ESTIMATING IMPACT OF TRANSPORT POLICIES ON MOTORWAYS OF THE SEA PROJECTS

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ABSTRACT

The main objective of the Motorways of the Sea (MoS) projects is to develop high quality maritime-based intermodal links to bypass congested land transport corridors so that they can provide an alternate competitive means of transport to unimodal road freight transport. The MoS projects are a political initiative of the European Commission (EC) but require the participation of private and public stakeholders. EC has proposed a number of policy measures to promote Motorways of the Sea projects. The need of the hour is to estimate the impact of the proposed policy actions on the performance of the Motorways of the Sea in order to develop effective set of policies to promote MoS on the selected transport corridors.

Conventional modeling techniques in Transport policy analysis have used macro-economic modeling techniques. Since freight transport service choice decisions are taken at Company level we argue that micro simulation using an Agent based modeling framework will provide a better framework for Transport policy analysis. We demonstrate that Agent based modeling and simulation is an effective tool to explicitly simulate the dynamics of transport service choice decision making at the operational level and Transport policy decision making at strategic level in the same model. The validation and flexibility of the developed Agent based model is illustrated by presenting a case study in the Atlantic maritime.

Simulation results indicate that policy measures that improve efficiency of MoS services are not sufficient to improve market share of MoS services in the Atlantic corridor. These measures must be supported by uniform rules and stricter enforcement of International road freight transport regulations for the success of MoS projects.

Keywords: Short Sea Shipping, modal competition, Motorways of the Sea concept, intermodal transport, International road freight transport

INTRODUCTION

With the establishment of the European single market in the early 1990s, European freight transport volumes have witnessed a sharp increase for more than a decade. If nothing is done, total European road freight volumes were forecast (before the economic crisis of 2008-09) to grow by about 60% or an additional 20.5 billion tone-km across the EU-25 (Baird 2007). To cope with this demand for freight transport, one of the proposed policy measures introduced in the European Commission's 2001 White Paper was to develop Motorways of the Sea projects as an alternative to long distance road haulage (EC 2001).

The main objective of the Motorways of the Sea (MoS) projects is to develop high quality maritime-based intermodal links to bypass congested land transport corridors so that they can provide an alternate competitive means of transport to unimodal road freight transport (EC 2001). The MoS projects are a political initiative of the European Commission (EC) but require the participation of private and public stakeholders. EC has proposed a number of policy measures to promote Motorways of the Sea projects. The need of the hour is to estimate the impact of the proposed policy actions on the performance of the Motorways of the Sea in order to develop effective set of policies to promote MoS on the selected transport corridors and induce modal shift.

There are a limited number of approaches available for assessing the impact of policy actions for modal shift in freight transport (Tsamboulas, Vrenken et al. 2007). Traditional transport models form a part of the aggregate 4-step modeling framework. The behavior oriented approaches within the aggregate 4-step framework is in transport mode choice (Liedtke 2009). Policy measures that affect behavior of agents such a shift to other carriers, pricing or transport capacity addition cannot be captured by these models. Instead additional assumptions regarding the reactions of shippers and carriers to a specific policy measure must be fed ex-post into the model steps of a 4 step modeling framework. This could result in consistency violations leading to unrealistic demand elasticities of transportation time and cost (Oppenheim N. 1995).

Other freight transport mode choice approaches are either based on network analysis Swedish Model or more recently on the concept of business logistics that place attention to all costs of the supply chain (SAMPLAN 2001; Blauwens, Vandaele et al. 2006). In the network analysis approach, modes and routes that minimize generalized transport cost on the networks are identified. Because of the strategic interactions between shippers and carriers in the market, shippers and carrier decisions in a transport system sometimes react in a way which cannot be predicted by generalized costs alone. Hence, network analysis approaches are unable to include specific properties of individual transport chains in their models i.e. they do not take the behavioral aspect of transport choice at Company level where the decisions regarding the actual transportation are made.

An alternative to the above are micro simulation models based on bottom-up approach. In this approach heterogeneous actors are created and equipped with behavior and interaction rules. In agent based models, these rules could either be implemented as properties of the actors generated by random drawings, in the case of available data, or by decision making algorithms.

We believe that micro-level models that explicitly simulate company level strategies (pricing and allocation of capacity) and interactions between the transport users and service providers will be able to deliver predictions that are more precise on the impact of policy implementation on the feasibility of Motorways of the Sea projects. Agent-based modeling provides us the necessary framework and flexibility to create micro-level simulation. Agent based models simulating transport chains have focused on the logistical aspects of transport users such as choice ordering strategies, planning of logistical chains, cost minimization of logistical chains while market prices and service quality (in terms of delivery times and delays) of transport services assumed to be pre-determined (Davidsson, Henesey et al. 2005).

