EAST WEST TRANSPORT CORRIDOR

REPORT

East West Transport corridor

Micro-level Simulator Description and

Simulation Experiment Results

2007

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The transport corridor Vilnius-Esbjerg via Klaipeda/Kaliningrad, Blekinge and Öresund is an important link between east and west in the Baltic Sea Region. Private stakeholders, authorities and universities want to take a joint initiative strengthening the corridor which contributing to sustainable growth and development along the corridor. EU-funding from BSR INTERREG III B was recently secured the 10 Dec 2005. Transports in the east-west direction are dramatically growing in the Baltic Sea Region. However, planning of transports and infrastructure is still made with national boundaries as point of departure. Transnational co-operation is needed if the opportunities of integration shall be capitalized. Although transport growth from Asia and the Black Sea is strong, the corridor between Vilnius-Esbjerg to the North Sea/UK and Benelux encloses severe problems that hamper the development. The project "East-West Transnational Transport Corridor " aims to strengthen the corridor through a wide range of activities dealing e.g. with development of an overall strategy for the corridor, infrastructure improvements, new solutions for business and logistics and strengthened transport research and co-operation between researchers.

Specific tasks are divided into five work packages:

WP1 Transnational Transport Corridor Devel opment Strategy

WP2 ITS a Tool for Innovative Actions in the Corridor

WP3 Improvements of Infrastructure Bottlenecks

WP4 Development of business and logistics

WP5 Knowledge development

One of the overall objectives is to establish a framework for co-operation between different kinds of actors. Therefore, the partnership consists of organizations from both public and private sectors. IKEA, Karlshamns AB, Railog, Smelte and LISCO are some of the enterprises involved. Ports and universities are important partners. National as well as regional and local authorities are represented. The project involves 47 partners from 4 countries. Region Blekinge is Lead Partner. Total budget is about 3,24 M€.

Lead Partner

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2 Introduction

This report addresses tasks 5.18 "Development and verification of E-W micro-level corridor simulator" and 5.20 "Simulation experiments and results" in the East-West Transport Corridor project "Development of a Sustainable, Efficient and Attractive Intermodal Transport Corridor".

Besides the positive effects of transportation, such as enabling economical development, transportation also have negative effects, such as noise, emissions, accidents, congestion and road wear. Public authorities often use governmental control policies, such as fuel taxes, road fees, and vehicle taxes to influence the actors in transport chains to make logistical decisions which have less negative effects. Further, public authorities are interested in carefully assessing the effects of infrastructure investments. To predict the effects of governmental control policies, macro-level simulation is often used. Macro-level simulation techniques 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. The focus is therefore on a rather coarse grain level and macro-level simulation does not capture the decision making of individual actors. Different types of transport chain strategies are often studied with traditional micro-level models (Terzi and Cavalieri, 2004). However, in traditional micro-level models, interactions between individual actors are not possible to capture, and the decision making process of the actors and heterogeneity among them are difficult to capture. We argue that agent-based simulation can be used to study the effects of governmental control policies in individual transport chains since the complex interactions which appear in the transport domain and decision making of actors can be captured. Time aspects are possible to capture with agent-based simulation, e.g., the influence of time-tables and time-differentiated taxes and fees. The heterogeneity of different types of actors and transport chains can be captured by introducing categories of actors and transport chains where categories such as usage of time-tables and frequency of transports are included.

This report begins with a short outline of TAPAS and its purpose. In Section 3 the usage of TAPAS is discussed. To illustrate the usage of TAPAS, simulation experiments are described in Section 4 and 5. Finally some conclusions and future work are presented in Section 6.

3 The TAPAS model

We have chosen to base TAPAS on agent technology. Multi Agent Based Simulation (MABS) differs from other kinds of computer-based simulation in that the simulated entities are modelled and implemented in terms of agents. We have represented actors, or roles, which appear in transport chains as agents in TAPAS. This enables us to represent characteristics of the different actors as well as its interactions. Each agent has a certain goal, for instance to minimise the transport cost. Figure 2.1 gives a brief overview of the agent structure in TAPAS. For a more detailed description of TAPAS, including the decisions and actions taken by the agents, as well as their interactions, see Holmgren et al. (2007). For a discussion of the transport chain actors and how they can be represented in our model, see Ramstedt (2005). Further, as MABS allows for the inclusion of "intelligence" in the decision making of the agents, different types of transport chain strategies used by the actors can be modelled.

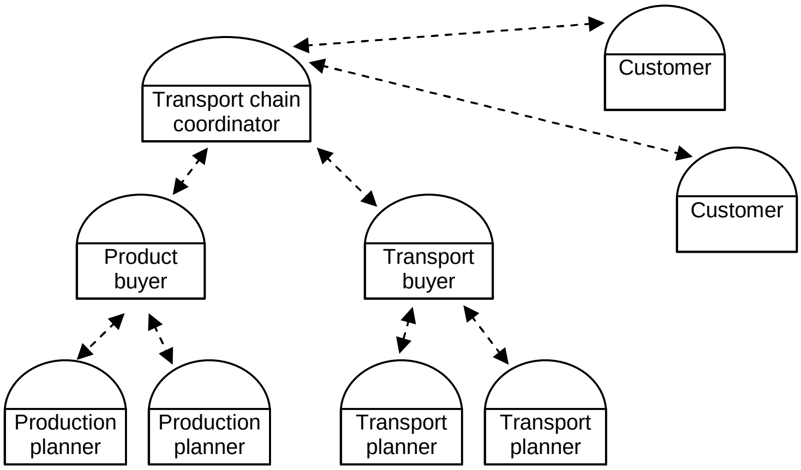

Figure 2.1. Overview of structure of transport chain actors in the micro-level model.

3.1 Purpose of the TAPAS model

TAPAS can be used to study different types of issues. The main aim of TAPAS is to function as a decision support system where the effects of governmental control policies and infrastructure investments are analysed in simulation experiments. Moreover, the competitiveness of transport corridors can be analysed. The main advantage is that the decision making of individuals can be captured, which enables a more detailed analysis of, e.g., decisions concerning mode choice. Moreover, the effects of time-differentiated taxes and fees and issues related to time-tables are possible to study with TAPAS, but not with macro-level models. TAPAS can capture the influence governmental control policies can have on the frequency and order quantity of transports. These aspects cannot be captured with macro-level models. Moreover, TAPAS includes stochastic consumer demand, transport times and production lead-times.

TAPAS can also give indications on the anticipated logistical decisions made by companies after introductions of new policy requirements, and consequently the effects of these decisions. Moreover, the model can give indications to companies how it is profitable to take decisions to reach certain goals.

The effects of the implementation of control policies that influence time- or distance-based costs (e.g., fuel taxes) and fixed costs (e.g., vehicle taxes), can be studied in different scenarios. It is also interesting to study a combination of control policies to study their interrelationships. For instance, there have been suggestions of how a kilometre taxation could be implemented in Sweden (Swedish Ministry of Finance, 2004) and which compensations that should be made to reach the desired effects. Suggestions of compensations are reduced vehicle taxation, an abolishment of the Eurovignette and reduced diesel taxation, which can be examined with TAPAS. Also, the effects of different types of differentiations of a kilometre taxation could be studied, such as a differentiation between rural and urban areas and between week days and weekends. Other aspects which are important to consider before an introduction of a kilometre taxation in Sweden are dealt with in the Arena project (http://www.arena-ruc.com/).
In the current version of TAPAS it is possible to study the effects related to the variable costs of the transport chain actors. The effects of investments of infrastructure, for instance in ports and road or railways, would also be possible to study with what-if analyses.

It is also possible to study changes of policy requirements in TAPAS. An example of a policy requirement which influence in a more long term is an increase of the maximum allowed truck weight. Today the weight limit restriction suggested within the EU is 40 tons, but there are countries with different restrictions, such as Sweden with a restriction of 60 tons. It is possible that the EU will increase its restrictions to the Swedish level, which will change the decision making of the actors in a transport chain. The effects, on for instance vehicle kilometres and modal split ant thereby on the environment, of such a change would be possible to study using TAPAS.

4 Usage of TAPAS

To perform meaningful experiments it is important to carefully consider the design of the simulation experiments. In this section, the input and output of TAPAS will be described, 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. Finally, the context in which TAPAS can be used is presented.

4.1 Input and output

Input to TAPAS is:

Available transport infrastructure

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, and
- average speed.

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

- geographical location,
- production, vehicle and storage capacity (see below for more details), and
- loading and unloading durations and costs for each vehicle type.

