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SEA MOTORWAYS AS A PART OF THE LOGISTICS CHAIN

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Abstract. This paper presents the main tools of Sea Motorways as an important part of the logistics chain and can be used presented methodically as a framework for designing logistics or supply chains along with sea motorways. Various factors influencing the choice of logistics chains with sea motorway part are described. The methodology of evaluating sea motorways and the logistics chain is furnished. The paper concludes by identifying the best logistics chains including sea motorways.

Keywords: logistics chain, transportation, sea motorways, transport corridors.

1. Introduction

Sea motorways as a part of the logistic or supply chain, thus search, development and optimisation thereof is the main task for researchers and practitioners working in the fields of transportation and logistics. Such regions like the Baltic Sea as well as Black and Caspian Seas are very important for the logistics chain and for developing the parts of sea motorways as these appear like big industry and population concentration areas featured around the above mentioned seas and act as important transport directions such as TRACECA etc. crossing these regions. Sea motorways must link logistics chains and people interests. The most important tasks within the integration process are good transport and optimisation of logistic links; thus, this work has to be done in both fields of science and practice.

Transport networks are very important for shifting the force of markets. Therefore, in the process of the EU extension, when linking the biggest markets such as China and EU, the priority attention has to be given to the development and modernisation of transport infrastructure to duly coincide in terms of time with the revision period of the Trans-European Transport Network. Sea motorways are a new adding system to the Trans-European Transport Network.

The Transport Network and main transport directions have to be planned, developed and subsequently constructed according to the economic criteria; since the Transport Network cannot be created in a single effort – for financial and technical reasons, it has to be developed in stages according to a schedule. Priorities have to be clearly defined. These should not be decided on the basis of national criteria, in other words, from the point of view of the greatest possible advantage for the country adjoining the respective traffic route. Planning and development measures must be carried out according to the requirements of trade and passenger and freight transport. If we talk of cost-benefit related planning and appropriate development measures to be applied, the criteria of benefit has to be understood specifically from the perspective of such big regions as EU, China, India trade and freight transport requirements.

However, it would also be rational to develop the sea motorways on the main directions integrating them into the future Transport Networks. It would be necessary to form a network of motorways on the sea that would serve best for the interests of industry and trade.

2. Main regions and directions of industry, trade and population

International trade generates transport. Based on the correlation GDP>Trade>Transport, the future trade flows by merchandise groups between the relevant countries can be modelled and forecasted according Jarzembowski (1998).

Industry concentration in the regions with the integration of the new important Countries and regions such as EU, China, India and other regions and countries is the main basis for forecasting cargo flows that have influ-

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ence on logistics chains and sea motorways especially as stated Mingozzi *et al.* (2000).

The main industry regions in today's World and the nearest future will be EU, China, India and North America. Trade between these regions and inside of the before introduced Countries and regions is important for selecting right transport directions.

At the same time, having at least a few parallel and independent transport routes excluding any negative technical, political or economical influence is a very important point. Fig. 1 shows an example of already existing and possible routes between the Far East and Europe.

Simultaneously, freight transport density in some regions is so high that makes problems for life quality (traffic jumps), decrease safety (especially on the roads) and requests looking for new solutions from politicians as well as from the researchers and practitioners working in the fields of transportation and logistics. Fig. 2 presents freight transport density in Europe.

As an example, a lot of transit cargo goes via Baltic ports and regions that are on the same distance scale from the Baltic Sea and imply a major influence on the Baltic transport system. The regions close to the Baltics having a real influence on the Baltic transport system and average distances from these regions to the Baltic Sea ports shown in Table 1 are displayed in EU Energy and Transport Figures (2006).

Investigation into all cargo turnovers through sea motorways is not quite correct since only specific cargo or goods transit has a real influence on sea motorways. Ro-Ro and container transportation via ports could be taken as the basis for investigating sea motorways. In same time, more and more goods like cars, some bulk cargo etc. are carried in containers. Under new conditions, the container and Ro-Ro transportation as the main elements of sea motorways should be taken into consideration.

3. Methodology of investigations

The models covering as many factors as possible and different supply chain elements should be used for logistics chains with a part of the motorways of the sea investigations models. A typical supply chain with sea motorways part model is taken as basics for investigating sea motorways and presented as an example in Fig. 3.

