or someone appointed by them can take on the LSB role and the LSP role can be played by a transport co-ordinator or a transport operator directly. On the LSB side it is common that the supplier of products charges its customer a price including the transport costs. On the LSP side, transport co-ordinators often perform minor physical activities themselves, primarily terminal handling, but their core competence is to co-ordinate the activities of transport and terminal operators and offer bundled services to the LSB.

The term third party logistics provider is not further used here due to the rather unclear definition. The terms 4PL, non-asset operator and non-vessel operating common carrier (NVOCC) are used in industry and in some research for denoting an actor that focuses on planning and administration of transport chains but never physically touches the goods. 4PL is regarded as an illogical term since the LSP controlling the LSB contacts would then be the second or third part, transport and terminal operators further down in the hierarchy would rather be the fourth part.

3.1.1 Customer behaviour

We assume there is demand of products. The product demand normally depends on a need in production or at a retailer. The final demand is expressed in orders sent by the customer. The order policy has an important influence on how the logistical operations are performed. There are different ordering polices, e.g., the (Q,r) model, which determines the order point and order quantity, and originally assumes a stochastic demand and fixed lead times. Bookbinder and

Cakanyildirim (1999) state that most models using the assumptions of the original (Q,r) model, focus on constant lead time and random demand, but they argue that it instead is the lead time that disturbs the co-ordination in supply chains. Therefore they propose a model with random lead times and constant demand. The economic order quantity (EOQ) formula, or the Wilson formula, which minimises the variable costs, is by Alstrom (2001) claimed to be the most common ordering policy in the industry to determine the optimal ordering quantity. The EOQ formula is claimed to have several drawbacks since several simplifications are made, for instance that the demand and lead time are fixed and known and that no stock-outs occur. Therefore, many modifications of the formula have been made, for instance, a safety stock is often added (see, e.g., Alstrom, 2001), sometimes the demand is assumed to be variable and the lead time can also be assumed to be variable (Bookbinder and Cakanyildirim, 1999). When the assumptions of the EOQ formula, e.g., constant demand, perfectly known fixed ordering cost, do not hold, the results (of course) become less reliable. Another drawback with the formula is that the assumed costs, such as the holding costs, are difficult to assess, therefore the obtained optimal quantity is not an exact quantity (e.g., holding cost rate that are used in models typically range from 10 to 30%). For instance, the holding costs can be assumed by the company to be a high value if it is desired to have low inventory levels.

3.1.2 Product Supplier behaviour

The production strategies used have an influence on the other logistical decisions, such as transport to customer, customer ordering, etc. Common supply chain strategies are pull or push strategies (Ahn and Kaminsky, 2005) where production is demand driven in the former and predetermined in the latter. Pull strategies imply difficulties to plan for transport in relation to production. Push strategies often use production resources better and the transport planning is enabled.

The production planning, e.g., producing continuously, in batches or as individual items, influences the co-ordination between transport and storage. For instance, production in batches can decrease the supplier inventory levels, compared to continuous production. The choice of an optimal batch size is somewhat similar to the choice of the economic order quantity. However, here the trade-off is between production costs and storage costs. Moreover, the batch size influences the possibilities to match the products to the available load units. See, for instance Riddalls and Bennett (2001) for further discussions. When an unexpected demand appears which the supplier cannot meet, there may be a need to prioritise the customer supply. In some strong consignor cases, the supplier classifies their customers to support the prioritisation for how to meet the customer demand.

We chose to model the producer of pull strategy, i.e. producing when customers order. We assume a producer has limited production which is allocated whenever new customer orders appears.

3.1.3 LSP behaviour

The actor that actually decides upon the transport mode differs between logistics chains and this is often stated in the agreement between the LSB and the LSP. In some logistics chains, the LSB has no preferences for the mode choice, therefore the LSP decides which transport mode that is most appropriate. In a strong LSP case, the LSP mostly makes the mode choice; while in the strong consignor and consignee cases, the LSB decides.