Available resources

Available resources are vehicles, inventories and production resources, which have these characteristics:

Inventories.

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

Production resources.

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

Transport resources (vehicles).

- initial location,
- type,

- maximum load capacity,
- timetables for certain vehicle types on certain transport links,
- distribution for probability of delay,
- fuel consumption,
- time-based costs (such as driver, capital, and administration),
- distance-based costs (such as vehicle wear and fuel),
- link-based costs, and
- environmental performance (emissions, such as CO_2, SO_2).

Consumer demand

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

Governmental control policies

Besides the input 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). Also, transport infrastructure investments can be studied in TAPAS.

Currently we regard the environmental performance in terms of amount of emissions (e.g., CO_2, SO_2) from transportation, but there are also other negative external effects of transportation, such as road wear, noise, etc. These negative effects can be valued as external costs to facilitate the analysis of both internal and external costs. For instance, if external costs are taken into account, it is possible to study the effects of internalisation of external costs. Estimations of external costs, such as ASEK (SIKA, 2000), ExternE (Bickel et al., 1997) and UNITE (Bossche et al., 2001) are possible to include in simulation experiments. Besides estimations of external costs, time value estimations are often used in macro-level models to include the decrease of product value due to long lead times (e.g., ASEK (SIKA, 2000)). In TAPAS we deal with this problem by introducing a cost (capital cost) based on the product value and the storage interest (possibly including effects of decreased value) which accumulates during transportation.

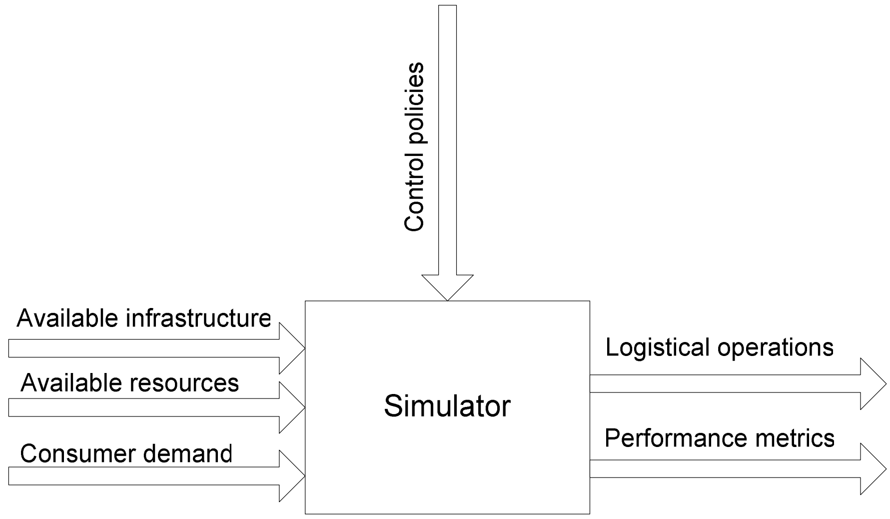

Figure 3.1. Illustration of input and output in the model.

The output from simulation experiments describes the logistical operations, and can for instance be:
- choice of traffic mode,
- choice of vehicle type, and
- route choice.

Moreover, the output can be described as performance metrics, some examples are:
Economical aspects
- costs for different actors (variable and fixed)
- revenues to public authorities

Quality aspects
- reliability of transport alternatives
- lead times
- shortage of products in customer inventory

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

This output will be possible to record for a particular transport chain actor.

4.2 Design and validation of scenarios

Scenarios studied in simulation experiments can be based on different types of sources, for instance, scenarios can be based on real world cases or on statistics of goods flows or combinations, see Figure 3.2. Advantages of real world case studies are that they are closely coupled to the reality and that the cases can be described with lots of details. However, a major disadvantage is that it is difficult to generalise the results from case studies, and often it is difficult to get information of cost parameters from companies since they do not want to reveal cost parameters due to its sensitivity in a competitive situation. Historical data on the other hand is typically easier to acquire, but are problematic to use in scenarios since much details of for instance the characteristics of transport flows are not included.

To facilitate the generalization and validation of the simulation results and to reduce these problems, *typical transport chains* and *typical transport chain actors* which represent transport chains and actors with certain typical characteristics can be defined. The characteristics of the transport chain and its actors influence how it is possible to perform the logistical operations, i.e., the freedoms of actions in the transport chain. The characteristics can for instance concern type of goods, the distance between the producer, the customer and possible intermediate storages, the decision making strategies, the appearance of the transport chain actors within organisations, which may indicate where the dominance of the transport chain is. This would facilitate the analysis and improve the generality of the simulation results since the effects are coupled to certain segments. Today there exist categorisations of goods types (such as the SITC categories (United Nations, 2006), the NST-R commodity groups (European Commission, 2004)), but to better capture characteristics of different transportation segments there is also a need to define typical transport chains and typical actors.

Typical transport chains and actors and their characteristics (as well as data describing them) have been defined by reviewing the literature, making interviews or questionnaires with the industry, and studying existing categorisations. Also the characteristics of the actual decision making of transport chain actors have also been developed by these methods.

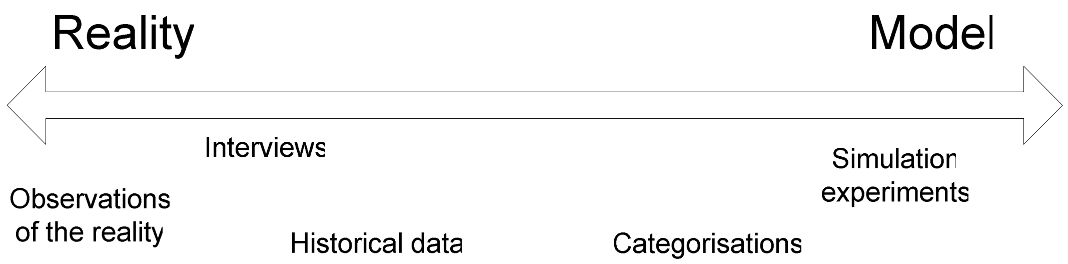

Figure 3.2. Different types of sources which can be used for design of scenarios and validation.

Further validation of TAPAS and simulation results can be based on other studies concerning the mode choice (e.g., (Cullinane and Toy, 2000)). Moreover, simulation experiments with TAPAS can be compared to observations, for instance from actual implementations of a kilometre taxation, such as the one in Germany. Before the introduction of the kilometre taxation in Germany, environmental groups among others wished that there would be a major modal shift for certain road transport volumes as a consequence of the kilometre taxation. However, so far no such effects have been observed. The positive economical and environmental effects that have been observed are connected to a more efficient usage of vehicles in terms of an increased vehicle load utilisation (McKinnon, 2006).

In some Swedish studies where macro-level models have been used, it has been predicted that there will be a modal shift for certain segments as a consequence of an introduction of a kilometre taxation (Swedish Environmental Protection Agency, 2003). However, since it is difficult to accurately capture the behaviour of transport chain actors, it is also possible that there will be the same effects which have been observed in Germany. This example illustrates the difficulty of making predictions with models.

4.3 Context for usage of TAPAS

TAPAS can be used in several contexts. It can be used for analysing breakpoints for when the actors change their decision making of logistical decisions, for instance as a consequence of increased fuel taxes. Examples of breakpoints that can be studied with TAPAS are choice of traffic mode, vehicle type and route. These breakpoints can be determined more accurately than in existing macro-level models, why the breakpoints and its corresponding costs, etc., can possibly be used for achieving more accurate parameter estimates to be used in macro-level models. To make use of such breakpoints, typical transport chains and actors need to be defined which can be used to map actors used in our micro-level model to market segments used in macro-level models.

The scope of such simulation experiments can in its simplest form be a transport chain with only one customer, producer and transport operator, and in a very complex, and not realistic, form include all transports in a country such as Sweden. The scenarios with typical transport chains and actors are probably the most meaningful usage of the model, since this can increase the knowledge for different categories of transport flows. In addition, it is possible for businesses to use TAPAS to determine cost-effective strategies given different (future) scenarios.

5 Basic EastWest Transport Corridor scenario

We have chosen to illustrate the usage of TAPAS with a scenario of a transport corridor between the Baltic States and England. The scenario is a part of a larger transport corridor between China and northern Europe. The transport corridor is interesting since it is possible that larger goods volumes will be transported via the Trans-Siberian railway, instead of with container ships directly from China to northern Europe which is currently the most common way. It is also interesting to predict and influence the mode and route choices made in the corridor from a regional perspective.