For investigating sea motorways, Oilier method can be used as it allows checking passenger or cargo flows at important fixed points subsequently finding out requested parameters Paulauskas (2002). As such the main fixed points can be taken ports or boarding crossing places on one side of the sea. For more detailed investigations, multi criteria investigation methods can be applied in books and papers like Baublys (2003), Paulauskas (2002) etc.

According to Oilier method, at the fixed points, quantities are checked by the field formulas shown below:

$$Q_x = q_x(x, y, z, t), \tag{1}$$

Fig. 1. Existing and possible transport directions between the Far East (China) and West Europe

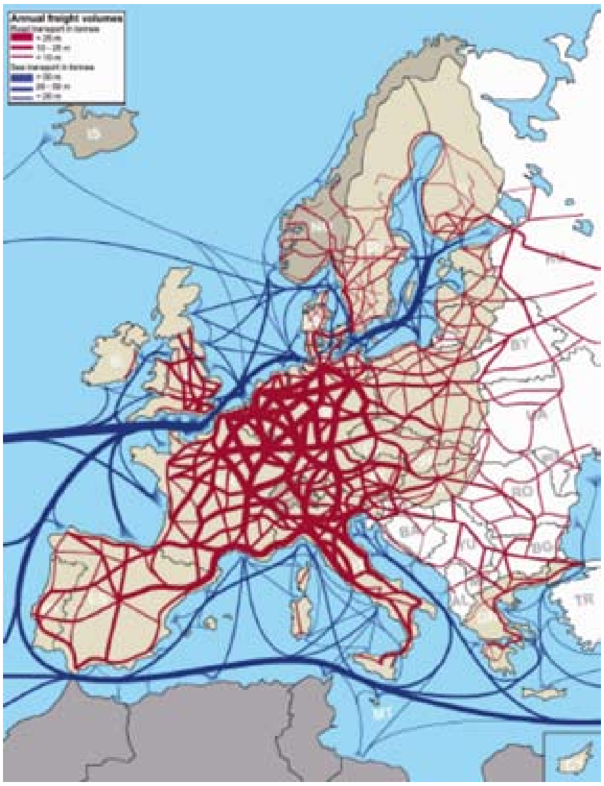

Fig. 2. Freight transport density in Europe and maritime links

Table 1. Regions neighbouring the Baltic Sea and average distances to the ports

Regions	Population, mln	Distance to Baltic sea, km
West Germany	30	500
Benelux Countries	28	400
Central and East Germany	25	250
Central Poland	18	350
Belarus	10	500
Central Russia	35	1 000
North-West Russia	8	600
Central and North Finland	2	300
North Sweden	2	200
Norway	2	500

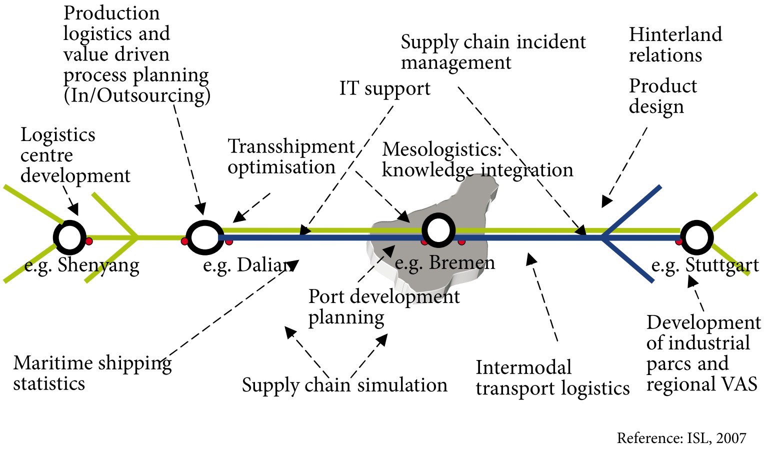

Fig. 3. Supply chain model (Bremen ISL logistics 2007 report)

$$Q_y = q_y(x, y, z, t), \tag{2}$$

$$Q_z = q_z(x, y, z, t), \tag{3}$$

where: Q_x, Q_y, Q_z – investigated quantities at the concrete fixed point on concrete directions; q_x, q_y, q_z – commodities at the fixed points; x, y, z – fixed point coordinates; t – time.

On the basis of the latter method, the possibility of finding the investigated cargo flow parameters for the actual directions or concrete logistics chains arises. In order to check the development perspectives of the transport market for the forecast horizon, a forecast method based on the specific elasticity (multi criteria) method for each commodity groups can be used Baublys (2003).