The TAPAS model developed in the INNOVA project used micro-level models focusing on specific transport chains to study the behavior of logistics/product groups instead of the traditional macro-level modeling approach in order to better understand the behaviour of those groups to different policy measures (Ramstedt 2008). Transport demand agents in TAPAS model focused on cost minimization of the full logistics chain by dynamically altering order size, frequency of shipments and selection of the type of vehicles. The dynamic altering of service price and service capacity by supply side agents to the demand for transport on the modal split of intermodal transport has not been explored so far. The attempt in our model is to focus on this aspect of the freight transport system and better understand the MoS market share of different policy measures.

Another micro-simulation model mapped tours of commercial vehicles in Calgary (Hunt and Stefan 2007). This model generated tours at the zonal level and then mapped the complex execution of tours in the city. At each stop, the next destination and stop duration was simulated by random choice. The parameters of the model covering sectoral, temporal and spatial dimensions were estimated using an extensive survey data of 37,000 tours and 185,000 trips.

(Liedtke 2009) developed an agent based approach to commodity transport modeling that assessed the effects of behaviour oriented transport policy measures while taking complex logistics reaction patterns into account. The behavior of individual actors was simulated using normative logistics models and accumulated market knowledge. Using bottom up approach, the model replicated interaction between shippers and carriers through simulated auctions of transport contracts resulting in tour generation.

This paper presents a brief technical description of the inter-regional freight transport market model that was developed as a decision making tool for micro-level simulation of modal competition between intermodal transport based on Motorways of the Sea and unimodal road transport on an inter-urban freight transport corridor. In this model, the individual actors of a transport chain such as producers and transport operators are modeled explicitly. The model replicates the complexity of transport choice and physical movement of loading units from origin to destination taking into account the market service price dynamics depending upon the supply-demand mechanisms. This makes the model more powerful than traditional approaches to transport simulation. Unlike traditional approaches that rely on assumed statistical correlations between different parameters, the developed agent based model is able to capture the dynamic interactions between individual actors as well as their heterogeneous activities and decision-making behaviours. In addition, this model is able to capture time aspects, such as the effects of ships' timetables, arrival times and time-differentiated costs and prices. To bring the model closer to reality, the model assumes stochasticity in transport demand, delays and damage.

The model can act as a decision support tool to give policy makers indications on the impact of policy actions on the market share of Motorways of the Sea and hence the feasibility of this service on specific transport corridors.

We illustrate the use of the model by describing a case study to predict the effects of 4 different policy measures – Interconnectivity, Port Liberalization and Customs Simplification, Internalization of External Costs and Harmonization of Road Regulations. Another possible application of the model is in assisting companies in making strategic decisions like adaptation of vehicle fleet to stochastic demand, ship service frequency and feasibility of participating in a transport corridor.

In the next section, we describe the model, which is followed by some reflections on its implementation and validation. Then a case study is described and finally conclusions are presented together with suggestions for future improvements.

DESCRIPTION OF THE SIMULATION MODEL

The developed agent based model simulates trade and transport between two regions connected by road and maritime-based intermodal transport infrastructure. A discrete number of transport users (Shippers, Logistics Companies, Forwarders) are assumed located in each of the Regions that hire transport for movement of their individual shipments to a destination in the other modeled region. A number of International Road Haulage Companies and a single maritime-based intermodal service provider are modeled as competitors in this corridor vying for contracts with transport users.

In general, transport users (Shippers/Forwarders/Logistics Companies) are assumed rational decision makers in the selection of transport services in the market. Transport services are contracted in the market depending on which service provider is offering highest utility to the customer based on the criteria of price, delivery time, expected delays and probability of damage. Service contracts vary from decision maker to decision maker. We assume a pre-determined transport demand but the frequency and time of shipment generation vary from one transport user to the other.

The simulation model uses a three-layered architecture – Regulatory, Market and Physical Layers (See **Error! Reference source not found.**). They are briefly discussed in the following sub-sections. All the three layers are interconnected such that decisions taken by agents in each layer influence actions in the other layers.