In this section the scenario design will be described followed by the simulation results and the analysis of the results.

5.1 Scenario design

The scenario consists of several possible transport alternatives for transportation of TEU (20 ft) containers from Kaunas in Lituania to Harwich in England. The transport links considered are:

- Rail transport from Kaunas to Klaipeda.
- Road transport from Kaunas to Esbjerg.
- 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 Harwich.

See Figure 4.1 for a rough illustration of the transport alternatives in the scenario.

Figure 4.1. Illustration of transport alternatives in the scenario, as well as in the EastWest Transport Corridor project (based on Sakalys (2006)).

Route 1 train – ferry – train – ferry

Route 2 train – ferry – truck – ferry

Route 3 truck – ferry

The containers contain goods with medium value, such as furniture or kitchen appliances. The producer is assumed to be located in Kaunas, and the customer is assumed to be located in Harwich, where there is a customer inventory.

In general, we have tried to use real world data from companies which possibly can use the corridor as much as possible, but when it has not been possible we have used some of the data from a study called the Scandic Bridge pre-study made on 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 from the Scandic Bridge study when we have not been able to find data.

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 probability distribution, of which the customer has access. The probability distribution used here is a Poisson distribution. The customer makes request of 1, 2 or 3 TEU, and when it has received the proposals, it chooses the cheapest feasible alternative based on transport costs as well as on the capital costs which are proportional to the transport time. Hence the consignment size is not fixed. See Holmgren et al. (2007) for further details.

- *Timetables*. In the scenario the trains and ships are transported according to timetables, while trucks not are restricted to timetables.
- *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 EastWest 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/) and (Ministry of Finance, 2004). We assume that all costs which occur from production to consumption are taken by the customer. See Section 3.1 for description of the cost parameters. 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 a train or a ship transport to the cargo, we take the proportion in weight of the consignment of the estimated average 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 partly 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 driverless trailer chassis.
- *Train transport*. 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.
- *Simulation length*. The simulation length is 25 000 cycles where one cycle represents 30 minutes.

The assumptions above represent the base case. In the simulation experiments we would like to study an introduction of a kilometre taxation on trucks in Sweden and its effects. The tax levels that we are examining are the most current levels suggested by SIKA (2007). 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. Different types of implementations are represented in the cases that are studied:

- Case 0. Current situation, no kilometre taxation and diesel taxation as today (0,36 euro/l).

- Case 1. A high kilometre tax as suggested by SIKA. Differentiation. Diesel taxation is lowered to the minimum level within EU (0,30 euro/l). Marginal cost principle as defined by SIKA is assumed.
- Case 2. A low kilometre tax as suggested by SIKA. Differentiation. Diesel taxation remains as it is today. Marginal cost principle as defined by SIKA is assumed.
- Case 3. The same average level of kilometre taxation is assumed for all vehicle types and euro classes. Diesel taxation is lowered to the minimum level within EU (0,30 euro/l).
- Case 4. A high kilometre tax as suggested by SIKA, including differentiation, but without compensation, i.e., current level of the diesel taxation.

Below some of the input data is given in the tables 4.1-4.4.

	Link 1	**Link 2**	**Link 3**	**Link 4**	**Link 5**
Nodes	Kaunas-Klaipeda	Klaipeda-Karlshamn	Karlshamn-Esbjerg	Kaunas-Esbjerg	Esbjerg-Harwich
Modes	Rail	Sea	Road, rail	Road	Sea
Length (km)	240	537	487, 517	1562	648
Av. speed (km/h)	19	37	78, 18	70	37

Table 4.1. Input data for the links.

	Truck Link 3 1TEU	Truck Link 3 2TEU	Truck Link 3 3TEU	Truck Link 4 1TEU	Truck Link4 2TEU	Train Link 1	Train Link 3	Ferry Link 2	Ferry Link 2
Capacity (TEU)	1	2	3	1	2	50	22	374	374
Av. vehicle util.						50%	50%	88%	88%
Max speed (km/h)	90	90	90	90	90	60	60	45	45
Time-based cost (euro/h)	40	40	40	40	40	18	18	1860	1860
Distance-based cost (euro/km per TEU)	0,68	0,39	0,32	0,56	0,31	0,01	0,39	0,64	0,51
CO_2 (g/km/TEU)	675	444	406	691	440	111	109	680	680
Km tax, case 1	0,14	0,15	0,16						
Km tax, case 2	0,11	0,12	0,12						
Km tax, case 3	0,16	0,16	0,16						
Km tax, case 4	0,14	0,15	0,16						

Table 4.2. Input data for the vehicle types.

	Node
Loading/unloading cost (euro/min)	0,39
Loading/unloading time (min/unit)	60
Preparation loading/unloading time (min/unit	60

Tabell 4.3. Loading and unloading cost and times. Costs and times are assumed to be the same for all different transport modes.

	1 TEU
Weight (tons)	11
Product value (euro)	20 000
Storage interest	0

Table 4.4. Assumptions of the transported units, one TEU container.

5.2 *Simulation results*

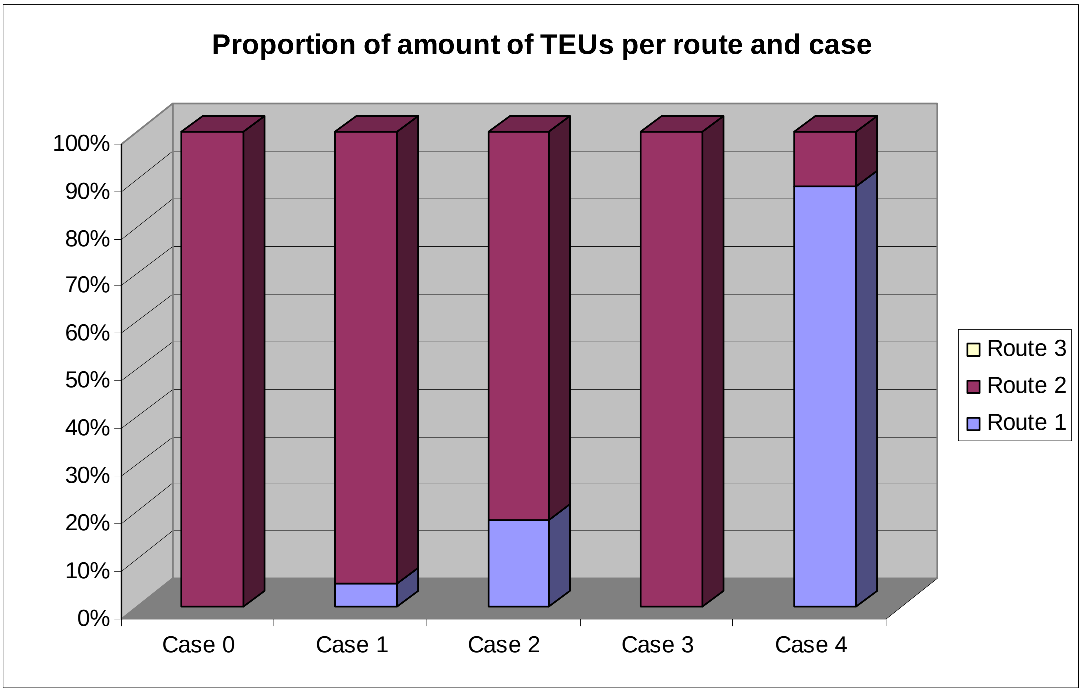

Figure 4.2. Proportion of TEUs per route and case.

From the simulation experiments it is possible to see the breakpoints concerning choice of traffic mode, truck type, transport route as well as the size of the consignments. Also, performance metrics in terms of for instance amount of emissions, the total costs, and the tax income to the public authorities. The simulation results show that the largest modal split from truck to train on the link between Karlshamn and Esbjerg is for Case 4 which has the largest amount of taxes for the transport chain actors. This corresponds to a change of the route choice (Figure 4.2).