Many studies on traffic mode choice have been published. Cullinane and Toy (2000), for instance, have performed a content analysis of studies on freight route and mode choice. They conclude that the importance of the attributes depends on how the study has been performed, for instance, if the study is a simple analysis or a more abstract analysis. However, most studies on transport mode choice concerns how important decision makers *value* certain criteria for the mode choice, i.e., the attributes that directly determine the decision process are often not considered. Some researchers (Nelldal, 2000 and D'Este, 1996) argue that before the studied attributes can have an influence on the transport mode choice, certain fundamental requirements have to be satisfied. D'Este (1996) describes the choice process as: (1) elimination of technically infeasible solutions, (2) elimination of options that fail to meet service requirements and (3) trade-off between service criteria. (1) can for instance be restrictions on the infrastructure and transport resources, (2) can concern delivery time requirements and product restrictions in handling while (3) is the difficult part where, e.g., cost is compared to high customer satisfaction. The mode choice studies can be used in modelling the mode choice, e.g., by weighting the attributes, after the possible solutions have been defined. Sheremetov *et al.* (2005), for instance, have used fuzzy approximations for imprecise measures, such as service level trade-offs in supply chains.

Caputo *et al.* (2005) state that mathematical programming techniques for solving transport planning problems often assume many simplifications, require large amounts of data, and are computationally demanding, which sometimes make them difficult to use by companies, and especially at small LSPs. Caputo *et al.* (2005) claim that the LSP has to plan manually and is left to its personal judgement in the choice between full load, part loads and consolidation for long-distance transport, which often leads to suboptimal solutions. Therefore a model to support the decision makers in the choice between full load or part load is suggested, based on minimising the transport costs. The full load costs are easily calculated but for part loads, the vehicle cost must be allocated to different consignments. The studied case represents the strong LSP case for the part load and the strong consignor case for the full load.

The possibility to transport products also depends on when the products are available for transport, e.g., if the products are available at the supplier's inventory, if the products just are produced, or if the products have to be produced. In the strong LSP case, the conditions are often very clear for the LSB and little room is left for negotiations. Moreover, this is probably the case where it is easiest to determine the transport lead time since timetables are often used and there are statistics on historical transports performance for the route.

We chose to model the logistics service providers' roles by assuming they strive for cost minimisation considering logistics restrictions (of capacity, availability particularities of the product etc.) The logistics service buyers are assumed to be able to consider non-direct cost minimisation issues such as including consideration of transport time.

4 Input to the Micro-level Simulation Model

In this section, the input and output of the micro-level simulation model will be described. This is followed by a discussion of design and validation of scenarios, and which type of data that should be used to be able to perform meaningful simulation experiments.

4.1 Input

Available transport infrastructure consists of links and nodes. *Links* are for instance road, rail and sea transport links, and its characteristics of the available transport infrastructure are for instance:

- connection with nodes,
- traffic mode,
- length,
- vehicle capacity,

- average speed.

Nodes are different types of terminals, facilities of customers or producers, and their characteristics are:

- geographical location (indirect from connection with links),
- production, vehicle and storage capacity,
- loading and unloading durations and costs for each vehicle type.

Available resources are vehicles, inventories and production plants, which have these characteristics (in addition to the characteristics described above):

Inventories.

- product types possible to store,
- storage interest (capital cost).

Production resources.

- type of product possible to produce (with characteristics such as mass, volume, value),
- production cost,
- delay distribution.

Transport resources (vehicles):

- initial location of transport resources,
- type of vehicle,
- amount of vehicles,
- maximum load capacity,
- time tables for certain vehicle types on certain transport links,
- distribution for probability of delay,
- fuel consumption,
- time-based (such as driver cost, capital cost),
- distance-based costs (such as vehicle wear cost and fuel cost),
- environmental performance (emissions, such as CO_2, SO_2).

Consumer demand is specified by:

- product type,
- demand distribution,
- location of customer.

Besides the inputs described above, governmental control policies can be added. Governmental control policies can either be regulative or fiscal, which can cause effects in terms of restrictions, increased costs, etc., for the transport chain actors (see Ramstedt (2005) for an overview).