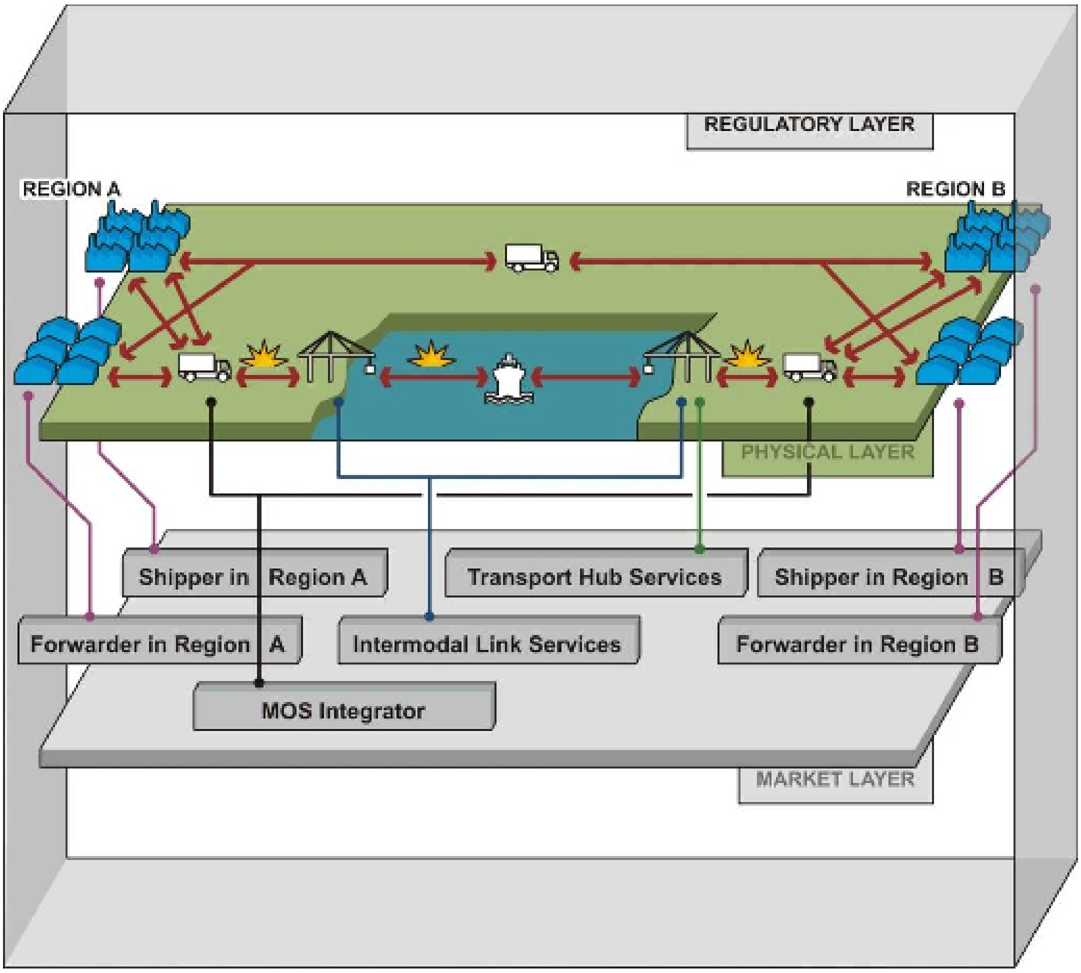

Figure 1: Representation of 3-layered agent based model architecture

Regulatory Layer

This constitutes the policy environment under which the decision-making actors and their agencies (equipments and infrastructures) act. The effects of policy actions are introduced from this layer in the market layer. These effects change the specific input parameters in the model (e.g. service costs, average vehicle speeds, taxes, etc.) that affect the choice of transport service by Transport User Agent during contract process.

Market Layer

Agents in the market layer are cognitive, goal seeking agents and have independent decision making abilities, although frequently acting under some kind of common implicit knowledge, which is largely an aggregate result of their individual feedback processes and of a partially shared interpretation of policies and regulations. Shipment generation, contract process and allocation of shipments to contracted service provider's transport vehicles are simulated in the Market layer. A number of decision makers i.e. Transport Users in Region A, Transport Users in Region B, Road Haulage Companies and MoS Integrator are identified as agents. Next, we present a simple description of the main features of the various types of agents.

Transport User in Region A and Region B (TU)

This represents a shipper or forwarding company located in Region A that generates shipments for delivery to one of the multiple destinations in Region B. The frequency and volumes of shipments generated by each transport user is predetermined for a week but the time and day of shipment generation is decided stochastically using a uniform probability function.

To transport a generated shipment each Transport User selects a service provider for each origin-destination pair separately in the contract process. The physical transport of all shipments generated by the Transport User for a particular destination is the responsibility of the selected service provider during the contract period.

Similarly, Transport Users in Region B generate shipments for delivery to one of the multiple destinations in Region A.

Unimodal Trucking Company (UTC)

This agent represents a single International Road Haulage Company offering door-to.-door service to clients in Region A and Region B. Each UTC has a fixed fleet of trucks determined at the start of the simulation.

The UTC is responsible for allocating trucks either from its own fleet or outsourced trucks to deliver the shipment orders of the Transport User that has contracted its services. The goal of each UTC is survival in the market and maximization of profits. UTCs manipulate prices in the market to either incrementally increase rates when their fleet occupancy is above a certain threshold (say >95%). Similarly, rates are reduced incrementally when fleet occupancy is below a threshold (say < 80%). The number of UTCs in the model dynamically changes when the aggregated market price rise or fall below a predetermined value.

In the contract process, when a UTC receives a Request for Offer (RFO), it computes the Offer price, expected delivery time, expected delays and probability of damage. The Offer Price is computed considering the following cost items:

- Time based costs (e.g. capital, interest and administration)
- Distance based costs (e.g. fuel and vehicle wear)
- Link based costs (e.g. road tolls)

Expected Delivery Time for unimodal Road transport

Truck agents travel along pre-defined paths and therefore have fixed distances for a given origin-destination pair. Expected Delivery times consist of:-

- Average truck speed (say, 70 km/hour)
- Truck Driver's Rest Hours (say, 9 hours of driving are assumed in each 24 hour period)

Actual delivery times are stochastic and the time it takes a truck to transport goods from origin to destination is assumed to follow a lognormal distribution (Noland, Small et al. 1998).