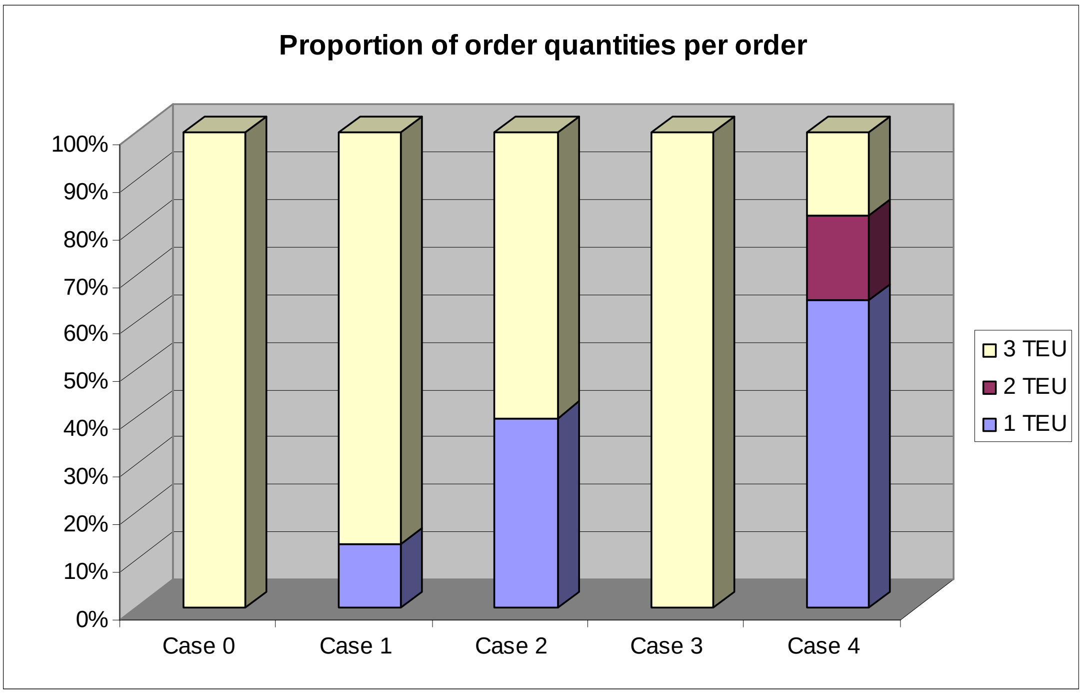

Figure 4.3. Proportion of orders per order size and case.

Another effect which can be observed is that the order quantities vary in the different cases. In Case 4 where train transports between Karlshamn and Esbjerg mainly is used, the order quantities are mostly 1 (Figure 4.3). The reason for this is probably that the cost per TEU for the customer is lower when choosing to have three containers on a large truck, while the costs per container for all order quantities are equal for the train alternative between Karlshamn and Esbjerg.

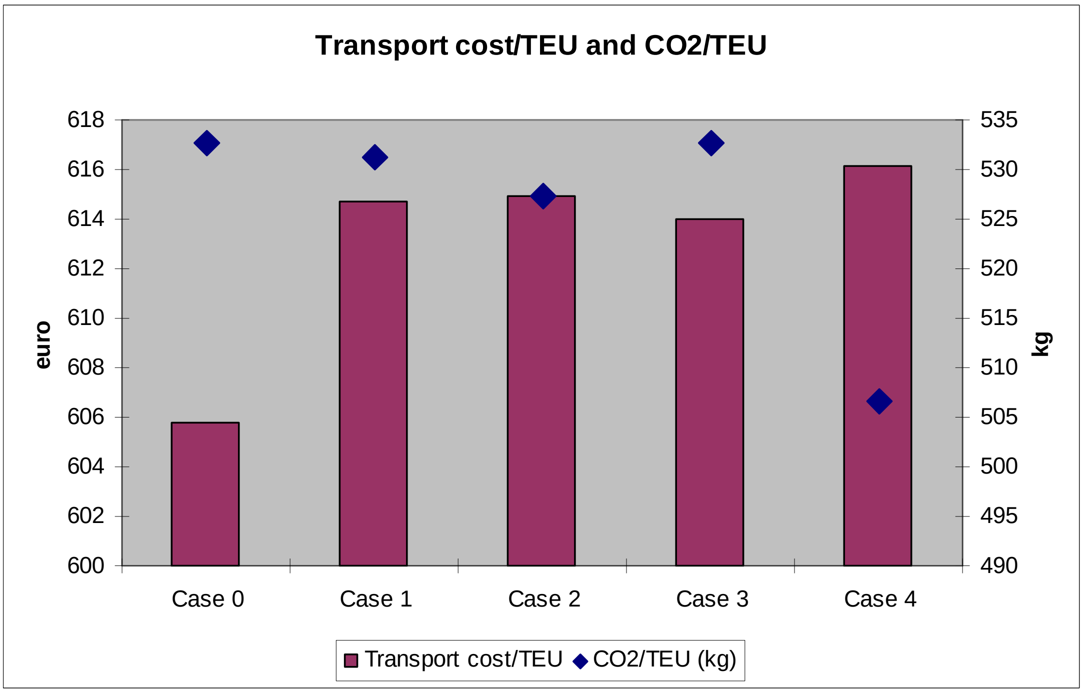

Figure 4.4. Transport costs (euro) per TEU for the customer per case and CO_2 per TEU.

In Figure 4.4 the transport costs per TEU for the customer and the amount of CO_2 per TEU are illustrated. The highest costs for the customer appear with the highest taxation, while the lowest costs appear for the current situation with no kilometre taxation. If delays from the planned arrival time to the customer occur, a delay cost will occur in terms of larger time costs. However, in these simulation experiments no delays occur. Concerning the environmental performance in terms of CO_2, as expected, the lowest amount of CO_2 appears in Case 4 where train is used more frequently instead of truck (which also is the case where the transport cost is the highest).

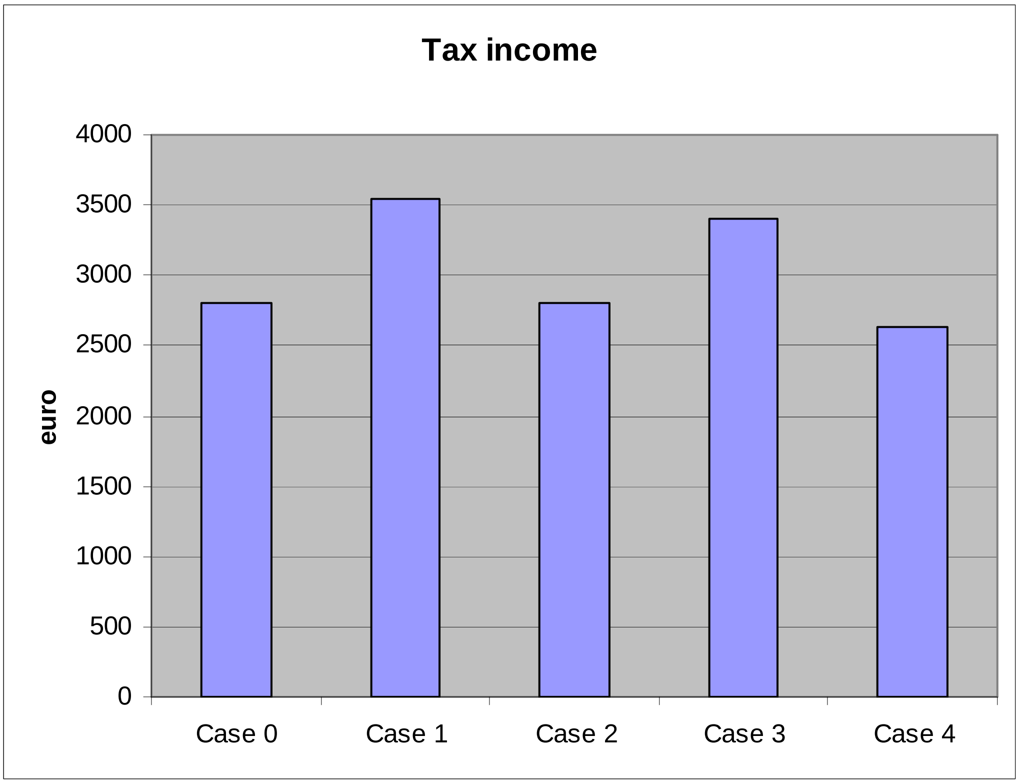

Figure 4.5. Total taxes for the public authorities in Sweden.

In Figure 4.5 the tax income (kilometre and diesel tax) to the public authorities in Sweden is illustrated. The lowest tax income occurs when there are fewer truck transports due to a large modal split to train transports.

