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The Role of Ferry and Ro-Ro Shipping in Sustainable Development of Transport[1]

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Abstract: As far as sustainable transport development is concerned, transfer of cargo from road transport to short sea shipping, which, according to the common opinion, generates lower external costs, is one of the objectives of the European Union policy. However, the latest research results indicate that some Ro-Ro vessels and ferries generate higher external costs than road transport. In light of this, benefits resulting from transferring the cargo from road to sea seem to be questionable. The main aim of the article is answering the question *whether*, and if so, *how ferry and Ro-Ro shipping contributes to development of sustainable transport?* In order to answer this question, an analysis of ferry and Ro-Ro shipping lines functioning in European transport system has been conducted.

The article presents research results based on an analysis of approx. 900 ferry and Ro-Ro shipping lines considering the length and time of voyage compared to alternative road transport. Usually, the course of sea shipping route does not cover the route of the road transport, and therefore the lengths of both routes frequently considerably differ, which significantly affects the total external costs generated by them. On the basis of the analysis, the shipping lines have been classified according to the criterion of their substitutability to road transport and their role in sustainable transport development.

Key words: External costs, Ferry shipping, Intermodal transport, Ro-Ro shipping, Short sea shipping, Sustainable transport

JEL Classification: R41, R48

Introduction

The current development of civilization has led to an imbalance between the economic development and natural resources, which entails a serious risk of economic, environmental, social and political instability. The idea of sustainable development was first defined by the World Commission on Environment and Development. In a report published in 1987 which was entitled "Our Common Future," sustainable development was defined as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (UN documents, 1987). The main

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priority of sustainable development is a compromise between economic and social development and protection of natural resources.

Sustainable transport is one of the main strategic objectives of sustainable development. The first definition of sustainable transport was developed by the OECD in 1996, according to which the sustainable transport should be understood as transport which "*does not endanger public health or ecosystems and meets the needs of the movement in accordance with the principles of the use of renewable resources below their regeneration capacity and use of non-renewable resources below the possibilities of developing their renewable substitutes*" (OECD, 1996). Richardson, modifying the definition of sustainability developed by the Brundtland Commission, describes sustainable transport as "*the possibility of meeting the transport needs of the present without compromising the ability of future generations to meet their own transportation needs*" (Richardson, 2005).

Sustainable transport is a transport that:

- is accessible, safe and environment-friendly;
- is affordable, operates efficiently, offers a suitable choice of means of transport and supports the economy;
- commits to reducing emissions and waste production including the possibility of an ecosystem to absorb them, the consumption of non-renewable resources and consumption of renewable resources, land use and the noise (*Assessment and Decision Making for Sustainable Transport*, 2004, cited in Pawłowska, 2010).

In this light, transport policy should be directed towards development of such modes of transport that both fully meet the transport needs and contribute to reduction of harmful impact on the environment.

Constant efforts to increase efficiency of European transport system while putting much pressure on reducing harmful effects on the environment has become a major objective of the common EU transport policy (White Paper, 1993; White Paper, 2001; White Paper, 2011). Transfer of cargo from road transport to other transport modes with less negative impact on the natural environment, especially to rail transport and inland shipping, became the basic task. By 2030, both modes of transport as well as short sea shipping would have to be nearly doubled (Thaler and Wiederkehr, 2004; Chen, Yang and Notteboom, 2014).

The growth of short sea shipping as an alternative for road haulage is mainly aimed at discerning social benefits resulting from lower external costs generated in maritime transport, lower number of accidents and reduced congestion (Perakis and Denisis, 2008; Lee, Hu and Chen, 2010; Medda and Lourdes, 2010). Paixao Casaca and Marlow (2002) point out that the lower social harmfulness of maritime transport is mainly due to the economy of scale, manifesting itself in a much larger capacity of ships than other transport means. Koliousis et al. (2013) points out that the development of short sea shipping is limited by deregulation of road haulage market.

External Costs in Transport

The problem of the assessment of the external costs of transport has been discussed since the early 1990s. The first studies referred to external costs of road vehicle and rail transport only, whereas the costs in inland and maritime shipping were often marginalized (Towards fair and efficient pricing in transport, 1995; White Paper, 2001). Since then, many publications concerning calculation of external costs have been published, some dealing with the calculation of external costs on specific transport routes (Weinreich *et al*, 1998) or in specific areas (Eriksen, 2000; Tzannatos 2010), others concentrating on externalities of a specific mode of transport (Janic, 2007; Forkenbrock, 1999, 2001; Rohács and Simongáti, 2007; Bloemhof *et al*, 2011).