Expected Delays

Delays are quoted in the Service Offers and are the aggregated difference of Expected Delivery times and Actual Delivery times for Road Haulage over a predetermined simulation time period (x months).

Probability of Damage

This variable is expressed as a percentage of all loading units damaged in transport. Damage to a loading unit during transport is determined by assuming a stochastic uniform distribution with a probability of occurrence (o). For road haulage (o) is assumed to be 0.05 while for MoS (o) is assumed to be 0.3 during winter season and nil during other seasons.

MoS Integrator (MoS)

This represents the agent that manages the Motorways of the Sea intermodal service and is assumed to operate the following resources in the Physical Layer:-

- Trucks for pre/post haulage in Region A & B
- Seaport terminals in Region A & B
- RoRo Vessels

For Transport Users that have contracted MoS service, the MoS Integrator allocates trucks for pre and post haulage, does booking for contracted shipments onboard the scheduled vessels and organizes port clearance before vessel departs from the departure port. During simulation, the MoS Integrator is assumed to manage shipping capacity by adjusting the number of ships on the shipping link. Each ship agent follows a regular scheduled shipping service calling 2 seaports, one in each region. A minimum of 2 weekly ship calls in each seaport is assumed for modeling.

The MoS Integrator also participates in the contract process and computes the Expected service price, Expected delivery time, Expected delays and probability of damage for this mode of transport.

Contract Process

The contract process and agent interactions are explained with the help of a sequence diagram (See **Error! Reference source not found.**). Communications between only one Transport User and a discrete number of Transport Service Providers (Road Haulage Companies and MoS Integrator) for a specific origin-destination route are shown to increase the readability of the diagram.

Each Transport User in Region A or B repeats the contract process for every shipment destination or whenever the contract expires.

A Transport User in Region A is assumed to create regular shipments for different customers located in different destinations inside the trading Region B and vice versa for Transport User in Region B.

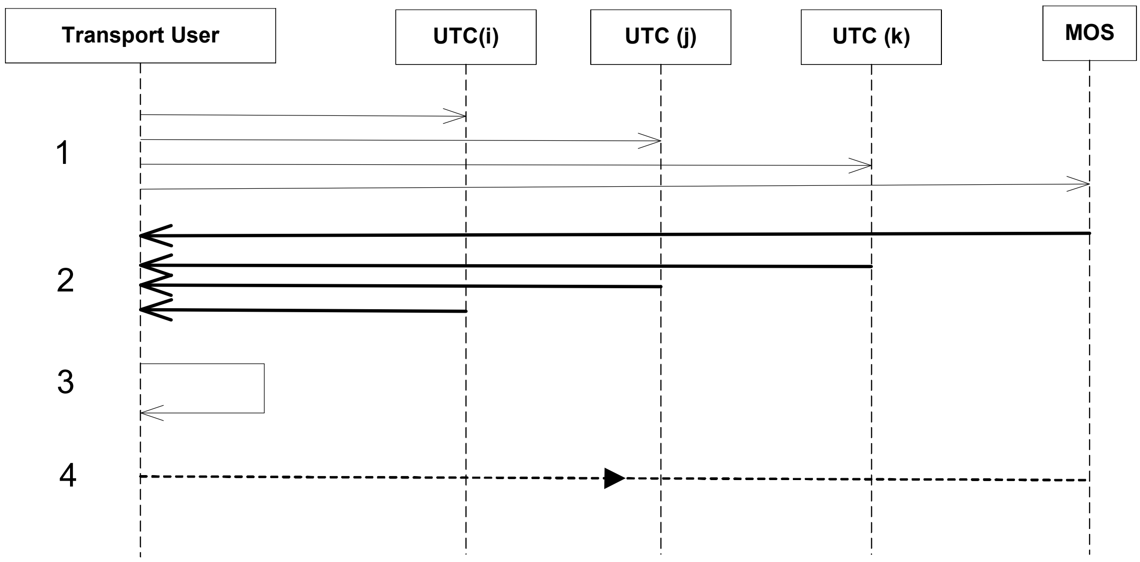

Figure 2: Sequence diagram of communications between each Transport User and Service Providers

The communication sequence is as follows:-

- (TU → UTC, MoS) A Transport User (TU) sends a Request for Offers (RFO) to a discrete number of UTCs and MoS Integrator (MoS) whenever the service contract on any o-d route expires or is non-existent. The RFO contains the TU identifier, shipment identifier, number of loading units in the shipment, origin, destination and time when shipment will be ready for transport.
- (UTC, MoS → TU) The UTCs and MoS receive the RFOs sent by UTC and each creates a service Offer for that RFO. The Offers are sent back to the TU. The Offer contains Offer Price, Expected Delivery times, Expected Delay, Probability of Damage and sender's identification. For MoS, ship schedule with the minimum departure port waiting time is used to calculate the Offer variables.