While assessing the importance of Pan-European transport corridor IX (the middle section) in the extended EU, it would be expedient to carry out forecasting research of potential flows. It would be also of great importance to ascertain what kind of specific motorways (in the East-West directions) would serve the interests of the Baltic Sea Region and the extended EU the best way.

The basic elements for the multi criteria forecasts are as follows, Paulauskas (2003):

- GDP forecasts for the countries concerned;
- European export and import forecasts (values at constant prices) for the relevant countries;
- Calculation of import and export for different commodity groups for each country;
- Projection of trade flows based on calculating for all commodities and countries (volumes), differentiated for exports and imports;
- Technical possibilities of selected directions;
- Geographical, hydro meteorological and other conditions for concrete directions.

For investigating the cargo flows to likely influence sea motorways as an example could be taken Eastern Baltic ports and the quantities of Ro-Ro units and container carriers (in TEU) at the fixed points.

Based on the existing cargo flow and dynamic of different merchandise development, especially those of importance to the sea motorways, it is possible to note the tendencies and forecast the regions which could be developed.

The runtime of ship sailing between ports is very important for sea motorways in order to maintain proper compatibility with other transport corridors, like for instance in the Baltic region – with inland transport corridors via Poland.

Full Ro-Ro ferry voyage time can be calculated as follows, Paulauskas (2002):

$$T = 2 \cdot T_r + T_{rez}, \tag{4}$$

where: T_r – ship's time for sailing and port operations between leaving one quay wall to reach the other one; T_{rez} – reserve time that depends on the distance between the ports.

Ship's sailing and times of port operations can be calculated as follows:

$$T_r = \frac{S}{v} + T_p + T_l, \tag{5}$$

where: S – distance between the ports; v – average sailing speed in-between the ports; T_p – time necessary for sailing within a port and port formality arrangement; T_l – time necessary for discharge and loading.

The time factor is very important for sea motorways regarding the possibilities of operating an optimal timetable based on the week schedule with a minimum number of ships, especially on the first stage.

The safety factors in sea motorways compared to other transport corridors play a very important role because Ro-Ro units usually carry expensive goods. The safety factor in transportation can be calculated as follows, Vensel (Венсель 1969):

$$P = \frac{1}{\eta_k}((1 - Q_1)(1 - Q_2)(1 - Q_3)(\ldots)), \tag{6}$$

where: P – positive probability; Q_i – negative probability; η_k – correlation coefficient.

Safety is calculated as a positive probability.

For a comparison between transport corridors as well as between sea motorways and inland transport corridors, a complex evaluation method can be used that

Table 2. Ro-Ro units dynamic on transport corridor No. 9 direction and other directions

Direction	1996	1997	1998	1999	2000	2001	2002
Corridor No. 9	182 500	214 200	173 180	122 079	138 300	161 460	167 505
Riga Bay	15 400	14 860	21 210	17 840	10 460	10 880	19 170
Finland Bay	72 470	75 900	85 020	88 470	89 760	102 630	105 800
TOTAL	270 370	304 960	279 410	228 389	238 520	274 970	292 475

can be calculated for the concrete sea motorway direction as follows:

$$E = \frac{1}{\eta_E} \sum (k_i \cdot M_j), \tag{7}$$

where: M_j – factors like costs, time of delivery, safety, environmental impact, navigation conditions, ice conditions etc; k_i – weight of the factors depends on a type of cargo, transportation possibilities etc. that can be found on the basis of multi criteria analysis; η_E – correlation coefficient that depends on the number of factors used in evaluations.

On the basis of methodologies presented in this article, it is possible to make an evaluation of the concrete transport corridor and sea motorway together with other parts of the whole transport corridor and find the difference between transport corridors as follows:

$$\Delta = \frac{E_i}{E_0}, \tag{8}$$

where: E_i – investigated transport corridor; E_0 – basic transport corridor to be taken as standard.

On the complex evaluation basis, it is possible to more accurately establish all advantages and disadvantages that would enable to take the final decision and provide correct explanations for investors and other market players on an existing concrete transport corridor as well as on the potential possibilities of a sea motorway.

4. Practical calculations for the sea motorways directions

Based on the information and following the methodology presented in this paper, calculations for different profiles are to be made, such as Ro-Ro development in different Baltic Sea regions, ship voyage time between different ports, time and safety factors, for instance, a road transport unit between Vilnius and Hanover in case of using a sea (potential sea motorway) and inland way. Finally, the complex evaluations of the concrete transport corridors are made.

