WMU Journal of Maritime Affairs, Vol. 8 (2009), No.1, 27–45

The External Cost of Speed at Sea: An Analysis Based on Selected Short Sea Shipping Routes

Xavier Martínez de Osés and Marcella Castells*

Universitat Politècnica de Catalunya

Abstract

According to the mid-term review of the EU White Paper on Transport, Short Sea Shipping (SSS) is expected to grow at a rate of 59% (metric tonnes) between 2000 and 2020. If we consider that the overall expected increase in both freight exchanges and volume is 50%, sea transport is one of the most feasible alternatives to reduce traffic congestion on European roads. Maritime transportation may compete with road transport as far as certain traffics are concerned, but only when assuming external costs. This paper analyzes several intermodal transport chains involving a sea leg by comparing the effect of pollutant emissions from different ship types and road transport in terms of potential external cost savings. The translation of these emissions into environmental costs shows, for certain conditions, savings in the case of sea transport that would justify the use of an environmental bonus to promote the sea option.

Key words: Short Sea Shipping, Southwest Europe, External Costs, Environmental Bonus

1 Introduction

The European transport policy undertakes to enhance sustainability in transport in order to boost economic activities in the whole European Union. The reduction of pollutant emissions and a better balance among transportation modes to cut road congestion are the pillars of the above policy. Although most developed countries use their national road network to transport freight despite its high cost, pollutant conditions and high rate of fuel consumption per cargo unit (Baird 2004), some public and private stakeholders have began to use freight rail and maritime options more extensively in search for a better alternative.

Maritime transport is one of the least polluting modes of transportation. Additionally, it contributes to the reduction of traffic congestion on European roadways. In particular, short sea shipping is considered the fastest way to sustainability although it could pose problems such as higher traffic growth rates and a subsequent increase of pollutant emissions in port areas. On the other hand, another advantage of ships over trucks and trains is that vessels need less fuel as a result of the relatively low

* Lecturer, Nautical Science and Engineering Department; Lecturer, Vice Dean of Institutional Relationships, Faculty of Nautical Studies of Barcelona, Technical University of Catalonia, Pla de Palau, 18, 008003 Barcelona, Spain, emails: {fmartinez; mcastells}@cen.upc.edu

 ISSN: 1651-436X print/1654-1642 online

speeds at which they travel (Mulligan and Lombardo 2006). Nevertheless, the IMO MEPC has noted that although sea transport is a fuel-efficient alternative, special attention must be paid to the issue of greenhouse gases (Burgel 2007).

Today increasingly faster ships are in a position to compete with trucks. However, the greater power demand and consumption rate of the former result in higher pollutant emission levels which, in turn, lead to the loss of their environmental advantage over road transport. This problem is analyzed below.

The present paper is divided into four sections. First, a brief review of previous research in this field by European research groups is presented. Second, environment regulations applied to transport policies and external impacts are defined. Next, the external costs of a particular short sea shipping route in SW Europe are quantified and evaluated. Finally, the conclusions propose an environmental bonus based on external cost savings associated with the use of the short sea alternative instead of road-only transport.

2 Previous Research

In 2005 the TRANSMAR research group, which belongs to the Technical University of Catalonia, initiated the INECEU[1] project which, after an exhaustive study, suggested alternative intermodal lines to road transport in SW Europe. Keeping in mind the figures of road traffic crossing the Pyrenean borders, the group analyzed most of the volumes moved between France, Italy, Germany and Spain.

Regarding the nature of the cargo, we should note that the South and South-East of the Iberian Peninsula, together with the Valencia coast, are big producers of fruit and vegetables, manufactured and canned food, and alcoholic drinks. These products are some of the largest cargo groups exported from Spain. Traffic also involves the transport of solid bulk such as building materials or scrap iron, along with oil and chemical products from ports near oil refineries. The study recommended to avoid using trucks for carrying dangerous or toxic substances and use ships with specially designed containers, or Ro/Ros, instead, which will provide a benefit to society as a whole. This study was further extended in other projects in 2007, where the environmental efficiency of several ships with different output power engines was assessed. Source data have been obtained from the REALISE[2] project, which concluded that higher speeds imply higher fuel consumption rates and result in increased pollutant emission levels. On the other hand, fast ships have a limited cargo capacity; in consequence, they are extremely environmentally inefficient in terms of fuel demand per tonne of freight.

1 Intermodality between Spain and Europe. Project funded by the Spanish Ministry of Transport (2005).

2 REALISE Project: Regional Action for Logistical Integration of Shipping across Europe. AMRIE. [http://www.realise-sss.org] (2005).

As far as environmental performance is concerned, several attempts have been made to estimate external costs in the transport sector. The most important results were obtained by some research projects, especially those within the 4th, 5th and 6th EU-framework programmes. Other projects that conducted similar research are RECORDIT[3], ENTEC[4], UNITE[5], INFRAS[6], ExternE[7], MOPSEA[8], EMMOSS[9], EMSA[10], iTREN-2030[11], and IMO proposals.