4.2 Output

There are some general outputs from the simulator in form of the logistical operations performed, which include:

- choice of traffic mode,
- choice of vehicle type,
- route choice.

These outputs form the bases for other outputs, such as, the performance metrics discussed above:

- costs for different actors: e.g.:
    - o variable: labour, fuel, maintenance, taxes, fees etc.,
    - o fixed: capital costs for transportation resources etc.,
- revenues to public authorities (tax income).
- reliability,
- lead times,
- relation between transport work and traffic work;
- emissions (e.g., CO_2, SO_2),
- energy usage,

5 Scenario

In this section the base scenario design will be described and extensions suggested.

5.1 The Base Scenario Design

The scenario consists of several possible transport alternatives for transportation of TEU (20 ft) containers from Vladivostok in eastern Russia (next to the border to China) to England. The transport links considered are:

- Rail transport from Vladivostok to Kaunas.
- Rail transport from Odessa (Illitjivsk) to Kaunas
- Rail transport from Kaunas to Klaipeda
- Sea transport from Klaipeda to Karlshamn
- Rail transport from Karlshamn to Esbjerg (electrical locomotives from Karlshamn to Taulov, diesel locomotives from Taulov to Esbjerg).
- Road transport from Karlshamn to Esbjerg.
- Sea transport from Esbjerg to Felixstowe/Harwich (the ports are next to each other).

See Figure 6.1 for a rough illustration of the transport alternatives in the scenario, as well as transport alternatives which are interesting to study further in the EastWest Transport Corridor project.