5.3 Analysis

The simulation experiments and results presented in the previous section have shown that it is possible to observe several effects of an introduction of a kilometre taxation, e.g., concerning order quantity, mode choice, route choice, etc. However, there is a need to analyse the simulation results in more depth, as well as to validate the results more. For instance, the simulation results concerning emissions and time issues will be compared to the results from the Scandic Bridge study. The comparison will mainly show if the results are reasonable or not, since not exactly the same data is used, and if TAPAS behaves as it is supposed to or not. Moreover, the results will also be validated with companies, public authorities, and academia in the EastWest Transport Corridor project to make sure that they regard the result as reasonable, especially the cost assumptions and the results in monetary terms. The simulation study also needs to be extended to also include confidence analysis for a number of parameters.

Other issues that are interesting in the EastWest scenario are:
- Changes in prerequisites for the transport chain actors in terms of lower costs and times in nodes. The price sensitiveness of the actors is interesting to study.
- Different aspects of demand and consumption, e.g., a changed demand distribution are relevant to study, as well as different settings of the ordering and consumption behaviour.
- The importance of the storage interest and product value.

The effects of more synchronized timetables are also of interest to examine, as well as more frequent timetables. The more synchronized the timetables are, the shorter will the overall transport time be.

There are different vehicle 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 to the Swedish level, i.e., maximum 60 tons.

In the scenario we have for instance included the following aspects (or functionalities of TAPAS):
- Intermodal transportation, i.e., transportation with several traffic modes with the same load carrier. Also, changes between vehicles types with the same traffic modes are possible.
- Restrictions of vehicle capacities.
- Loading/reloading.
- Timetabled as well as non-timetabled (demand driven) transports.
- Time window for delivery.

Another aspect, which is possible to include, but has not been included in the current scenario is different types of roads. Road types can for instance be rural and urban roads and roads with different maximum speed.

6 Extended EastWest Transport Corridor scenario

We have implemented an extended scenario in which the following nodes are added:
- producer in Shanghai
- producer in Odessa
- terminal/hub in Fredericia
- terminal/hub in Vladivostok/Nakhodka/Vostochnyy
- terminal/hub in Kaunas (no longer producer!)

and links:
- ferry between Shanghai and Vladivostok
- train between Vladivostok and Kaunas/Klaipeda
- ferry between Shanghai and Felixstowe
- train between Odessa and Kaunas/Klaipeda
- ferry between Klaipeda and Fredericia
- truck between Fredericia and Esbjerg
- ferry between Odessa and Harwich/Felixstowe

A number of different measures to increase the competitiveness of the corridor was evaluated.

6.1 Scenario design

In the first simulation study we assume that the production is taking place in Shanghai. In this case, the relevant transport network is illustrated in Figure 5.1.

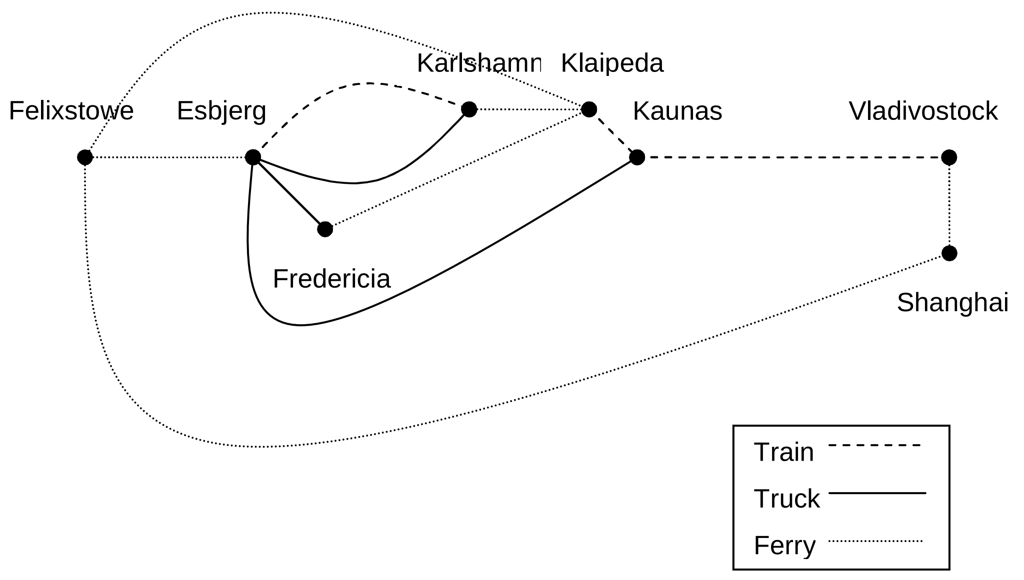

Figure 5.1. The extended scenario (Shanghai).

Thus, in this case there are six transport alternatives, or routes:

1. Shanghai (ship) Harwich/Felixstowe
2. Shanghai (ship) Vladivostok (train) Kaunas (truck) Esbjerg (ferry) Felixstowe
3. Shanghai (ship) Vladivostok (train) Kaunas (train) Klaipeda (ferry) Karlshamn (train) Taulov (train) Esbjerg (ferry) Felixstowe
4. Shanghai (ship) Vladivostok (train) Kaunas (train) Klaipeda (ferry) Karlshamn (truck) Esbjerg (ferry) Felixstowe
5. Shanghai (ship) Vladivostok (train) Kaunas (train) Klaipeda (ferry) Felixstowe
6. Shanghai (ship) Vladivostok (train) Kaunas (train) Klaipeda (ferry) Fredericia (truck) Esbjerg (ferry) Felixstowe

In the second study we assume that the producer is situated in Odessa, see Figure 5.2.

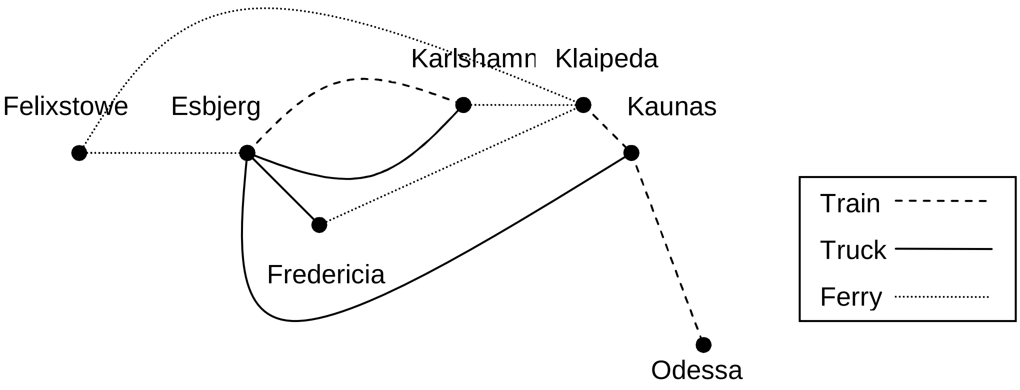

Figure 5.2. The extended scenario (Odessa).

Thus, in this case there are six transport alternatives, or routes:

7. Odessa (train) Kaunas (truck) Esbjerg (ferry) Harwich/Felixstowe
8. Odessa (train) Kaunas (train) Klaipeda (ferry) Karlshamn (train) Taulov (train) Esbjerg (ferry) Harwich/Felixstowe
9. Odessa (train) Kaunas (train) Klaipeda (ferry) Karlshamn (truck) Esbjerg (ferry) Harwich/Felixstowe
10. Odessa (train) Kaunas (train) Klaipeda (ferry) Harwich/Felixstowe
11. Odessa (train) Kaunas (train) Klaipeda (ferry) Fredericia (truck) Esbjerg (ferry) Harwich/Felixstowe

The timetables used in the scenario are based on real world timetables when possible (see Appendix for timetables and other data describing the links).

The train transports in Sweden occur mainly during night. The speed in Denmark during the day is slower than the transports during night in Sweden. Electrical trains are assumed from Vladivostok to Kaunas and Klaipeda. Electrical trains are used from Karlshamn to Taulov, and from Taulov to Esbjerg diesel trains are used. We assume a rather low speed for truck transport from Kaunas to Esbjerg since it includes resting times for the driver (as indicated by Tomas Petterson, FoodTankers) to reflect existing regulations. Diesel trains are assumed from Odessa to Kaunas and Klaipeda. More details on the vehicles can be found in the Appendix.

The principle used for modelling the production is make-to-order. (The production lead-time however is assumed to be rather short, less than a day.) We study two types of products, one with rather high product value (e.g., computers) which is 100000 €/kg, and one with a lower value (e.g. furniture) which is 20000 €/kg. For 1 TEU (39 m^3) the weight is the same, 11 tons, as well as the storage interest rate, which is 0,10% per day of the product value. The assumed/acceptable lead time also differs, it is 40 day for the lower value products and 31 days for the higher value products.