When all the service providers have responded to the RFO with their competing Offers, the TU selects the Offer that shows the highest utility value to the TU. The utility value for each Offer is computed using a Random Utility Discrete Choice Nested Logit Model. The discrete choice model was derived from a Stated Preference Survey in which a number of Shippers, Forwarders from Porto and transportation experts in the academic field from Instituto Superior Te'cnico (Lisbon) and University of Antwerp (Belgium) participated (Baindur 2010).

- (TU → UTC(i) or UTC(j) or UTC(k) or MoS) The service provider that sent the Offer with highest utility receives a confirmation message (is contracted by the TU for a fixed period). During the contract period, this Service provider will handle the transport of all TU's shipments with the same origin-destination.

Other service providers that do not receive any confirmation message are assumed rejected and the contract process terminates.

The Agent based model was developed on the AnyLogic Version 6.4.1. Software platform. The software has developed a set of primitive and library objects that allow modeling different agent behaviors and environments easily.

To verify and calibrate the models the Unit Testing Method was employed (North and Macal 2007). A bottom up approach is used wherein each behavioral algorithm function is individually tested before adding it to the model. We used this method for verification at every step of model development.

Unlike physical systems that have established procedures for model validation, no such guidelines currently exist for Agent based modeling. Therefore, a subjective process of validation is used for validation of these models.

In the initial phase of model development, structured interviews with Industry professionals representing seaports, Shipping Companies and Intermodal Service Operator were carried out to elicit information on the decision making behavior of shippers, road hauliers and shipping companies in mode choice, pricing and carrier capacity to understand the dynamics of transport demand and supply in the freight transport market system.

SEAROAD CASE STUDY

We have chosen to illustrate the application of the model on a transport corridor between North Portugal and United Kingdom. The Searoad case study is based on two failed experiences of Searoad Intermodal Transport Company to establish a regular RoRo service between Leixões port and Southampton port, connecting North and Central regions of Portugal with United Kingdom in 2001 and 2003 in the Atlantic maritime corridor. In this section, the scenario design will be described followed by simulation results and analysis of the results.

Base Case Scenario

In the base case scenario, Searoad Company employs two RoRo ships on the main haul shipping links between Southampton and Leixões seaports on a twice-weekly shipping service. Pre and post haul in UK and Portugal are done by domestic road haulage Companies in UK and Portugal. Searoad intermodal services directly competed with International Road Haulage Companies that offered unimodal road services.

In the simulation experiments, we study the introduction of 4 policy actions on the market share of Searoad Services and consequently the viability of such services. The assumed effects of each of these policy actions on the performance of transport alternatives is tabulated (See Table 1). All simulation experiments start at 00:00 hours on 1st of January and run for 3 years. The time step unit used in the simulations is 1 hour.

Table 1: Policy Actions simulated by the Policy Maker Agent and its impact on the model parameters

Serial No.	Policy Actions	Assumed effects on Road Services	Assumed effects on MoS Services	Sources
I	Improving port connectivity with land transport corridors		Port operations time ~ -5% Port costs ~ -10% Pre/post haul speeds: +5%	EXPE DITE project
II	Port liberalization and Customs simplification		Port operations time ~ -60% Port Administrative time~-80%	Estimated during interviews
III	Internalization of external costs	Distance costs~+€0.29/km/unit	Distance costs: Shipping: €0.58/km/unit Pre/post Haul: €0.79/km/unit	RECORDIT; FINESSE projects
IV	Harmonization of Road Regulations (Labour laws and fuel taxation)	~20% Road Price reductions not possible Total Trucking costs: ~+5% Total Trucking time: ~+5%		RECORDIT; IQ; EXPEDITE projects

Source: Adapted from (EXPEDITE 2002)

Below some of the input data is given in the tables:-

Table 2: Searoad Case study input parameters and their assumed values

Input Parameters	**Values**	**Input Parameters**	**Values**
Avg. Pre/post Haulage speed Portugal	65 km/hour	Pre/post Haulage cost in UK	200.21(€/day) / 0.91(€/km)
Southampton Port Administrative time	2 hours	Pre/post Haulage cost in Portugal	125.13(€/day) 0.57(€/km)
Southampton Port Operations time	2 hours	International road haulage	207.95(€/day) / 0.44(€/km)
Ship Ldg/Disch. Rate – Southampton port	30 LU/hour	Southampton Port Charges	€165/LU
Avg. RoRo ship speed	25 km/hr	Leixões Port Charges	€165/LU
Sailing distance: Leixões - Southampton	1315 km	RoRo Ship Charges	€1396/LU
Ship Berthing/Unberthing time in each voyage	6 hours	Leixões Port Operations time	2 hours
Leixões Port Administrative time	2 hours	International road haulage speed	65 km/hour
Ship Ldg/Disch. Rate – Leixões port	30 units/hour	Total RoRo Ship Capacity	150 semi-trailers
Pre/post Haulage speed UK	60 km/hour	Max. driving hrs./day in road transport	9 hours/day
Annual Trade Growth	2%		

The model was calibrated by using input parameters on average transport costs from published sources such as (RECORDIT 2001; TIS 2005). From interviews and discussions with academicians, experts and practitioners in European transport and logistics, we arrived at plausible values for the remaining input parameters such as average delivery times, average transport costs, average delays and probability of damage for road and intermodal transport individually. Stated Preference surveys were conducted and the Agent based model was calibrated with these results to simulate a set of different technological and policy scenarios.