The principle of charges reflecting the marginal cost of resources used is aimed at efficiency and equity (COM(95)691). If users perceive the full cost of their actions, then, they will make efficient choices between modes (and in the decision of the extent to travel as well). The equity argument requires users to pay in some way for the full cost of their actions. The case for marginal cost pricing has been put forcefully by the 2001 White Paper (COM 2001(370)). In this argument there are two distinct strands. One concerns the principles for infrastructure charging and the other the integration of external costs. A White Paper of 1998 (COM(98)466) examined means of levelling off the diversity found in infrastructure charging regimes both between member states and between modes. The Paper proposes a framework of charges based on the 'user pays' principle, which should also include a charge for any external costs that the user imposes. The charges, it argues, should be based on marginal costs and, if possible, vary according to the type of infrastructure used, the time of day, the distance covered, and the size and weight of vehicles.

The values and valuation conventions of the UNITE project (Nellthorp et al. 2001) were considered in the RECORDIT project. The first cost component (a) was the willingness-to-pay (WTP) for safety by the vehicle user for fatalities was taken from UNITE, as were risk values for severe and light injuries (estimated as 13% and 1% of the risk value for fatalities). In accordance with UNITE, no explicit estimate for component (b), the WTP of relatives and friends is applied.

For air pollution damages, recent studies relied on the ECOSENSE model (also often cited as the "EXTERNE model") developed by IER within the EXTERNE project series. Differences in results between the updates of the EXTERNE project stem from updated valuation and updated meteorological data. Different assumptions concerning

---

3 Real cost reduction of door-to-door intermodal transport. AMRIE (2001).

4 Quantification of emissions from ships associated with ship movements between ports in the European Community. Chris Whall et al. (2002).

5 Unification of accounts and marginal costs for transport efficiency, (2003).

6 Report evaluating transport external costs, funded by UIC (2004).

7 ExternE Project: Externalities of Enegy, supported by the E.U.[www.externe.info] (2005).

8 Monitoring Programme on air pollution from SEA-going vessels. Annick Gommers et al. (2006).

9 Emission model for maritime, inland waterway and rail for Flanders. Transport & Mobility, Leuven (2007).

10 Air emissions from ships working paper to inform member states' discussions in relation to the revision of MARPOL Annex VI, Workshops on air emissions from ships (2007).

11 EU project initiated in 2007. Network analysis tool for transport in the EU, scenario forecast for 2030 covering transport, energy, environment and economy.

particle emissions (non-exhaust particle emissions are not included), use of "years of life lost" (rather than "per case of fatality") and site dependent differences across Europe influence the comparison with the most authoritative study on air pollution.

The assessment of externalities from global warming focuses on carbon dioxide emissions. A value of 37 euro per tonne of CO_2 emitted is used, which is based on an "avoidance cost" approach to reach a specific target. The target applied is of a 5.2% reduction; equal to the OECD average agreed at the Kyoto process and is regarded as a EU-wide reduction target. A cost-effectiveness analysis was applied in order to reach the target in the optimal way. Finally, the external congestion costs were estimated in the RECORDIT project by modelling the interaction between demand and supply on the road network under consideration. Time losses are quantified by the use of speed-flow curves, which demonstrate the impact of an extra vehicle on overall speeds (and hence the extra delay caused).

The mentioned results on external costs could be compared with the findings from six other studies like INFRAS/IWW (2000), EXTERNE (2000), PETS (1998), QUITS or TRENEN II STRAN (1998). All of these studies were concerned with passenger as well as freight movement, considering those external costs as a whole. RECORDIT (and thus REALISE) results were expressed at emission factor costs, which is the method used by the authors to compare the external costs of road and sea transport chains. Some other approaches developed in Europe should be mentioned, such as the MEET (Methodologies for estimating air pollutant emissions from transport), which describes a methodology for calculating the emissions from sea-going vessels, among the methodology for the other transport modes. The company ENTEC UK Limited conducted a study on behalf of the European Commission to quantify, among other aspects, the ship emissions of SO_2, NO, CO_2 and hydrocarbons for the year 2000 in the North Sea, the Irish Sea, the English Channel, the Baltic Sea and the Mediterranean. For the PM pollutant, they only quantified the in-port emissions.

We should also note the importance of several projects with respect to external costs of transport. The EMS (Emission registration and -Monitoring for Shipping) project, carried out by the Dutch AVV (Adviesdienst Verkeer en Vervoer), which had as target mapping the different emissions from sea-going vessels in inland shipping for the Netherlands. The TREMOVE, which stands for Transport & Mobility Leuven, used its own transport model TREMOVE and the methodology set up by ENTEC to calculate and record the emissions from sea-going vessels. It is also worth mentioning the TRENDS (TRansport and ENvironment Database System) project, in which the authors set up a methodology to determine the emissions from the four most important transport modes (road transport, railways, shipping, aviation). The TRENDS methodology was used also in some RECORDIT modules like in the "Energy Consumption and Air Pollutant Emissions from Rail and Maritime Transport". However, most of the methodologies did not pay any attention to the technological evolution of sea-going ships. The EMS approach was the only exception with respect to this and it was further used in the MOPSEA project.