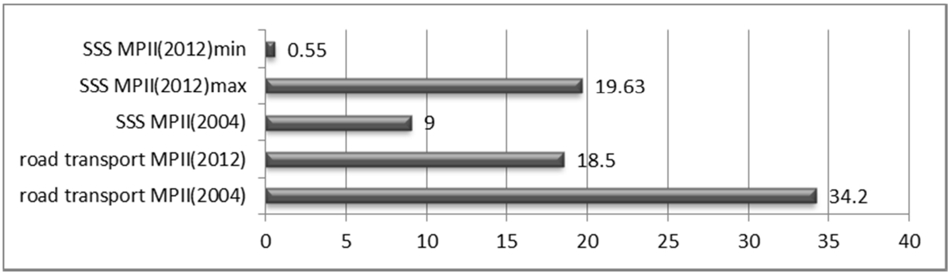
The first publications considering the aspect of external costs in sea shipping clearly pointed out that the maritime transport is much more environment-friendly than road haulage. *Proposal for a Regulation of the European Parliament And of the Council, on the granting of Community financial assistance to improve the environmental performance of the freight transport system* (2002) pointed out that the external costs generated by short sea shipping were six times lower than those generated in road haulage. The difficulties of valuation of external costs of transport result from a different level of impact that transport has on the environment; here, the impact depends on the level of traffic. Every vehicle has a different effect on traffic flow, and therefore on level of pollutants and greenhouse gases emissions, traffic accidents and congestion.

Many programs aiming at the assessment of the external costs of transport based on marginal costs methodology (e.g. UNITE, 2003; RECORDIT, 2003) have been realized from the beginning of the 21st century. In INFRAS/IWW (2004) authors presented the total and average external costs generated in road, rail and air transport, as well as in inland shipping for EU 17 countries.

On the basis of the aforementioned programs a method of calculating external costs of transport for the purposes of Marco Polo II Program (MPII) was developed in 2004. (Ex ante Evaluation Marco Polo II 2007-2013, 2004). In the program, the external costs generated in short sea shipping were definitely higher than in the Proposal quoted above, nevertheless, they were three times lower than in road haulage. As far as the pollution emission and noise generated by the transport means as well as the level of road safety is concerned, the progress achieved in road haulage in the last 15 years made the external costs of the mode of transport significantly lower (Geurs and van Wee, 2004). When compared to all other transport modes, the scale of reduction of external costs generated by road transport was the greatest one. In 2006, a guide with a consistent methodological framework for the assessment of the project in terms of social benefits was published (HEATCO, 2006). In contrast to the publications mentioned previously, authors proposed valuation method based on unit costs of emissions and the costs of individual accidents. This approach allows us to evaluate the external costs differently for each means of transport.

The fact that MPII did not reflect the diversity of external costs depending on capacity, fuel consumption and emission standards of transport means led to a revision of the method of valuation of external costs of transport. In 2012, new directives concerning the assessment of the external costs of transport for the needs of Marco Polo II Program were published (Brons and Christidis, 2012). This caused simultaneous changes in the level of external costs. The new version proposed nearly two times lower external costs generated in road transport than those in the version from 2004. In maritime transport, external costs ranged from EUR 0.55 /1000 tkm for bulk or general cargo and LNG fuelled vessel up to EUR 19.63 /1000 tkm for Ro-Ro or Ro-Pax, Hi-Speed and high sulphur fuelled vessel, while in MP II (2004), the external cost generated in maritime transport was equal to EUR 9 /1000 tkm for all SSS ships.

Figure 1 External Costs in Short Sea Shipping (SSS) and in Road Transport Proposed in Marco Polo Program (EUR/1000tkm)



Source: own drawing based on: European Commission, 2004; Brons and Christidis, 2012.

Table 1 Emission of Pollution in Road and Sea Transport on Cargo |Unit* (CU) (kg/CU·1000km)