There was a broad consensus from industry experts on the plausibility of simulation results. This process completed the agent based model verification and validated.

Table 3: Nested Logit Model Estimation Results for Searoad Case study

Service Attributes and Variables	**Value**	**Standard Error**	**t-test**
SSS Constant	0.0	Fixed	
Road Constant	1.1615	4.0496e-1	2.8683
Expected Delays	-5.0986e-2	2.4742e-2	-2.0607
Expected Damage rate	-9.6328e-2	5.60177e-2	-1.90365*
Offer Price	-3.9172e-3	1.6015e-3	-3.3765
Expected Delivery Time	-2.7323e-2	9.34336e-3	-2.9244
Model Parameter – SSS	1.0	Fixed	
Model Parameter – Road	2.27445	9.28485e-1	2.4496
Note: * indicates the statistical significance less than 0.2%.			
No. of Obs. = 60; Log. L=-83.1777; L. Ratio test=98.6477; Rho2 = 0.592994; Adjusted Rho2=0.157			

SIMULATION RESULTS AND ANALYSIS

The results of the base case scenario constitute the calibration of the model and as such the foundation upon which the policy scenarios are evaluated for plausibility. The total transport volumes transported by road and Searoad in 3 years simulation time are shown in **Error! Reference source not found.**. Factors contributing to the low transport volumes of Searoad intermodal services are explained below:

- Road transport services are the incumbent transport services and a bias factor in the utility of this transport mode is adjusted in the transport service discrete choice model;
- Road services are relatively cheaper than Searoad intermodal services (on average €100 cheaper per loading unit) although the average delivery times by each transport mode are almost the same.
- The damage probability of Searoad services in the sealinks is assumed higher during the winter season while the probability in road transport is steady at approximately 3% probability throughout the year (**Error! Reference source not found.**).

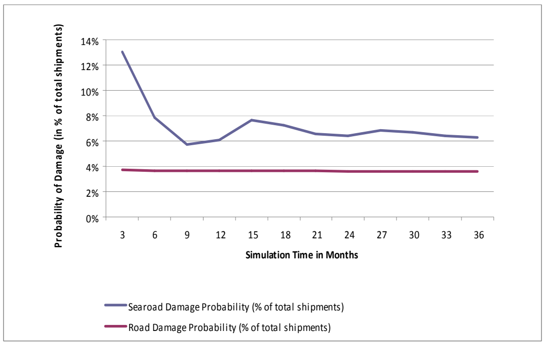

Figure 3: Base Case – Probability of damage of transport modes along simulation time

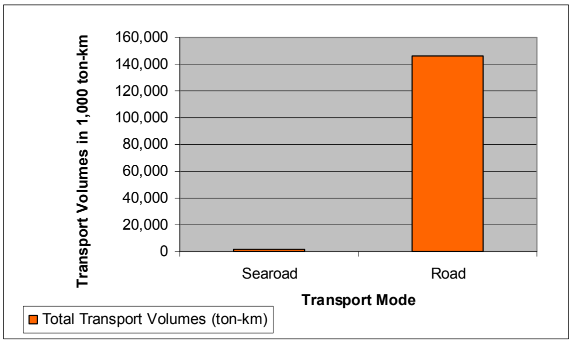

Figure 4: Base Case - Total transported volumes by transport mode in 3 years model simulation time

The results of the 4 scenarios are summarized in **Error! Reference source not found.**, **Error! Reference source not found.** and **Error! Reference source not found.**. From the simulation results in **Error! Reference source not found.**, we see the change in Searoad transport volumes in different policy scenarios. The simulation results show that the largest gain in terms of transport volumes (i.e. modal shift from road to Searoad services) is in Case 4, i.e. the case where fuel taxation and driver wages across the Member States is harmonized. This corresponds to the establishment of a level playing ground for competition between different transport modes. By doing so, road hauliers are unable to exploit the discrepancy in costs (which is estimated to be as much as 20% of total transportation costs) to their advantage (COMPETE 2006). Moreover, stricter enforcement of road regulations is expected to discourage truck drivers to flout working hour regulations, with the indirect positive effects of safety improvement in road transport operations.

By improving interconnectivity of Searoad transport infrastructure (Case 1), moderate gains in Searoad transport volumes are observed. Moderate gains in Searoad transport volumes are also observed in Case 2, i.e. port liberalization and simplification of Customs formalities. Therefore, from simulation results the most effective single policy measure for encouraging modal shift to Searoad services is the harmonization of road regulations.