3 Environmental Balance of Transport Activities

Through its sustainable development strategy and the White Paper on transport, the European Union has expressed its interest in reducing transport-related impacts. In this sense, a common set of measures has been proposed to respond to environmental threats from transport activities. Regarding road transport, the European Parliament has adopted the Euro V and VI, which are increasingly stricter regulations on vehicle pollutant emissions, in particular particle emissions and nitrogen oxides (NO_X) limits. Coming into force on 1st September 2009, the Euro V establishes an 80% decrease in particle emission limits, which implies the need of fitting particle filters in vehicles in the future. The Euro VI will come into force in 2014 and will impose stricter limits to reduce nitrogen oxides up to 68% of current levels.

Maritime transport emissions are mainly regulated by the MARPOL Convention and some specific European regulations. The new regulations regarding SO_2 and NO_X maximum emission levels aim to reduce this kind of pollutant components, which will be the weak point of maritime transport in the future. Of all modes of transport, the maritime one is responsible for the largest amount of SO_2 emissions into the atmosphere, which is only compensated by the use of low sulphur fuels or exhaust gas cleaning systems. However, sulphur emissions from maritime transport only account for 6% to 12% of total anthropogenic emissions (Chengfeng 2007).

Figure 1. Fantastic Ro/Pax ship berthed at Barcelona port (Source: www.merchantships.info)

Despite this scenario, in 2000 about 44% of total NO_X emissions into the atmosphere in Europe were attributable to road transport and 36% to maritime transport (TERM 2002). Road transport is the main source of CO_2 emissions, contributing 91.7% to EU transport greenhouse gas emissions. When including sea shipping in a breakdown of transport-related CO_2 emissions, it appears that, in Europe, maritime transport accounts for only about 6% of total greenhouse gas emissions, which explains the interest in reducing the share of road transport.

Unlike the positive balance of atmospheric emissions from maritime transport, the balance for road transport is negative. This justifies the support actions to intermodal chains with marine sections based on short sea shipping links as a way to maximize sustainable mobility within Europe. Therefore, maritime transport has a clear environmental advantage over other modes. Additionally, traffic congestion, accidents and noise costs are minimized. As a result, sea transport is regarded by many as a better alternative (European Commission 2001).

Nonetheless, High Speed Crafts' progressive entrance into short sea shipping traffics as a way to compete with road speeds also involves greater fuel consumption rates because of high output engines and increased emissions, not forgetting that the oil price poses an economic threat to operating companies.

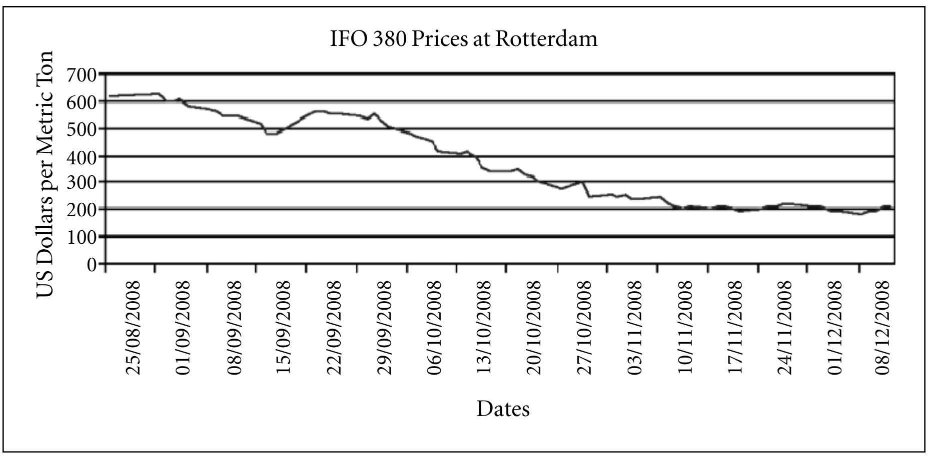

Figure 2. Evolution of IFO 380 prices in USD per metric ton during four months of 2008 (Source: Own, based on www.bunkerworld.com data)

Table 1. Routes obtained from the ANTARES study

Route	Origin	Loading Port	Discharging Port	Destination
Route 1	ZAL Azuq. of Henares	Valencia	Naples	Naples
Route 2	ZAL Barcelona	Barcelona	Civitavecchia	Rome
Route 3	Zal Alicante	Alicante	Genoa	Milan
Route 4	CETABSA Burgos	Tarragona	Genoa	Milan
Route 5	CTB Benavente	Gijón	Hamburg	Berlin

Other factors affecting the pollutant emissions level from short sea shipping are fleet age and the increase in number of trips.