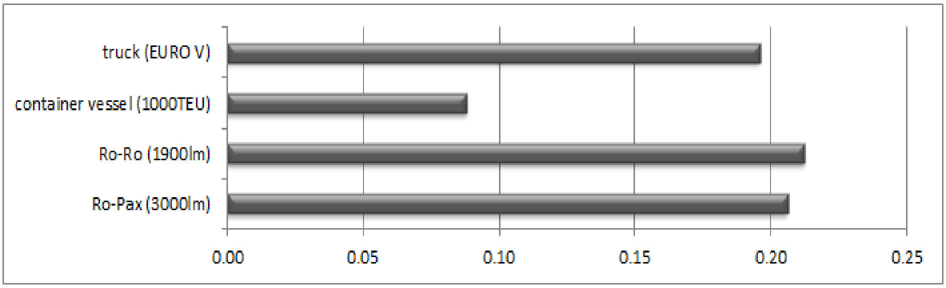
contamina-tion	Ro-Pax (3000lm)	Ro-Ro (1900lm)	Container ship (1 thou. TEU)	Truck (EURO V)
CO_2	1,492.39	1,535.94	478.24	1506.43
NOx	33.16	34.13	15.04	1.66
SOx (SECA 2010)	10.46	10.77	3.35	0.05
SOx (SECA 2015)	1.05	1.08	0.34	0.05
NMVOC	1.20	1.24	0.50	1.05
PM	1.99	2.05	1.46	0.20

**Cargo Unit- semitrailer or 45'container*
Source: Kotowska, 2014.

A research of external costs conducted by Castels et. al. (2012) based on three model vessels: a container ship, a Ro-Ro and Con-Ro vessels, and one road truck (of up to 50-ton capacity) showed that the external costs generated by Ro-Ro and Ro-Pax ships present higher values than road transport. The Ro-Ro ship generates EUR 0.0046 / tkm and Ro-Pax ship generates EUR 0.0073 / tkm, while road transport only EUR 0.0029 / tkm. Slightly different, however, also confirming the fact that Ro-Ro vessels and ferries generate considerably higher external costs than it had been so far believed, are the results presented by the research realized within the NSC (2013). The analysis of the pollution emission developed on the basis of real fuel consumption showed that the model Ro-Ro and Ro-Pax ships emit significantly more sulfur dioxides, particulate matters and non-methane volatile organic compounds than road vehicles (table 1) (Kotowska, 2014).

However, the external costs appear significantly lower than it might be supposed on the basis of the pollution level alone. Most of the pollution generated by vessels is produced away from inhabited areas and that is why they affect human life and health to a much lesser extent. Moreover, ships generate considerably less noise and congestion that are so common in road traffic; in sea transport, these are a rare phenomenon (Kotowska, 2013). Not without significance is the fact that in comparison to road transport, there are much fewer accidents involving fatalities in maritime transport. In 2009, about 35 thousand people were killed and further 1.5 million injured in road accidents on the territory of the European Union (Eurostat Database, 2013), whereas in the same period, 559 accidents and 52 fatalities of seafarers occurred in maritime transport within the water areas of the European Union countries (European Maritime Safety Agency, 2010). Figure 2 presents the external costs generated by Ro-Ro and Ro-Pax vessels which are slightly higher than the costs generated by 40-ton Euro V road truck.

Figure 2 External Costs in Road Transport and Short Sea Shipping [EUR/(cargo unit*km)]



Source: Kotowska, 2014.

Methodology

On the basis of the study results presented in Fig.2, a conclusion might be drawn that Ro-Ro and ferry transport, against common opinions, not always brings more social benefits than road transport. However, the analysis based only on unit external costs may lead to erroneous conclusions. The course of sea shipping route does not usually cover the route of the road transport, and therefore the lengths of both routes can considerably differ, which significantly affects the total external costs generated by them.

The main purpose of transferring the cargo from road transport to land-sea transport chain consists in reducing total external costs. Therefore, the benefits (B) from this transfer can be identified as the difference between total external costs generated in road transport (EC_{RT}) and alternative land-sea transport chain (EC_{LS}):

$$B = EC_{RT} - EC_{LS} = l_{RT} \cdot ec_{RT} - l_{LS} \cdot ec_{LS} \tag{1}$$

where the unit external costs (ec_{LS}) in land-sea transport chains is calculated as follows:

$$ec_{LS} = \frac{ec_{RT} \cdot l_{PH} + ec_{MT} \cdot l_{MT}}{l_{PH} + l_{MT}} \tag{2}$$

where:

l_{LS} – length of land-sea transport chain (km)

l_{PH} – length of pre-haulage in land-sea transport chain (km)

l_{MT} – length of maritime transport in land-sea transport chain (km)

l_{RT} – length of alternative road transport (km)

ec_{RT} – unit external costs in road transport ($\frac{EUR}{cargo\ unit \cdot km}$)

ec_{LS} – unit external costs in land-sea transport chain ($\frac{EUR}{cargo\ unit \cdot km}$)

ec_{MT} – unit external costs in maritime transport ($\frac{EUR}{cargo\ unit \cdot km}$)