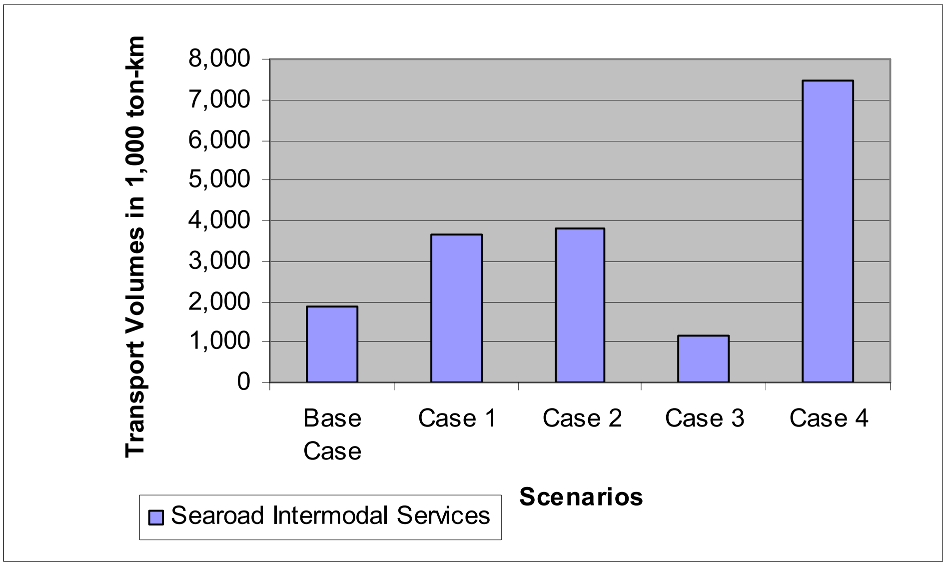

Figure 5: Volumes transported by Searoad intermodal services in different scenarios

In **Error! Reference source not found.**, the average transport prices per Loading Unit for the customer using road or intermodal transport are illustrated. The highest costs for intermodal transport occur when external cost pricing as policy measure are applied to all transport modes. Though shipping is less polluting per unit load in greenhouse gases, the pollution levels of Nitrous oxides, sulphur oxides and polycyclic aromatic hydrocarbons (PAH) far exceed those of trucks. Studies have shown that ships emit as much as 30-50 times more sulphur oxides per ton-km than a truck and almost twice as much Nitrogen Oxides per ton-km than the latest truck models today (Swedish NGO 2008). The PAH quantity per energy unit in marine fuels used by ship machinery is almost 30 times more than diesel fuel used in trucks (EEB 2004). Obviously, the external costs of shipping will be much higher than road transport modes and the advantages of low carbon ship emissions are lost when sulphur, nitrogen and PAH are included in the external cost pricing.

The lowest charges of Searoad services were achieved by the liberalization of port services. This measure was assumed to improve port efficiency by reducing port Governmental bureaucracy (exemptions or selective inspections of Customs, Health, Vetting, Security for vessels, goods and personnel routinely calling the same ports).Secondly, the provision of customized shipping services (pilotage, towage and mooring/unmooring) were offered at competitive rates.

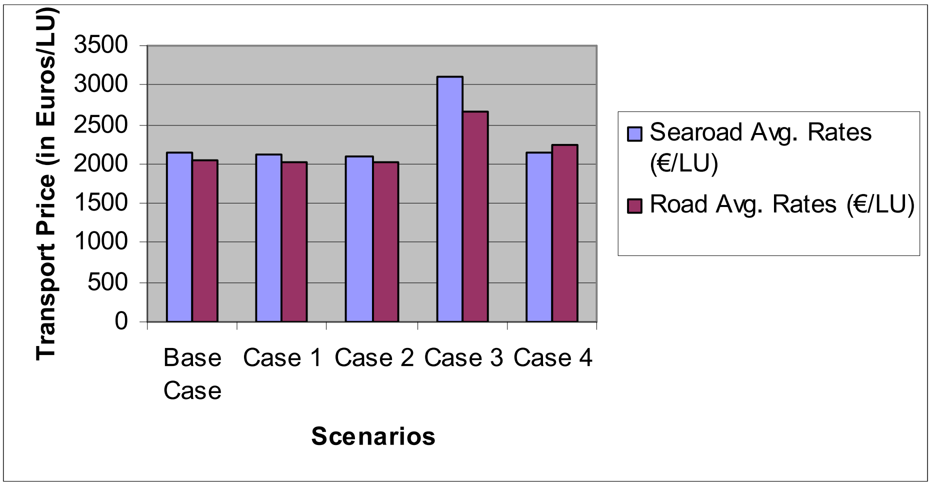

Figure 6: Comparison of average rates of unimodal road and Searoad services in different scenarios

Finally, we studied the impact of these policies on the average delivery times of each transport mode. Results in **Error! Reference source not found.** show that Searoad services were fastest in Case 2 i.e. after port liberalization, while all other policy options had negligible impact on the average delivery times. For unimodal road haulage, delivery times were longest in Case 4 because of stricter enforcement of drivers' resting hours.