4 Study Methodology

This section compares the environmental impact and the external costs for five intermodal routes considered more efficient than the same link served by a unimodal chain. We have considered three different speed ships (conventional, fast conventional and high speed), using data from REALISE, a thematic network on short sea shipping which provides prices of external costs from both sea and road transport. The selected target routes, the most efficient in the ANTARES study[12], all leave from Iberian Peninsula ports and have different destinations in Western Europe (Table 1).

The selected Ro/Pax ships' particulars are shown in Table 2:

Table 2. Main particulars of analyzed Ro/Pax ships

Ship	Linear Meters (ml)	Speed (knots)	Power (kW)
Conventional	1850	18	25916
Fast convencional	1700	27	31680
High speed craft	900	40	68000

The following criteria are considered in our study:

The REALISE project took the datasets in the EIG (2002), based upon the COPERT III calculation module, which were the most recent and complete available. We propose to take these datasets into consideration with regard to the estimation of fuel consumption by trucks. The data are given in g/km. The calculation unit used by the authors gives the consumption in g/tkm.

The air emission factors for road transport were derived from the most recent EIG report and were given in g/km. The air emission factors in g/kg fuel were calculated taking the fuel consumption into account. Since not all the pollutants were listed in the EIG report, additional information was extracted from the CBS database with regards to SO_2 and CO_2 emissions. We must note that the S has a negative environmental impact value (i.e. a positive environmental impact). Its cost had to reflect this positive impact.

The basis for these emissions is the EURO V specifications that will be applied in September 2009. The cost of each ton of pollutant was taken from the RECORDIT project, which also took them from the final report of the EXTERNE project. The noise and accident values were taken from the report Friends of the Earth published

12 Environmental efficiency analysis on the different typology of high speed ships in short sea shipping lines against their alternative on road. Research group TRANSMAR. Department of Nautical Science and Engineering. UPC. Barcelona (2007).

in February 2000. This report analyzes the external costs for transports using train, ships and trucks with the same cargo on four different routes. In 1997, the Federal Highway Authorities published a study on Estimated Highway Congestion costs on a high number of situations ranging from countryside to cities (FHWA, *1997 Federal Highway Cost Allocation Study*, USDOT). The medium estimate for all highways was set at 9.11 cents per mile.

a. The cost categories are divided into two:
   – Environmental external costs: local air pollution, global warming and noise pollution.
   – Non-environmental external costs: accidents and traffic congestion.
b. To evaluate the impact of the evolution of transport emissions, the scenario considered is a future hypothetical improved condition in which stricter regulations are applied, like the Euro V, to road (in force for new trucks as of 2009) and maritime transport, resulting in a 10% decrease in all current emissions, except for S, SO_2 and NO_X.
c. The cargo capacities of the selected Ro/Pax ships are considered, keeping in mind that they are real ships serving short sea shipping traffic, as the conventional one in Figure 1. Cargo capacity was calculated dividing the ship's total linear capacity by 19.5 meters,[13] including the number of trucks (assumed FEUs) that the ship is able to carry (Table 3). The cargo is measured in FEU (very close to trailer length) as it is the common unit of freight in sea and road legs and we assume the container to be filled to 75% of its full capacity[14]. Thus, the maximum container payload of 25 tons (maximum total weight allowed is 40 tons) is limited to 18.5 metric tons on average. This is in line with the hypothesis drawn in the REALISE inception report.

Table 3. Cargo capacity of Ro/Pax ships

Ship Type	Cargo Capacity in (FEU)
Conventional ship	128
Fast conventional ship	94
High speed craft	50

d. The main engine specific fuel consumption rate is strongly affected by the propulsion systems installed, such as engine (Table 4), gear, shaft and propulsion arrangements. Nevertheless, modern diesel engines use half the fuel consumed daily by old inefficient steam engines with the same power outtake (Endresen et al. 2007).

13 Trailer length is considered 19.5 meters, as stated by the EC Directive 2002 of 18th February 2002 as maximum length for an articulated trailer of 16.5m, 1.5 meters being added between trucks.

14 Data obtained from the Emission Inventory Guidebook (EIG) on the COPERT III calculation model (2002).

For instance, the largest old passenger liners, like the Olympic and the Titanic, burned 620 tons of coal per day at 21.7 knots on average[15].

The main reasons for the decrease in consumption lie in the improved energy efficiency of the fleet (note the phasing out of steam ships) and the reduction in speed and installed power in certain types of vessels. For our purposes, we consider the hourly consumption of each ship on the basis of 200 g/kW per hour. Because almost all ships mentioned here are propelled by four-stroke diesel engines, the final consumption rate depends on the main engine output and working rate.