Ro-Ro transport dynamic of directions for transport corridor No. 9 as well as other directions are spread as follows:

- Kaliningrad, Klaipėda, Liepaja are included in transport corridor No. 9 direction (West – East direction);
- second direction – Riga direction (West – East direction);
- third direction – South – North direction (South West part of the Baltic and Finland Bay ports).

Statistics and calculation results as an example are presented in Tables 2–6.

As shown in Table 2, the main Ro-Ro direction is the direction for Transport corridor No. 9 and the reason for such dynamic is good Ro-Ro shipping lines connection, good road network eastward from the Baltic ports and lighter hydro meteorological conditions in comparison with other directions. Table 6 does not include Ro-Ro flows between Central and Northern part of Sweden to Helsinki and Tallinn – Helsinki routes.

Voyage time of the Ro-Ro ships between the main population and industry concentration regions located close to the South-West of the Baltics and Eastern Baltics and Finland Bay ports based on the methodology presented in this paper are produced in Table 3.

The results seen in Table 3 show how the weekly timetable depends and that transport corridor No. 9 is the best position of having ports as sailing speed depends on this direction where it is possible to make 3 voyages per week per one Ro-Ro ship.

Ro-Ro ferries voyage time at the shortest distance between the Eastern and Western coasts of the Baltics (corridor No. 9 on the Eastern Baltics) is presented in Table 4.

Ro-Ro voyage time in Tables 3 and 4 includes a return sailing from one port to another, loading and unloading time, ship's sailing time within the ports and reserve time. Fast ferries have not been investigated meanwhile, yet they could be very perspective in the

Table 3. Ro-Ro voyage time between South-West Baltic ports and Eastern Baltics and Finland Bay ports in relation to Ro-Ro ship speed

Port	16 knots	20 knots	24 knots
Kaliningrad	58 h = 2.4 d.	50 h = 2.1 d.	45 h = 1.9 d.
Klaipėda	64 h = 2.6 d.	55 h = 2.3 d.	48 h = 2.0 d.
Liepaja	68 h = 2.8 d.	58 h = 2.4 d.	51 h = 2.1 d.
Ventspils	75 h = 3.1 d.	65 h = 2.7 d.	58 h = 2.4 d.
Riga	98 h = 4.0 d.	83 h = 3.5 d.	74 h = 3.0 d.
Tallinn	110 h = 4.6 d.	93 h = 3.8 d.	82 h = 3.4 d.
Helsinki	116 h = 4.8 d.	98 h = 4.0 d.	86 h = 3.6 d.
St.-Petersburg	144 h = 6.0 d.	122 h = 5.1 d.	107 h = 4.5 d.

Table 4. Ro-Ro ferry voyage time in between Blekinge Ports (Karlshamn, Karlskrona) and South-Eastern Baltic ports in relation to Ro-Ro speed

Port	**16 knots**	**20 knots**	**24 knots**
Klaipėda	43 h = 1.8 d.	38 h = 1.6 d.	34 h = 1.4 d
Kaliningrad	46 h = 1.9 d.	41 h = 1.7 d.	36 h = 1.5 d.
Liepaja	43 h = 1.8 d.	38 h = 1.6 d.	34 h = 1.4 d.

future, especially en route between Blekinge region and South-Eastern Baltic ports.

Based on the methodology used herein, a road transport voyage from Vilnius (Lithuania) to Hanover (North Germany) has been considered, when using a transport corridor with potential sea motorway Ro-Ro ferry Klaipėda – Kiel, Klaipėda – Karlshamn and an inland transport corridor via Poland. The results of these investigations are offered in Table 5.

Table 5 displays that Ro-Ro ferry speed is taken as per conventional ferry with the same 22–24 knots speed on both directions.

The above introduced results have been checked within over 30 transport companies that use all three transport corridors. They confirmed the presented results to be realistic in case the companies would pay taxes as everywhere road transport units drive according to the regulations.

For a complex evaluation of the above mentioned transport corridors the following factor weights were included Paulauskas (2002):

- price with weight coefficient 0.35;
- time with weight coefficient 0.20;
- safety with coefficient 0.25;
- hydro metrological conditions in Spring time with weight coefficient 0.10;
- border crossing with weight coefficient 0.05 (effective May 1, 2004 safety control according ISPS Code should be applied);
- other factors with weight coefficient 0.05.