For both product types, the amount of TEUs consumed is assumed to be on average 2 TEUs every fourth day. However, the consumption takes place in a stochastic manner. There is an ordering opportunity for the customer every day. The ordering is based on the EOQ principles where an optimal ordering quantity is searched for (Holmgren, 2007). The safety stock level in the customer storage is 20 TEUs in the beginning of the simulation. The maximum stock level is 40 TEU.

The simulation experiments are run for 10 000 cycles, where one cycle corresponds to 30 minutes.

We examine four different measures to improve the competitiveness of the EastWest transport corridor, i.e., the transport alternative from Klaipeda-Karlshamn-Esbjerg-Felixstowe, when the producer is located in Shanghai.

- *Measure 1* (M1) Increase the frequency of departures (trains and ferries) for the links between Klaipeda and Karlshamn, Karlshamn and Esbjerg, and Esbjerg and England so that there is a departure each day.
- *Measure 2* (M2) The speed of the ferries and trains on the above links is increased. Fast ferries are assumed to be used between Klaipeda and Karlshamn, and Esbjerg and England. This implies higher fuel consumption. The freight trains between Karlshamn and Esbjerg are assumed to be given a higher priorities why a higher speed can be used. Moreover, the timetables are better synchronized to fasten the transport time in the EastWest transport corridor.
- *Measure 3* (M3) Shorter times in the nodes are assumed, for instance due to port infrastructure investments. The fixed loading and unloading times in the nodes are here assumed to be 30 min, instead of 150 minutes. Moreover, the customs time is assumed to be shorter when the train is leaving Russia. This will imply that the transport times for the train transport between Vladivostok and Kaunas/Klaipeda is shortened. Customs is modelled as a short link in Vladivostok and Kaunas. In the base case the customs takes three days when passing a Russian border. In the base case the customs is assumed to take three days when passing the Russian border, while in this measure the customs time is assumed to be one day instead. The timetables are also adjusted after these new prerequisites.
- *Measure 4* (M4) Measure 4 is based on Measure 3, but a kilometre tax is also added on trucks when using the roads in Sweden. The implementation is the same as the one in Case 4 in the kilometre taxation study in Section 4 above, i.e., a high kilometre tax and the current diesel tax.

6.2 Simulation results

First the simulation results of the scenario with a producer in Shanghai are studied, followed by the results of a producer in Odessa.

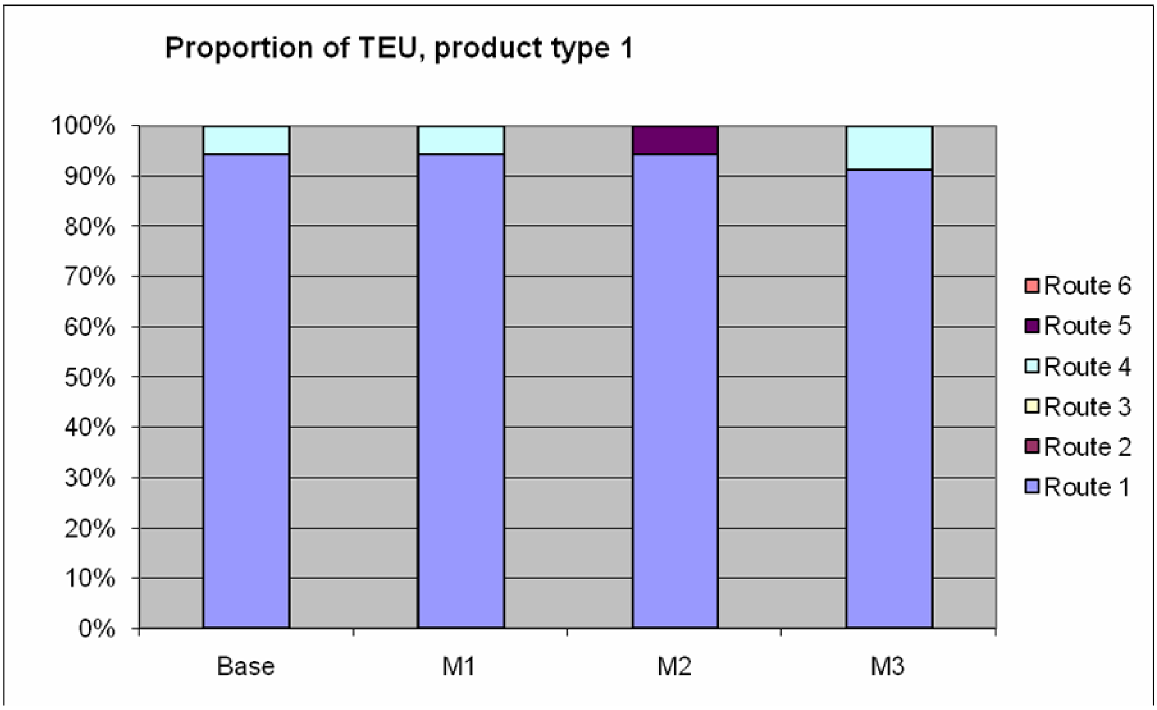

Table 5.1. Proportion of TEU for product type 1.

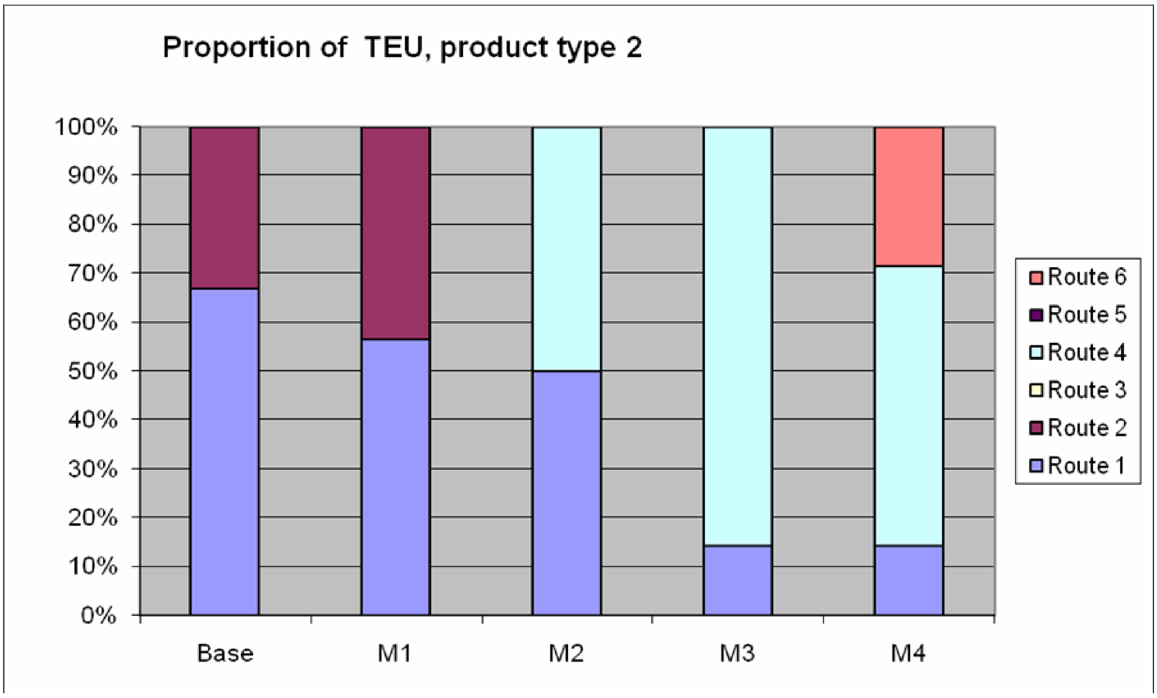

Table 5.2. Proportion of TEU for product type 2.

In the tables above the proportion of TEUs per route and case is illustrated. In the base case the direct transport with container ship is dominating (Route 1). This reflects the real world situation rather well since container ships mainly are used today for transportation from China to northern Europe.

The results reflect that time is valued higher for transportation of product type 2 than transportation of product type 1 since this product type is more sensitive to changes in transport times and transport frequencies. Faster transport alternatives are mainly chosen.

For transportation of product type 1, only Measure 3 slightly reduces the amount of containers transported directly to the customer. For transportation of product type 2, Measure 3 (and of course Measure 4) also has the largest effect on reducing the amount of containers transported directly to the customer.