If we assume that the unit external costs generated by ferries and Ro-Ro (ec_{MT}) ships is the same as in road transport (ec_{RT}) then based on the research results presented on fig. 2 , the equation 1 can be simplified as follows:

$$ec_{MT} = ec_{RT} = ec \tag{3}$$

the equation 1 takes a form:

$$B = (l_{RT} - l_{MT}) \cdot ec \tag{4}$$

considering what has been mentioned above, it can be concluded that:

$$\forall l_{RT} > l_{LS}: B > 0 \tag{5}$$

Formula 5 informs that all Ro-Ro and ferry lines, where shipment is reducing transport distance of freight comparing to alternative road transport, also contribute to reduction of external costs of transport, and thus play an important role in the sustainable development of transport.

It is not possible to evaluate the impact of this segment of the shipping market on sustainable transport development without analysing the shipping lines' courses, since in the case of sea shipping, the shipment route does not cover the alternative road haulage route. This significantly affects the ratio between the lengths of both transport ways and, hence, the total external costs in both transport chains.

To answer the questions of *whether*, and if so, then *how ferry and Ro-Ro shipping contribute to development of sustainable transport*, an author's analysis of ferry and Ro-Ro lines operating within the European transport system was carried out. For the purpose of the analysis the database comprising of 878 ferry and Ro-Ro lines operating on the Baltic, North and Mediterranean Seas was executed. The database covered the following issues concerning the shipping lines:

– port of departure
– port of destination
– the sea distance between the terminals

- time of the voyage
- type, age and size of the vessel operating the line.

For each of the analyzed shipping line characteristics of the alternative road connection (if there was any) was determined: the distance and average time of truck haulage. Road haulage time was determined at the average truck's speed of 60kph including the mandatory rest time for drivers according to the dependence:

$$T_{RT} = \begin{cases} t_{js}, & t_{js} \le 20 \\ t_{js} + 10.5; & 20 < t_{js} \le 40 \\ t_{js} + 21; & 40 < t_{js} \le 58 \\ t_{js} + 31.5; & 58 < t_{js} \le 76 \\ t_{js} + 42; & 76 < t_{js} \le 94 \end{cases} \tag{6}$$

where:

T_{RT} – Total time of the road haulage (h)

t_{js} – Time of the vehicles' haulage (h)

On the basis of the data collected a classification of shipping lines according to the criterion of the lines' substitutability in reference to road transport was conducted. The suggested classification is expressed by the possibility of substituting sea shipment by its alternative land transport and the ratio between the lengths of the land-sea transport chain and the land chain. Membership of ferry and Ro-Ro lines in their particular categories determine their role in the sustainable transport development.

Results

73% of the ferry and Ro-Ro lines considered are mandatory (without alternative land routes), out of which approximately 63% connect island regions (as the only connections with the mainland) and the other 10% are the lines for which, due to the lack of appropriate infrastructure, there is no possibility of road transport. The first group covers connections with the Italian, Spanish, Portuguese, French and Greek islands on the Mediterranean Sea (35% of all the analyzed connections) operated mainly by passenger-car ferries (only 16% is operated by Ro-Ro vessels), connections between Danish, Finnish as well as the British islands with the mainland. The second group includes mainly the shipping lines between European ports of the Mediterranean Sea and the African ports (30% of the line serviced by Ro-Ro vessels).

If we take into consideration the lack of the possibility to replace these lines with the alternative road transport, it cannot be assumed that these lines in any way contribute to reduction of external costs of transport. This does not mean, however, that they do not contribute in any way to sustainable transport development. The lines enable meeting transport and commercial needs of the inhabitants, improve safety and support development of tourism, and thus contribute to social-economic development, which is one of the priorities of sustainable development.