An evaluation of transport corridors is presented in Table 6 below (the results to be considered as guiding indication, since every single case requires additional study and decisions regarding the factors to be included and respective weights of the factors).

In Table 6, the factors were calculated as the best result divided to other results.

On the basis of the results received as provided in Table 10, we may conclude that a transport corridor with Ro-Ro ferry via Karlshamn with the existing possibilities is the best one if compared with a transport corridor via Kiel at ca. 2.5%. In comparison with an inland transport corridor it shows better at ca.14.1%.

Karlshamn and Karlskrona are located very close to the network of the main roads in Sweden which ensures a very fast passage to reach Copenhagen and other regions.

The second field of sea motorways activities containing the reserves of extensive cooperation in the areas of transport investigation as well as practical transport activities is the development of a modern logistics centre network throughout the Baltic Sea Region. Networking logistics centres will have a positive effect on sea motorways in these respects:

- increased mobility of freight efficiently using various possibilities of interconnection between different transport modes,
- increased use of existing infrastructure,
- quality of transport services,
- creation of new permanent jobs,
- efficient use of modern information and communication technology,
- better business conditions for small and medium transport companies.

Table 5. Voyage Vilnius – Hanover investigation results

Transport Corridor	One-Way Trip Time consumption, hours	Costs (Basic Prices), EUR	Safety Factor: Positive Probability
By Ro-Ro ferry Klaipeda – Kiel	36	998	0.988
Inland transport corridor via Poland	48	1 200	0.973
By Ro-Ro ferry line via Karlshamn	30	1 020	0.985

Table 6. Evaluation of the transport corridors between Vilnius and Hanover when using an inland transport corridor via Poland and Ro-Ro ferries via Kiel and Karlshamn as a sea motorway

Factors and Weights	Transport Corridor with Ro-Ro Ferry via Karlshamn	Transport Corridor with Ro-Ro Ferry via Kiel	Inland transport Corridor via Poland
Price factor	0.85	0.84	1.00
Weight of the price factor	0.35	0.35	0.35
Time factor	0.62	0.75	1.00
Weight of the time factor	0.20	0.20	0.20
Safety factor	0.988	0.985	1.00
Weight of the safety factor	0.25	0.25	0.25
Hydro-meteorological factor	1.00	1.00	0.95
Weight of the hydro meteorological factor	0.10	0.10	0.10
Border crossing factor	1.00	1.00	0.93
Weight of the border crossing factor	0.05	0.05	0.05
Other factors	1.00	1.00	1.00
Weight of the other factors	0.05	0.05	0.05
Correlation coefficient	0.95	0.95	0.95
TOTAL	0.914	0.937	1.043

Common multilateral investigations and studies will be very functional for all parties aimed at revealing the possibilities and ways of how to develop intermodal transport, create and optimize sea motorways and network the best links between the multiple countries of the Baltic Sea Region.

5. Conclusions

1. The Baltic Sea region develops very rapidly and features as very important for all Europe and particularly for the states and regions located around the Baltics.
2. Transport links in the Baltic region are very important not only for the Baltic Sea countries or neighbouring states but also for the countries and regions located close to this area and having great interest to the Baltic Sea transport network.
3. Sea motorways on the Baltics have obvious advantages in comparison with other transport systems as a great deal of transport units employ Ro-Ro ferry lines as the main transport system which is the basis for sea motorways.
4. Ro-Ro transportation in the Southern part of the Baltic Sea has rapidly enhanced over the last few years. Hydro meteorological conditions, good roads and railway network on the Eastern side of the Baltics have combined to make real possibilities of developing the main East–West transport corridors direction and sea motorways.
5. Transport corridor No. 9 and roads linked to this transport corridor will play a more important role in the new EC framework, and thus the optimal prolongation of this transport corridor on the other side (Western part) of the Baltic Sea should be initiated.
6. The southern part of Sweden which is geographically very close to South-Eastern Baltic ports like Klaipeda, Liepaja, Kaliningrad etc. should play a more important role in developing transport and industry in the future.
7. Proper dynamic of passenger and cargo flows development of transport links between South-Western and Eastern Baltic ports over the last ten years indicates this transport direction as having good perspectives able to optimize transportation between West and East markets.
8. Transport corridor No. 9 and roads linked to this transport corridor will play an essential role under the new EC conditions.

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