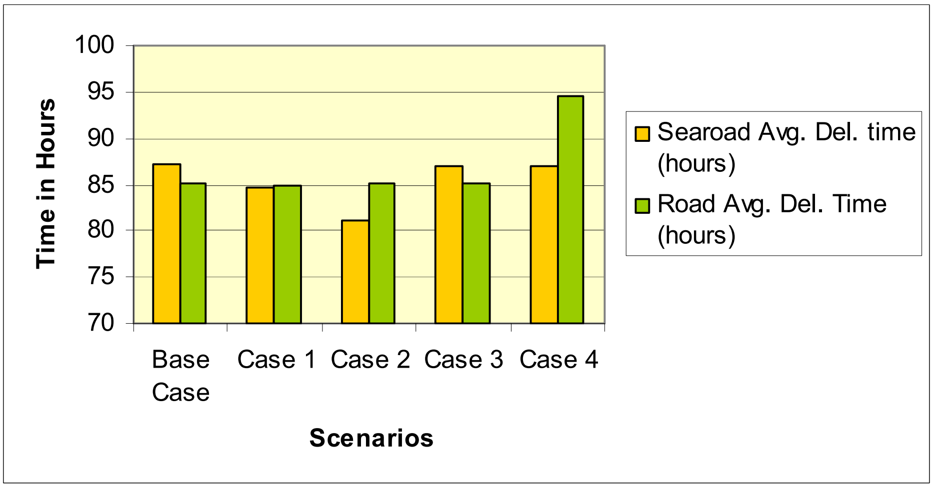

Figure 7: Comparison of average delivery times of unimodal and Searoad services in different scenarios

The simulation experiments have shown that it is possible to assess the effects of specific policies, however there is a need to obtain a richer set of data (including for other corridors), as well as to validate the results. The agent-based model was able to explicitly simulate the following functionalities in the model:-

- Motorways of the Sea type intermodal transport i.e. transportation with shipping for main haulage with the same loading unit;
- Restrictions of vehicle capacities and truck driving regulations;
- Loading/discharging in seaports;
- Administrative procedures carried out for each road transport;
- Timetabled shipping schedules;
- Dynamic adjustment of transport capacity (by increasing or reducing the number of vehicles) to demand for transport on the trade corridor by Road and Intermodal Companies;
- Introduction of stochasticity in the model functionality to replicate the real world;

Further experiments using the model could include the analysis of different combinations of the above 4 policy measures on the performance of Searoad intermodal services and modal split. The model should also be tested on different maritime corridors and shipping links by adjusting the model parameters to local market conditions.

CONCLUSIONS AND FUTURE WORK

We presented a micro-level simulator for a wide scope of transportation. By using agent-based technology, we were able to simulate the decision-making activities as well as the interactions between the actors. Physical movements of each loading unit from origin to destination are also explicitly simulated in the Physical Layer of the model. This is almost impossible to do in traditional modeling techniques.

The model simulated the Searoad case study in the Atlantic corridor. The base case scenario demonstrated that Motorways of the Sea projects would be a failure in the business as usual scenario (Base Case). The results of the stated preference survey estimated that shippers were most sensitive to damage and delays in transport services. In terms of price, the Searoad option was unable to compensate for damage and delays as a consequence of rough weather on the shipping leg during winter months. This is reflected in the base case market share of Searoad services.

From simulation results some general conclusions on the performance of Motorways of the Sea in the Atlantic corridor in different policy scenarios can be expressed:

Around 300% increase in market share of Searoad services is expected with harmonization of fuel taxation and driver wages in all Member States. In doing so, unfair price advantage in favour of road transport would be removed which would make Motorways of the Sea projects more attractive to shippers.

Policy measures to improve port-hinterland connectivity and port performance to facilitate faster movement of shipments from/to ports was estimated to increase Searoad market share by approximately 90% in each case. These policy actions are considered to have a moderate impact on MoS given that the base case market share is less than 3% initially.

Contrary to general perception, implementing external cost pricing uniformly to all transport modes reduced Searoad market share by half from base case scenario. The reason is that external costs of ship emissions of sulphur oxides, nitrogen oxides, particulate matter in comparison to road transport per unit load are high and therefore reflected in the price of MoS transport when this policy measure is implemented.

- However, there is still scope for further development of the model. Possible extensions are conducting separate random utility discrete choice models for modal choice of high, medium and low value goods and including it in the Agent based model.
- Allowing decision-making agents to learn from experience, e.g., transport users to reject service offers from the transport providers that demonstrated poor quality of transport service.
- Simulate competition from private railway undertakings in the same serviced trade corridor.
- Deeper understanding and simulation of the complex transport user-supplier negotiation processes.

We have demonstrated that it is possible to simulate complex micro level interactions between transport user - service provider for transport service selection based on service criteria (price, delivery time, delay and damage). Further, we simulate the effects of policy actions on the modal choice and ultimately the modal split of maritime-based intermodal transport. This model finds applications useful to policymakers and industry to assess the effects of proposed policy actions to promote MoS and improving the service quality of MoS services on the market share of MoS services.

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