Table 4. Specific fuel consumption (SFC) for different engine and fuel types (Source: Endresen et al. 2007)

Engine Type	Reported SFC in g/kWh
Diesel	200–240
Turbine oil	290–305
Turbine coal	
Steam engine oil	700
Steam engine coal	

Although the total fuel consumption rate depends on the maximum engine output, the average power is assumed to be 85% of MCR (Maximum Continuous Rate) of installed power. However, the average main engine load and speed vary dramatically for different ship types. Some authors have reported an average load of 80% MCR based on statistical data. For example, bulk carriers tend to have slightly lower average values (72% MCR) than tankers (84% MCR). Accordingly, load can range from about 60% MCR up to 95% MCR for the analyzed ships (Floedstroem 1997). For our purposes, the selected engine load was fixed to 80% of engine load when sailing and 20% for time spent at ports during operations (Table 5).[16]

Table 5. Hourly consumption based on engine load and power

Ship Type	Speed	Tm/Hour (80%)	Tm/Hour (20%)
Conventional ship	20	4,1472	1,0368
Fast conventional ship	27	5,0688	1,2672
High speed craft	40	10,88	2,72

15 Encyclopaedia Titanic, http://www.encyclopedia-titanica.org/discus/messages/5919/6509.html

16 On page 15 of the paper by Endresen et al. 2007, they explains that the fuel consumed by auxiliary engines in ports and at sea may amount to less than 10% of installed power. We adopt a 20% figure in view of the greater amount of electric power required by a Ro/Pax ship as that considered in our study.

e. The emission factors considered are taken from the REALISE database. The following are the results for Route 1, i.e. between Valencia port and Naples port, with a conventional ship.

Table 6. Calculation of initial data and results obtained for the conventional ship

	Origin	Destination
Route	Azuqueca Henares	Naples
Road unimodal distance (km)	2106.4	
Maritime distance (km)	1314.9	
Road intermodal distance (km)	374.1	
Ship's name	Fantastic	
Linear meters	1850	
Speed of ship (in knots and km/h)	18	33.336
Ship's Power (kW)	25916	
Number of FEU (theoretical)	66	
Load factor (SHIP)	70%	
Hours of navigation by SSS	39.44	
Type of ship	Conventional ship	

	Fuel Consumption (kg/h)	
Fuel consumption (kg/h) SHIP	5183.208	
Load (truck) – maximum 25 Tm	18.75	
Load Factor (Truck)	75%	

Obligatory data (shaded) | Data obtained (unshaded)

The above data allow assessment of the external costs for the entire unimodal (road) and intermodal chains in the selected route. Total truck fuel consumption per trip is obtained by multiplying road distance from origin to destination by consumption per kilometre and we assume that 80% of the total distance is covered by road transport and 20% is under congestion conditions. Truck consumption rates are also estimated in 15.8 grams of fuel per metric tonne and kilometre on highway and 25 g/Tm x km under congestion conditions (Source: REALISE project data). Emission prices are not related to fuel costs but to costs assumed by society, mainly the pernicious effects of pollutants on human health and the public health system.

Tables 8, 9 and 10 display the results of external costs in Route 1 comparing the unimodal chain and the intermodal chain (with a conventional ship). The calculations in these tables, based on the emission factors from the REALISE project shown in table 7 illustrate the environmental impact on the proposed route by the selected vehicles.

Table 7. Emission rates considering diesel EURO V for road transport and for sea transport 10% less of the environmental impacts than actual situation on all fronts except for S and SO_2 emissions are expected to be regulated more severely. Emission of that pollutant is expected to go down by 40%, due to the foreseen implementations of certain regulations. A final exception is NO_X, which is supposed to go down by nearly 50% (Source: Own based on Technologies and instruments for ship emissions abatement. In Ship emissions of SO_2 and NO_X: The need and strategies for future reductions. Katholieke Universiteit. Leuven, 2003)

Emission Factors	ROAD Euro V	SSS
SO_2 (g/kg fuel)	0,114	30
NO_X (g/kg fuel)	18,75	19,36
CO (g/kg fuel)	5,75	8,1
Nm-VOC (g/kg fuel)	2,316	2,466
PM (g/kg fuel)	0,45	6,84
CH_4 (g/kg fuel)	0,095	0,099
CO_2 (g/kg fuel)	3323	2853
S (g/kg fuel)	0,05	15

Table 8. Unimodal chain external costs in selected route (Source: Own based on REALISE model)

Pollutant Gas	Air pollution Cost (in €)
SO_2	33.09
NO_X	1851.63
CO	0.44
nm-VOC	67.79
PM	3087.45
Total	5040.41
Cost types	
Transhipment (in €)	1.11
Noise (in €)	38031.66
Accidents (in €)	9180.06
Congestion (in €)	5972.28
Global warming (in €)	219.21

The left column of Table 8 shows the pollutant gas for a EURO V truck, travelling on the selected route under the previously mentioned conditions in point 4. The right column shows the cost of each pollutant gas emitted by the truck emission, after the hypothetic travel. For instance a truck travelling 2,106.4 km, consumes around 45.95 kg of fuel (32.92 kg on a highway leg and 13.03 kg. under congestion conditions).

If the emission factor taken is 0.114 g/kg fuel on a highway and 0.071 g/kg fuel under congestion, the total emissions are 3.75 g and 0.92 g of SO_2, that is, 4.67 g. If the cost considered is of 7,002.67 €per kg of SO_2, the result would be around 33 € The same calculation is done per each emission factor with its specific cost.