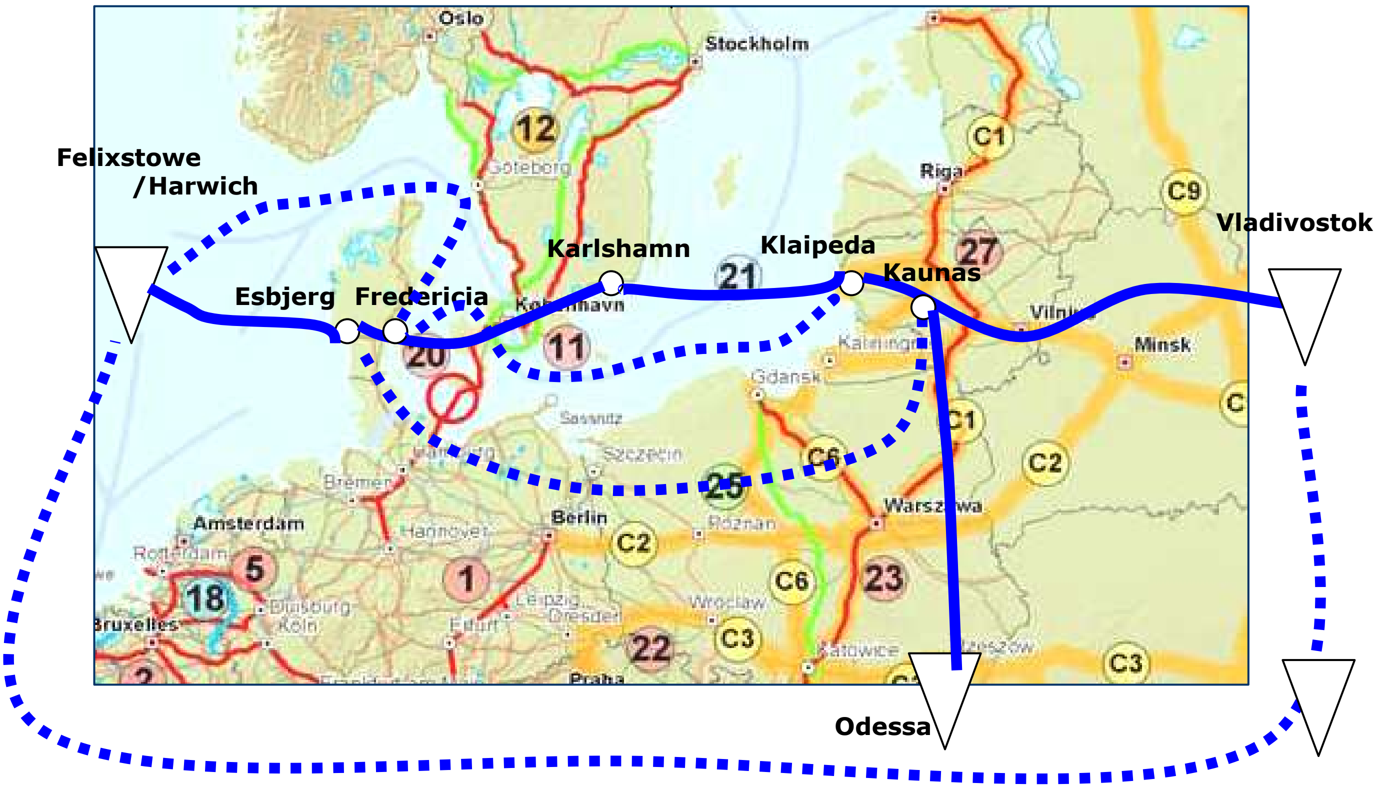

Figure 6.1. Illustration of transport alternatives in the scenario, as well as in the East West Transport Corridor project, based on Sakalys (2006).

In addition to the base route in the East West Transport Corridor there are additional links to include for comparison:

- Sea transport directly from Vladivostok to Felixstowe/Harwich.
- Road transport from Kaunas to Esbjerg.
- Sea transport from Klaipeda to Fredericia
- Sea transport from Fredericia to Felixstowe/Harwich

The containers contain goods with medium value, such as furniture or kitchen appliances. The producer is assumed to be located in Vladivostok, and the customer is assumed to be located in Felixstowe. In reality, the goods typically originate in China.

In general, we have tried as much as possible to use real world data from companies which can possibly use the corridor, but when it has not been possible we have used some of the data from a study called the Scandic Bridge pre-study regarding transport alternatives from Klaipeda to Esbjerg, i.e., a part of the transport corridor (CTT – DTU & SDU, 2004). The analysis in the Scandic Bridge study is made with a GIS (Geographical Information Systems) tool. Since we are able to use more detailed data in our simulation experiments than in the pre-study, we have chosen to use real world data when possible, and averaged data used in the Scandic Bridge study when we have not been able to find suitable real world data.

The following are the assumptions and data that we have used in the scenario:

- *Order behaviour/quantity*. The product demand is not fully known to the customer. However, there is a forecast of the demand, in terms of a distribution, which the customer has access to. The customer demand is specified in numbers of containers of size TEU in this basic scenario. The customer is assumed to have an inventory. The customer makes request of 1, 2 or 3 TEU, and when it has received the proposals, it chooses the cheapest alternative, based on transport costs as well as on inventory holding costs which are proportional to the transport time and product value, which meets the customer's requirements.
- *Time tables*. In the scenario the trains and ships are transported according to time tables, while trucks are not restricted to time tables. The time tables are either existing time table frequencies, or time table frequencies that are possible to be introduced in a short-term perspective.
- *Time assumptions*. We have tried to make reasonable transport times assumptions based on some transport operators operating on transport links in the scenario. When we have not been able to find accurate information we have used data from the Scandic Bridge pre-study (average speed assumptions). In intermodal nodes (Klaipeda, Karlshamn, Esbjerg and Kaunas) we consider loading and unloading. The loading times are based on information received from a port in the transport corridor, and this data is then used in all nodes.
- *Cost assumptions*. The cost assumptions are based on the costs which appear in some of the companies participating in the East West project, as well as more general costs partly found from Sveriges Åkeriföretag (http://www.akeri.se/). Fuel prices have been collected from the European Commission and EuroStat (2005) and Swedish fuel tax levels from SPI (http://spi.se/). We assume that all costs which occur from production to consumption are taken

by the customer. The costs are either time-based or distance-based. The time-based costs include cost parameters such as driver costs and inventory holding costs (capital cost), and the distance-based costs include cost parameters such as vehicle wear costs, fuel or electricity costs and taxes. We have not been able to find data for all cost parameters and transport alternatives, instead we have tried to get the overall costs as accurate as possible.