When a kilometre tax is introduced on trucks in Sweden (the same implementation as Case 4 in the kilometre study in Section 4), a change in route choice appears. Route 4 is still chosen for most of the containers, but Route 6 is also chosen.

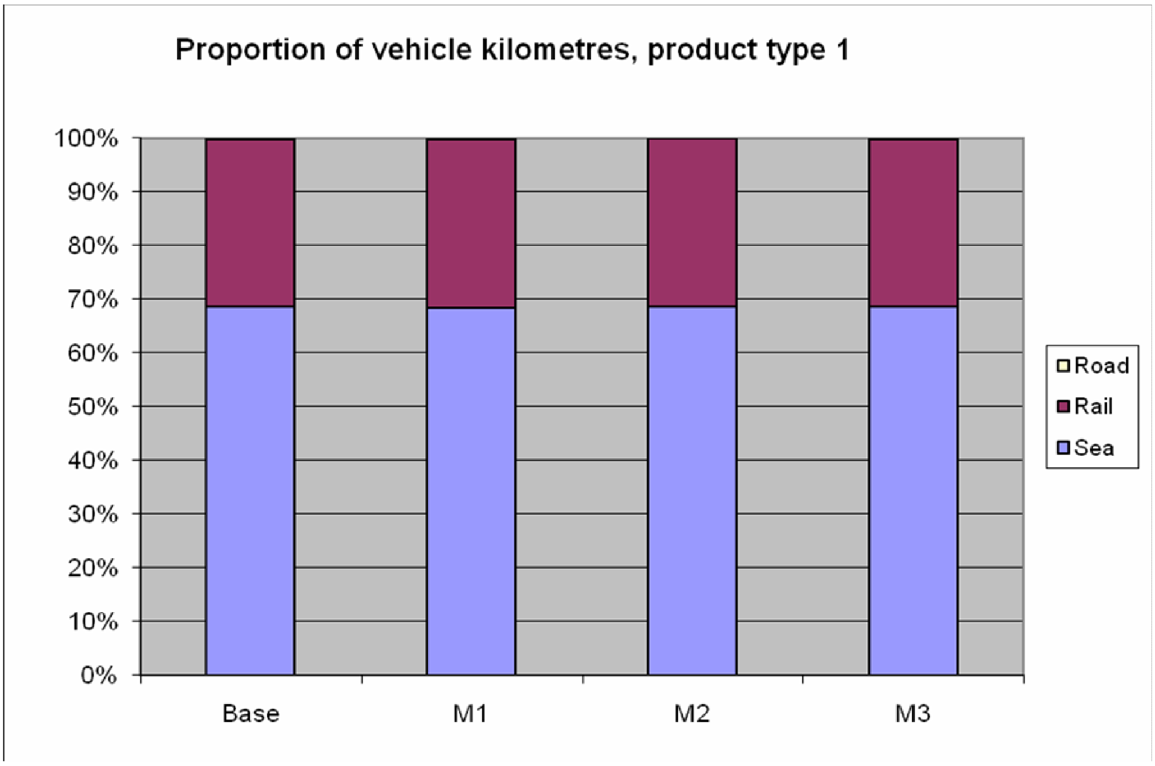

Table 5.3. Proportion of vehicle kilometers per mode for product type 1.

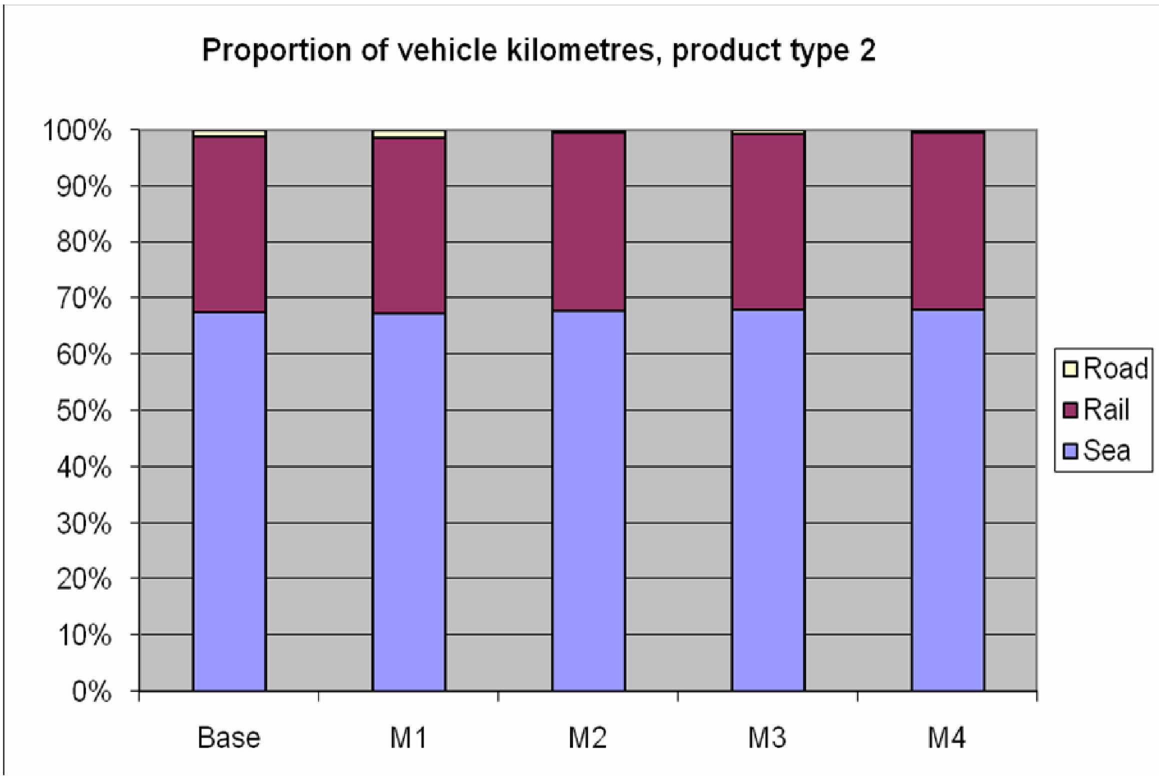

Table 5.4. Proportion of vehicle kilometres per mode for product type 2.

Table 5.3 and 5.4 above illustrate the modal split (based on vehicle kilometres). Of course, the largest amounts of vehicle kilometres are sea and rail due to the long distance from China to Europe, the vehicle kilometres transported in Europe are rather few when regarding the whole transport chain.

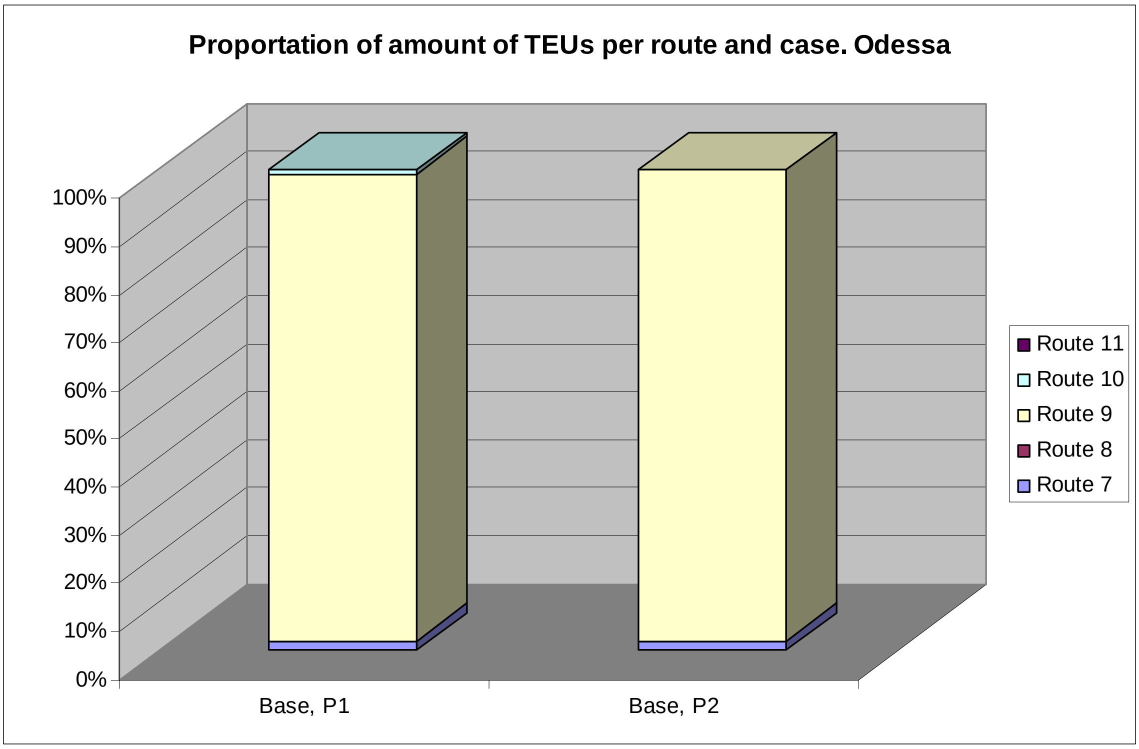

Table 5.7. Proportion of amount of TEUs for the Odessa scenario.