For intermodal transport, the study is divided between road legs and sea legs (Table 9). The same criteria for the unimodal calculation is applied to the former (Table 8).

Table 9. Intermodal chain external costs of the SSS in selected route (Source: Own based on REALISE model)

Pollutant Gas	Air pollution Cost (in €)
SO_2	21307.64
NO_X	4917.43
CO	1.58
nm-VOC	174.42
PM	26773.65
Total	53174.72
Cost types	
Noise (in €)	0.56
Accidents (in €)	311.09
Congestion (in €)	524.64
Global warming (in €)	–8851.71

The different consumption rates of hostelling and manoeuvring operating modes, at a specified MCR, are considered for SSS assessment (Table 10), as previously specified.

As can be seen, sulphurous emissions, mainly due to the sulphur content of marine fuels, are still the weak point of maritime transport. A global average of 2.5% sulphur content is considered, ranging from 0.5% for distillates to 2.7% for heavy fuel. We must emphasize that high-viscosity heavy fuel tends to have higher sulphur values than low-viscosity fuels. Annex VI to the MARPOL Convention and the NO_X technical code amendments were approved at the Maritime and Environment Protection Committee (MEPC) 58th session (October 2008), following the draft amendments on prevention of air pollution from ships agreed by the IMO Sub-Committee on Bulk and Liquid Gases (BLG) at its 12th session, held in February, and further agreed at the MEPC 57th session (April 2008). Today, ships operating in the North Sea are required to demonstrate compliance with new exhaust emission standards after the full implementation of the North Sea SO_X Emission Control Area in November 2007.[17] In a SECA, the sulphur content of fuel oil used onboard ships must not exceed 1.5% m/m. Alternatively, an exhaust gas cleaning system can be fitted. Directive 2005/33/EC also aims to reduce the impact of ship emissions by imposing lower SO_X and PM limits, i.e. a maximum sulphur content of 1.5% m/m in marine fuels used by ships operating within SECAs and for all passenger ships calling at EU ports as well as a maximum sulphur content of 0.1% m/m in light marine fuels used by ships in port and inland navigation.

Table 10. External costs of the transhipment and hostelling, phases, in selected route (Source: Own based on REALISE model)

Pollutant Gas	**Air pollution Cost (in €)**
SO_2	1080.40
NO_X	301.24
CO	0.57
nm-VOC	46.46
PM	1066.65
Total	2495.33
Cost types	
Noise (in €)	0
Accidents (in €)	0
Congestion (in €)	0
Global warming (in €)	–59.09

5 Preliminary Results

The results in the below tables allow estimation of potential savings with a conventional vessel in the intermodal chain by comparing both alternatives for each of the evaluated external cost items in route 1.

It should be noted that, as the intermodal chain includes a sea leg, a negative value in global warming is obtained. This is because sulphur emissions have an immediate cooling effect in the air and are computed as a negative contribution to air warming. Table 12 shows the total economic savings resulting from shipping one FEU by the intermodal instead of the unimodal mode. In this table, ship emissions are obviously divided by the number of carried trucks onboard (see Table 3) and the cost per FEU of the sea leg is also provided. By adding the external costs of sea legs, the external cost of the total intermodal chain is obtained. This value is then compared with

[17] Previously the Baltic Sea Area had been designated as a SECA, being operational since May 2006.

that of the road-only chain and the difference provides the external cost savings (if any) per FEU and trip. Finally, these savings are divided by road distance and the resulting figure is the economic savings per FEU and kilometre not travelled.

Table 11. Total external costs of the unimodal and intermodal solutions (Source: own calculations based on emission factors from table 7 and results from tables 8, 9 and 10)

	Air Pollution Cost (in €)	**Noise Costs (in €)**	**Accident Costs (in €)**	**Congestion Costs (in €)**	**Global Warming Costs (in €)**	**Total (in €)**
Road unimodal	5,041.51	38,031.66	9,180.06	5,972.28	219.21	58,444.72
SSS intermodal	53,174.72	0.56	311.09	524.64	–8,851.71	45,159.30
Transhipment	2,495.34	0	0	0	–59.09	2,436.25
Road intermodal	896.29	6,754.48	1,630.39	1,060.69	38.93	10,380.79
Total	56,566.35	6,755.05	1,941.48	1,585.33	–8,871.87	57,976.33
Intermodal chain potential savings						468.40

Table 12. Total external costs savings obtained by comparison of the unimodal and intermodal solutions, taking the 200 g/h kW consumption rate (Source: Own, based on pricing costs from REALISE, 2005)

Potential Savings (€) per FEU	**Savings (€) per FEU and Road km not Traveled**
7.0531	0.0033

The table below illustrates the final results of the savings for each selected target route (Table 1) and ship type (Table 2), considering fast and high speed crafts. Note that the negative values correspond to those where the unimodal chain involves lower external costs than the intermodal chain.