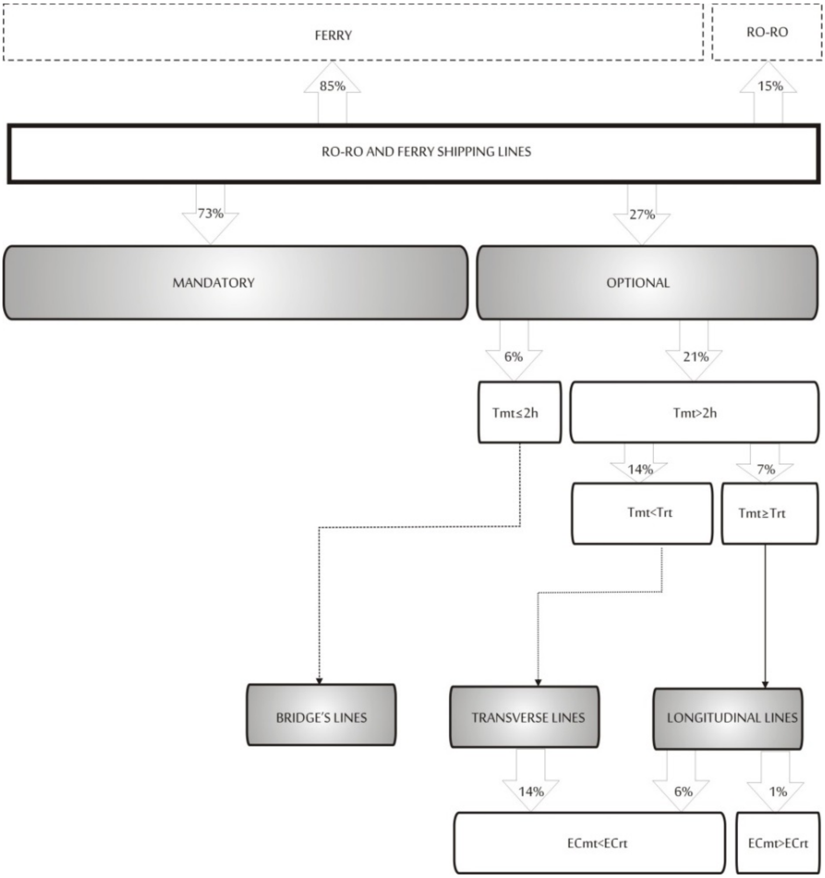
27% of all the lines in our analysis are of optional character. They can be divided into three types:

- bridge lines

– transverse lines
– longitudinal lines.

The classification of ferry and Ro-Ro lines is presented in Figure 3.

Figure 3 Ferry and Ro-Ro lines Classification



Source: own drawing.

– T_{mt} – voyage time
– T_{rt} – road haulage time
– C_{mt} – external cost in maritime transport
– EC_{rt} – external cost in road transport

Bridge type shipping lines (6% of shipping lines identified) are short lines of up to 2 hours of haulage time. They make natural extensions of land roads and are serviced only by ferries. Some bridge lines appear to be alternatives to permanent infrastructural constructions, e.g. Rodby-Puttgaden line is an alternative connection to the bridge between Nyborg and Korsør. The lines service self-propelled units, and their development is closely connected with the dynamics of road freight. Rather than being competitive to road freight, they contribute to its development. Due to the role they play, they do not contribute to the reduction of the transport external costs, either.

The second group (about 14% of all identified lines) makes transverse lines, where the voyage lasts over 2 hours but shorter than via the alternative road haulage. Similarly to bridge lines, these lines are complementary to land routes. They are mainly lines connecting terminals located on the opposite coastlines of closed water areas, e.g. the Baltic Sea, the Adriatic Sea and the northern part of the Mediterranean Sea (figure 4).

Their strong competitive position is due to the fact that both the time and the cost of freight via these lines are lower than those in road haulage. The time of shipment which approximately equals the mandatory rest period for drivers is an additional advantage for about 30% of them. The significance of the lines has increased with the introduction of restrictions concerning drivers' working time as well as the road fees on European highways, due to which some of the freight was transferred from bridge lines to transversal lines. Thanks to their shortening of the freight distance, out of all the analyzed ferry and Ro-Ro lines, these lines contribute to the reduction of external costs of transport to the greatest extent.

Figure 4 Ro-Ro and Ferry Transverse Lines.

Source: own drawing.

The third group includes lines where the voyage takes longer than the alternative road haulage, which makes their competitive position weakest in relation to the road haulage when compared to the above identified groups. The lines feature high substitutability in relation to road shipment. As routes of most of them are parallel to the continent coastline, they can be defined as longitudinal. They constitute only 7% of the identified ferry and Ro-Ro lines, and most of them are serviced by Ro-Ro ships.

Longitudinal lines are primarily connections in the following relations:

- west - east on the Baltic and/or North Sea connecting mainly Finland and Sweden with Belgium, Great Britain, Germany and Poland, Germany with Russia, Lithuania and Latvia, as well as the lines on the Mediterranean Sea, e.g. between Italy and Spain, Italy and Turkey, or Belgium and Spain;
- north – south, e.g. between Norway and Germany or Belgium and Great Britain (figure 5).