- *Vehicle utilisation*. Default vehicle load factors for train and ship transports from NTM (2005) are used for cost calculations, as well as calculations of the environmental performance. These vehicle load factors are used by NTM for certain vehicle types which correspond to the vehicle types used in this scenario.
- *Environmental performance*. When we allocate the environmental performance of the cargo of a train or a ship transport, we take the proportion in weight of the consignment of the total amount of cargo in a specific rail freight carrier, like for instance in Knörr and Reuter (2005). We use the calculation methods of NTM for international transportation to determine the environmental performance in terms of emissions. We could have used the emission factors described in the Scandic Bridge study, but since we want to include as much details as possible we choose NTM instead. Also, both methods are originally based on the same calculation method.
- *Sea transport*. Currently there are only RoRo ship on the links Klaipeda – Karlshamn and Esbjerg – Harwich. Therefore we assume that the containers are transported on mafi, or on a trailer chassis without a driver.
- *Train transport*. On the link between Taulov and Esbjerg diesel locomotives are used. Therefore there is a need for a change from electrical locomotives to diesel locomotives in Taulov. However, since this is not an intermodal node we do not take loading and unloading times and costs into account. Currently (autumn 2006) there are no electrical trains from Karlshamn, but an electrification of the railway is under construction and scheduled for completion during the summer 2007.
- *Governmental control policies*. Current levels of variable taxes are used in the scenario, i.e., fuel taxes and kilometre taxation.

5.2 Future scenarios

The assumptions above represent the base case of the East West Transport Corridor for the micro-level simulation. Further, we intend to study changes in the prerequisites for the transport chain actors. Below we outline a number of such scenarios which have been agreed to be of interest by the partners in the East West Transport Corridor project. With respect to the set-up of the corridor we have:

- Infrastructure investments (e.g. terminals - ports, rails and roads), which affect the time and reliability of a link and/or a terminal.
- Operators investments and choice of for instance ships and trains, which affect time and costs of transport on links.
- Redundancy of capacity and different transport alternatives, which affects reliability.
- Technologies (e.g. automated handling systems and ICT), which mainly affect time and cost of transport.
- Assumption on future volumes, which affects timetables (frequencies) and transport times (if congestions).

Further we have extended scenarios with respect to planning of operations:

- The effects of better coordinated time tables, as well as more frequent departures in the time tables. The more tightly the time tables are connected, the shorter will the overall transport time be.
- Hub services, which affect the time of transport.
- Demand distribution over time (e.g. variations over weeks and months), which affects the demand specification.

In addition it may be of interest to study scenarios with respect to external governmental decisions:

- There are different vehicle weight restrictions within the EU. Since the goal is to harmonise the prerequisites for businesses in the EU, it is possible that the maximum allowed vehicle capacity will increase (e.g. to the Swedish level of maximum 60 tons).
- An introduction of a kilometre taxation in Sweden. It is interesting to study what the effects will be after an introduction of a kilometre taxation in terms of modal choice, choice of vehicle type as well as the size of the consignment and the corresponding economical, environmental and quality performance. The tax levels that we are examining are the levels that formally have been suggested in Sweden (Swedish Ministry of Finance, 2004), see Table 6.5. The suggested kilometre taxation is differentiated based on the euro class of the truck, as well as on the total weight of the truck. The compensation in the proposal which we are examining is a lower fuel tax.

Further it is useful to only include the Baltic Sea region to be able to compare the results more easily with the Scandic Bridge study. Such comparison is important for validation. The exact extensions to the base scenario need to be defined based on forthcoming results of simulating the base scenario.

6 Discussion

The base scenario has been validated by the partners and the parameter values of the base scenario have been gathered, as discussed above. More validation of the parameters is however needed. In the next phase of the work on the micro-level simulation, continued validation of the input as well as of the output will be important tasks. In addition, we need to investigate which future scenarios are most relevant.

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