Table 13. Savings (€) per FEU and road km not travelled per route and ship type

Route	**Coventional**	**Fast Conventional**	**High Speed**
Route 1	0.0033	0.0333	–0.5022
Route 2	0.0536	0.0788	–0.4627
Route 3	–0.0068	0.0248	–0.5853
Route 4	–0.0697	–0.0490	–0.5148
Route 5	–0.0899	–0.0503	–0.7041

In general, conventional ships are the most environmentally friendly of the three types. The difference between fast conventional and high speed crafts is bigger than that between conventional and fast conventional ships. This slight advantage can be eliminated if stricter regulations (Euro VI) for road transport are considered. On the other hand, our study reveals that the selected fast conventional ship can be more sustainable than the conventional one, as can be seen in Table 12. Both vessels have similar particulars of cargo capacity and power output, but the former can reach higher speeds, resulting in shorter travel times and lower pollutant emission levels. This is because, although fast conventional ships have greater powers, the working time is less and the total consumption is minor than that of less powerful ships travelling for a longer time.

In general, it has been observed that multimodal transport is not always more advantageous than unimodal transport as far as external costs are concerned. Moreover, when stricter regulations are applied, savings will be even lower as road transportation policies are considerably more severe than those for sea transport. After analyzing the five routes, a general study of the external costs of existing routes was conducted. These routes are currently exploited by European and Spanish shipping companies and have their origin and destination in several European and Spanish ports. Two areas where the maritime lines have similar sea and road distances were defined, i.e. the Mediterranean and the Atlantic areas.

The comparison of the results obtained for each maritime zone reveals that both have rather similar mean cost values. The mean values of average routes in the Mediterranean and Atlantic zones are:

Table 14. Average external cost savings per FEU and kilometre of road not travelled of the Mediterranean and Atlantic routes. (Own source)

	Mediterranean Route	Atlantic Route
Average external cost savings per FEU and kilometre of road not travelled	0.24	0.21

A slight advantage of the Mediterranean arc can always be observed, particularly in the annual results since, in the case of trips, weekly frequencies increase, implying more annual trips and greater accumulated savings. A discount calculated by multiplying the constant found by the number of kilometres of road not travelled could be offered to carriers covering any existing or new Short Sea Shipping route between Spain and Europe inside the above described areas. Moreover, economic and environmental costs would decline and road traffic would be alleviated.

6 Conclusions and Further Research

Increasing oil prices pose a threat to high speed crafts, which are heavily penalized for their high consumption rates, resulting in higher operational costs. In addition, there is concern about their poor environmental performance. However, this type of vessel is a good alternative for certain freight operations. The present study confirms that a ship sailing at 40 knots presents no advantage on the selected five routes, in addition to having limited cargo capacity. The intermodal option in the analyzed cases provides hardly any external cost savings for the five routes because the difference between road and sea distances is sometimes negligible. In addition, road legs in those intermodal chains are too long. These results would be different in those cases in which the difference between road and sea distances is bigger, and also with shorter road legs.

Keeping in mind the selected routes and ships, fast conventional ships seem to be the best alternative for some routes because of their combination of high speed and large cargo capacity. Nevertheless, each route has different economic, geographic and environmental conditions which only one specific type of ship can perfectly adapt to. If the ship gives higher external cost savings than the road-only chain, the administration could promote the sea alternative by means of an environmental bonus to be offered to trucks boarding ships instead of travelling by road only. The exact quantity of the bonus would depend on the route and ship type and could be evaluated by the above proposed method, that is, obtaining a savings figure per kilometre not travelled by road. This figure could account for 20% of ship fares. Moreover, fuel, tire wear, driver salary and driving time costs would be reduced. An example is the environmental bonus offered by the Italian government in several routes to endorse trailers and trucks boarding ships instead of covering routes by road only. This action has also been taken by the Basque autonomous government in Spain, which assures that the sea option has been increased by 20% in the funded lines.

Keeping in mind only the shown scenario where fast ship in route 2 is compared with road transport as being the marine option providing best external costs savings, the bonus potentially offered by the administration to the truck company would be a maximum of 7.88 cents per kilometre not travelled by the truck. Nonetheless, some authors (e.g. García Menéndez, Martínez and Piñero 2003, and Pérez 2004) found that, as far as modal shift is concerned, the maritime share would grow in a higher proportion as a result of an increase in road transport cost rather than a decrease in the price of freight. Crossed elasticity in the choice of maritime transport over road transport is about 1.075%; that is, the probability of selecting maritime transport increases by 1.075% for each 1% of road transport cost increase. An improvement of customer service or faster customs procedures in maritime transport results in an elasticity rate of about 0.641%. This means that a reduction in freight transport costs of approximately 1% would increase the probability of choosing sea transport by 0.641% only.

Some other economic considerations should be kept in mind, for example avoiding the possibility that a truck could be funded by two administrations at the same time. In addition, the Mediterranean administrations should take measures to avoid the passing of heavy trucks loaded with toxic or dangerous goods through highly touristic and ecological values, such as the Costa Brava, the Cote d'Azur or la Costa di Fiore; as it may became a serious economic and ecological problem in case there is an accident.