In the Odessa scenario it is not possible with direct transport with container ship, so instead the largest amounts of containers are transported with Route 9, i.e., with truck from Kaunas to Esbjerg.

6.3 Analysis

From the simulation experiments of the extended scenario it has been shown that it is possible to make use of TAPAS for a more complex scenario of a long transport chain. Moreover, we have shown that it is possible to make use of TAPAS when studying different product types with different characteristics regarding product value and time requirements (lead time). The simulation results illustrate that the transport alternative choice differ for different product types.

Of course there are several other measures which are interesting to study in order to make the EastWest transport corridor more competitive, for instance by increasing the frequency of the trains in the Transsiberian railway. In order to get transportation by train in the corridor it is probably necessary to adjust the cost parameters for the transport alternatives. Also, it would be interesting to study the effects of a combination of measures.

More validation of the results are necessary, for instance by the partners in the EastWest project and by other experts. Sensitivity analysis is also important to perform to distiguish how reliable the results are. For instance the importance of the lead time is interesting to further study.

7 Conclusions and Future work

We have discussed the usability of TAPAS in general terms and the usage of the model has been illustrated with simulation experiments. It should be noted that these experiments illustrate the possible usage of TAPAS, rather than provide trustworthy figures on which to base important decisions. Further verification and validation of TAPAS and its input are necessary before this step can be taken.

So far the decision making of the transport chain actors are only based on cost aspects. Since time-based costs are included, speed and frequency are accounted for. However, for real world transport chain actors, other parameters also have an important influence on the logistical decision making. Examples of other parameters except cost which have an important influence are network coverage, reliability, as well as current co-operations. These parameters could be captured in different ways, e.g., in monetary terms. Further, the EastWest projects partners have validated that environmental performance is a relevant performance indicator.

As pointed out in the paper, TAPAS has many advantages to current macro-level models. However, due to the micro-level approach, TAPAS requires large amounts of data which is problematic when a large system is simulated and large amounts of data need to be collected. When the simulated system is large, the complexity increases and complicates the validation of the simulation results. Moreover, the categorisation of typical transport chains, products, and actors are important to be able to generalise the results from simulation experiments.

Future studies related to the East West TC includes simulation experiments on import/export to/from Sweden/Denmark/Lithuania that complement the transit transport studies performed, as well as, larger simulation experiments to further verify of the results, including statistical sensitivity tests, etc.

Further work with the usage of TAPAS may include estimations of external costs to be able to compare external costs to internal costs, and to study issues of internalisation of external costs. Moreover, cost parameters that could be interesting to include as input in a later version of TAPAS are fixed costs, such as vehicle taxation. Then long term issues such as investment decisions can be studied.

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9 Appendix

Link	Link 1,2	Link 3,4	Link 5,6	Link 7,8	Link 9,10	Link 11,12	Link 13,14
Nodes	Vladivostok, Kaunas	Shanghai, Vladivostok	Kaunas, Klaipeda	Taulov, Esbjerg	Kaunas, Esbjerg	Klaipeda, Karlshamn	Karlshamn, Esbjerg
Mode	Rail	Sea	Rail	Rail-diesel	Road	Sea	Road
Length (km)	10760	1500	240	81	1562	537	487
Average speed (km/h)	19	31	19	18	36	36	63
Administrative order cost	7	7	7	0	7	7	7

	Link 15,16	Link 17,18	Link 19,20	Link 21,22	Link 23,24	Link 27,28	Link 29,30
Nodes	Karlshamn, Taulov	Esbjerg, England	Klaipeda, Fredericia	Fredericia, Esbjerg	Odessa, Kaunas	Shanghai, England	Klaipeda, Harwich
Mode	Rail	Sea	Sea	Road	Rail	Sea	Sea
Length (km)	436	648	900	95	1494	15000	1950
Average speed (km/h)	55	39	33	63	37	21	36
Administrative order cost	7	7	7	7	7	7	7

Links (timetable)				
Nodes	Vladivostok, Kaunas	Shanghai, Vladivostok	Kaunas, Klaipeda (via Transsib)	Klaipeda, Karlshamn
Mode	Rail	Sea	Rail	Sea
Timetables, freq.	1/week	1/week	1/week	6/week
Trp time	23 d			
Departure	Mon, kl 00.01 (min 1)	Sat, min 480	Wed, min 1000	Day1, min 1080*
Arrival	Wed, min 600	Mon, min 480	Thur, min 400	Day2, min 540

Links (timetable)				
Nodes	Karlshamn, Taulov	Taulov, Esbjerg	Esbjerg, England	Klaipeda, Fredericia
Mode	Rail	Rail-diesel	Sea	Sea
Timetables, freq.	3/week	7/week	3/week	2/week
Trp time				
Departure	Sun (Tue, Thu), 1320	Day1, 495	Tue (Thu, Sat), min 1125	Thur, min 720 (Sun, min 1200)
Arrival	Mon (Wed, Fri),	Day1, 765	Wed (Fri, Sun),	Fri, min 1110 (Tue, min

	360		780*	360)

Links (timetable)				
Nodes	Odessa, Kaunas	Kaunas, Klaipeda (fr Odessa)	Shanghai, England	Klaipeda, Harwich
Mode	Rail	Rail	Sea	Sea
Timetables, freq.	1/week	1/week	1/week	2/week
Trp time			30 d	
Departure	Mon, min 55	Tue, min 1080	Sun, min 1200	Thu (+Sun), min 720,
Arrival	Tue, min 900	Wed, min 514	Fri, min 840	Sat (+Tue), 432

Vehicle									
Description	Container ship	Container ship	Ferry RoRo	Ferry RoRo	Ferry RoRo	Ferry RoRo	Train el. large	Train diesel large	Train el. Smaller
Used on link	27,28	3.4	11.12	17.18	19,20	29,30	1,2,5,6	23,24,5,6	15.16
Vehicle types	1	2	3	3	3	3	4	5	6
Capacity (TEU)	5280	3440	374	374	374	374	50	50	22
Av. vehicle utilization	0.8	0.8	0.88	0.88	0.88	0.88	0.5	0.5	0.5
Time-based cost (euro/h)	5400	1860	1860	1860	1860	1860	24	30	7.2
Distance-based cost (euro/km)	925	636	197	160	180	180	3.3	6.4	16
Distance-based cost (euro/km per TEU)	0.175	0.185	0.527	0.428	0.481	0.481	0.066	0.128	0.727

Vehicle										
Description	Train dieseL	Truck 1 TEU	Truck 2 TEU	Truck 3 TEU	Truck 1 TEU	Truck 2 TEU	Truck 1 TEU	Truck 2 TEU	Truck 3 TEU	Train diesel
Used on link	7.8	13.14	13.14	13.14	9,10	9,10	21.22	21.22	21.22	7.8
Vehicle types	7	8	9	10	8	9	8	9	10	7
Capacity (TEU)	22	1	2	3	1	2				22
Av. vehicle utilization	0.5									0.5
Time-based cost (euro/h)	7.2	39.72	39.72	39.72	39.72	39.72	39.72	39.72	39.72	7.2
Distance-based cost	21	0.68	0.79	0.95	0.67	0.78	0.62	0.72	0.85	21

(euro/km)										
Distance-based cost (euro/km per TEU)	1									1

	Node
Loading/Unloading cost (euro/min)	0.39
Fixed loading/unloading time (min)	150
Variable loading/unloading time (min)	1

Partners of East West TC

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Aerotech Telub
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County Administrative Board of Blekinge
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Klaipeda University
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Municipality of Karlskrona
Municipality of Klaipeda
Municipality of Sölvesborgs
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