Figure 5 Ro-Ro and Ferry Longitudinal Lines.

Source: own drawing.

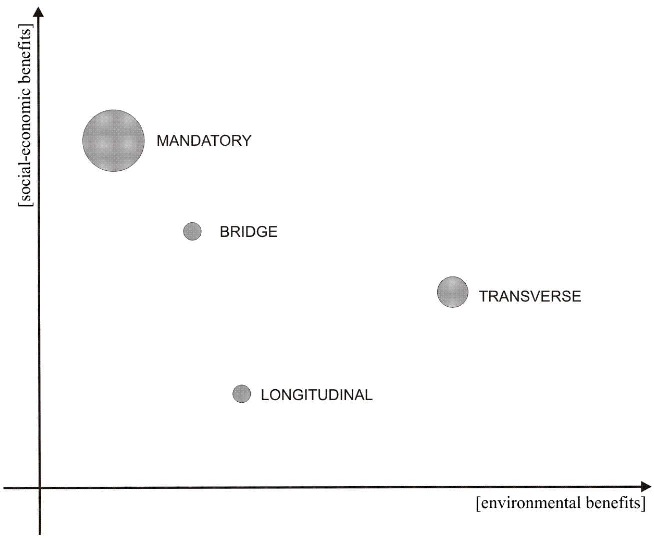
Due to the course of the longitudinal lines in relation to the alternative road routes, and bearing in mind the presented analyses concerning the external costs generated by Ro-Ro ships, ferries and road vehicles, social benefits resulting from the shipment via these shipping lines may seem disputable. However, it is worth emphasizing that routes of 43 out of 52 shipping lines classified into this group were shorter than the alternative road routes. Only 9 connections did not meet the criterion. This does not change the fact that the cargo transported on longitudinal lines may generate higher external costs than the direct low-emission (Euro V norm and higher) road vehicle transport. Especially due to the fact that in order to assess total external costs generated in land-sea transport chains correctly, costs of pre-haulage transport as well as the costs generated in the port terminals should be considered.

Conclusions

The answer to the questions of whether, and if so, then how ferry and Ro-Ro shipping contributes to the development of sustainable transport is not obvious. The impact of the shipping lines analyzed on sustainable transport depends on their length, duration of voyage, the course in relation to the road route and the type of the vessel they are serviced by.

Three fourths of the Ro-Ro and ferry shipping lines operating within the European shipping market are of mandatory character, and their activity brings rather social-economic than environmental benefits. They contribute to sustainable development by meeting the transport and trade needs of the inhabitants. They improve the safety of the regions and influence development of tourism.

Figure 6 The Influence of Identified Types of Ro-Ro and Ferry Lines on Sustainable Transport



Source: own drawing.

The rest of the Ro-Ro and ferry shipping lines is of optional character and has to compete with direct road transport. The majority of the other shipping connections serviced by ferries and Ro-Ro vessels contribute to shortening of shipment route in relation to the alternative road transport and, hence, to reduction of total external costs generated in transport**,** which is the main aim of sustainable development. Despite the fact that they reduce the freight distance, bridge lines are natural extensions of land routes and thereby contribute to their development. Their impact on sustainable development is low, and rather than from reducing the external costs, it results from socio-economic benefits (just like mandatory lines). The third group of optional lines, longitudinal lines, do not contribute to reduction of external costs resulting from environmental pollutants. The impact on sustainable development results rather from the fact that by transferring the cargo from road to sea, they reduce the road congestion and accidents. The influence of identified types of Ro-Ro and ferry lines on sustainable transport is presented on figure 6.

To sum up, it needs to be stressed that not in all conditions of maritime shipment bring more environmental benefits than direct road haulage. External costs in short sea shipping are affected significantly by fuel consumption which depends upon the vessel's load capacity, her age and operational speed. Voyage duration, the number of ports in a round trip, and the distance at which cargo is transported to/from the port hinterland are factors that have their significance, too. The benefits resulting from the short sea shipping in each case should be assessed individually.

Despite the ambiguous results, support of development of short sea shipping may be substantiated by the fact that in maritime transport, unlike in the other transport modes, there is a possibility to considerably enlarge vessels' capacity. The permissible parameters of ships employed in short sea shipping do not result from legal conditions (as it is the case in road and rail transport) but from natural or infrastructural limitations. In practice, it means that together with dredging navigable canals, fairways of the port entrance or building new deeper quays, conditions for launching bigger size vessels to be operated will be created, which shall result in further reduction of unit external costs generated in maritime transport.

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