References

Baird, A. 2004. Investigating the Feasibility of Fast Sea Transport Services. *Maritime Economics and Logistics* 6:252–269.

Becker, J.F.F., A. Burgess and D.A. Henstra. 2004. No Need for Speed in Short Sea Shipping. *Maritime Economics and Logistics* 6:236–251.

Bendall, H.B. and A.F. Stent. 2001. A scheduling model for a high speed containership service: a hub and spoke short-sea application. *International Journal of Maritime Economics* 3:262–277.

Blonk. W. 2003. *Prospects and challenges of Short-sea Shipping*. Proceedings from the second European research roundtable conference on short-sea shipping. Brussels.

Burgel, A.P. 2007. Air pollution from ships: Recent developments. *WMU Journal of Maritime Affairs* 6(2): 217–224.

Chengfeng, W. and J.J. Corbett. 2007. The costs and benefits of reducing SO_2 emissions from ships in the US West Coastal waters. *Transportation Research Part D: Transport and Environment* 12(8):577–588.

Chesneau, L.S. and M. Carr. 2000. Waves and the mariner. *Mariner's weather log* 44 (3). National Oceanic and Atmospheric Administration. Silver Spring.

Conference on Marine Vessels and air Quality. 1–2 February 2001. San Francisco, CA. American Bureau of Shipping (ABS).

Endresen, O., E. Sorgard, H.L. Behrens, and P.O. Breu. 2007. A historical reconstruction of ships' fuel consumption and emissions. *Journal of Geophysical Research* 112(D 1230):1–17.

European Commission. 2001. *The White Paper on Transport: towards 2010. Time to decide.* Brussels: European Commission.

———. 2005. High Level Group of the European Commission. *Extension of the Major Trans-European Transport Axes to the Neighbouring Countries and Regions*. Brussels: European Commission.

———. 2006. *Mid-term review of the European Commission's 2001 White paper on transport*. Brussels: European Commission.

Floedstroem, E. 1997. *Energy and emmission factors for ships in operation. KFB Rep.* Swedish Transport and Commerce Res. Board. Swedish Maritime Administration & Mariterm AB. Gothenburg, Sweden.

García-Menéndez, L., I. Martínez-Zarzoso, and D.P. De Miguel. 2004. Determinants of mode choice between road and shipping for freight transport. *Journal of Transport Economics and Policy* 38(3): 447–466.

González Laxe, F and I. Novo Corti. 2007. Las autopistas del Mar en el contexto Europeo. *Boletín económico del ICE* nº 2902:33–45.

Karayannis, T., A. Papanikolaou, and A.F. Molland. 2000. *The introduction of high-speed ferries into the eastern mediterranean.* Proceedings of the 7th International Congress of IMAM, Naples, Italy.

La Llotja. 2006. *Estudi Llotja infraestrucutres i territori: El transporte marítimo de corta distancia en Cataluña.*

Lagoudis, N., M. Lalwani, M. Naim, and J. King. 2002. Defining a Conceptual Model for High-Speed Vessels. *International Journal of Transport Management* 1(2):69–78.

Laine, J.G. and A.P.J. Vepsalainen. 1994. Economies of speed in sea transport. *International Journal on Physical Distribution & Logistics Management.* 24:33–41.

Latorre, R. and R. Foley. 1999. *High Speed Coastal Transport Emergence in the U.S.* http://www.ccdott.org/.

Lombardo, G.A. 2004. *Short Sea Shipping: Practices, Opportunities and Challenges.* TRanposrGistics, Inc. White Paper Series, May 19.

Marchant, C. 2002. *The effect of supply chain structure on the potential for modal shift. Evidence form the UK Marine Motorways Study.* http://www.sml.hw.ac.uk (26/09/2005]

Martínez de Osés, F.X. and M. Castells. 2007. *Wave height incidence on Mediterranean Short Sea Shipping routes*. http://tethys.org.

———. 2007. *Analysis of the environment efficiency on the different typology of high speed ships in short sea shipping lines against their alternative on road.* Research group TRANSMAR. Department of Nautical Science and Engineering. UPC. Barcelona.

———. 2008. Heavy weather in European Short Sea Shipping: Its Influence on Selected Routes. *The Journal of Navigation* 61:165–176.

Mulligan, R.F and G. Lombardo. 2006. Short Sea Shipping. Alleviating the environmental impact of economic growth. *WMU Journal of Maritime Affairs* 5(2):181–194.

Olivella J., F.X. Martínez de Osés, and M. Castells. 2006. *Las autopistas del mar como alternativa al tráfico de los Pirineos*. Barcelona Digital, SL.

Olivella J., F.X. Martínez de Osés, M. Castells and R. González. 2005. *Intermodalidad entre España y Europa, el Proyecto INECEU*. Barcelona Digital, S.L.

TERM. Transport and Environment Reporting Mechanism. 2002. European Environment Agency.