ASSESSMENT FOR POSSIBLE FUTURE ECA ADOPTION IN THE MEDITERRANEAN AREA (Short Sea Shipping vs. Road Transport)

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Abstract: In accordance to the Appendix III of MARPOL´s Annex VI, six criteria are proposed for emission control area (ECA) definition: a clear delineation of the proposed ECA; land and sea areas at risk; emission quantification and impact assessment; prevailing weather conditions; data on marine traffic; and land based measures concurrent with the ECA adoption. This paper carries out an scenario analysis 2012 onwards and until 2020, comparing both intra-European road transport and multimodal transport chains in the Mediterranean area. Thus assessing maritime transport's emissions and impacts in comparison with land based road transport. Therefore from the aforementioned six criteria this paper considers two: emission quantification and impact assessment; and land based measures concurrent with the ECA adoption.

Keywords: Short Sea Shipping transport, road transport, emission control areas, Mediterranean Sea, air pollution.

1. Introduction

There is a growing voice calling for an ECA in the Mediterranean claiming significant damages to the environment, crops and health produced by emissions from shipping both in Mediterranean Sea board countries as well as further in shore. The last ship emissions inventory for the Mediterranean developed by Entec UK limited in 2007 appointed that intra-European movements, i.e. Short Sea Shipping (SSS), contributed in 2005 significantly to emissions in the Mediterranean Sea, as 38% of the fuel consumed corresponded to intra-European movements (16% domestic and 22% between EU countries).

Building on the statistics of "*Maritime transport statistics – short sea shipping of goods*" published by the Eurostat, short sea shipping traffic volumes in the Mediterranean are already recovering from the downturn suffered due to the current economic crisis. Containerized and RoRo cargo which in 2010 represented 29,4% of the total short sea shipping volumes in the Mediterranean are emerging strong, registering highest traffics shares ever.

Table 1
Short sea shipping cargo volumes in the Mediterranean, 2005 – 2010

CARGO (Thousand tonnes)	2005		2006		2007		2008		2009		2010	
Liquid bulk goods	291.826	52,3%	287.750	51,0%	294.392	50,3%	293.462	49,8%	280.776	49,8%	276.919	48,6%
Dry bulk goods	90.518	16,2%	93.533	16,6%	92.124	15,8%	91.847	15,6%	101.578	18,0%	89.621	15,7%
Large containers	87.698	15,7%	91.626	16,2%	97.778	16,7%	102.646	17,4%	101.569	18,0%	104.444	18,3%
Ro-Ro (self-propelled units)	28.267	5,1%	30.024	5,3%	31.090	5,3%	35.124	6,0%	26.815	4,8%	40.331	7,1%
Ro-Ro (non-self-propelled units)	25.402	4,5%	25.764	4,6%	31.851	5,4%	23.102	3,9%	22.019	3,9%	22.529	4,0%
Other	34.807	6,2%	35.929	6,4%	37.659	6,4%	43.170	7,3%	30.945	5,5%	36.118	6,3%
TOTAL	558.518		564.626		584.894		589.351		563.702		569.962	

Source: Own, based in Eurostat

This papers objective is to assess the need to implement an ECA in the Mediterranean ensuring the competitiveness of SSS in comparison with road transport in terms of emissions and impacts of air pollutants (NOx, VOCs, $PM_{2,5}$, SO_2) and GHGs (CO_2). This means that only maritime alternatives competing with road transport are considered, which indeed are container and RoRo services. Results only reflect direct emissions, those arising during the actual transport. Indirect emissions occurring upstream and downstream the transport chain are not considered. Moreover both local and rural impacts caused by emissions to air are assessed. Local impact estimation, needs of great emission site detail; therefore, a bottom-up approach has been chosen for the emissions' geographical characterization (Miola et al. 2010). On the other hand the rural impact is country specific, and therefore its quantification does not require that much and precise information.

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Following the introduction section (section 1), this paper continues with the methodology (section 2) where the assumptions and calculations underlying the results are described. Following section 2, section 3 presents the baseline and future scenarios in which calculations are carried out. Once the methodology and scenarios are known, a case study is presented (section 4). Afterwards results are discussed (section 5) in order to finally present some conclusions (section 6).

2. Methodology

In a first instance the transport chains to be simulated need to be characterized, identifying parameters inherent to the route and fleets engaged. Second, both maritime and road transport policy contexts are studied and scenarios projected 2012 onwards and until 2020; in order to estimate emission factors according to the regulatory framework and fleets engaged. Finally once the emission inventory for the considered trade link has been carried out, the impact caused by the emissions is valuated according to the sensitiveness of the emission site.

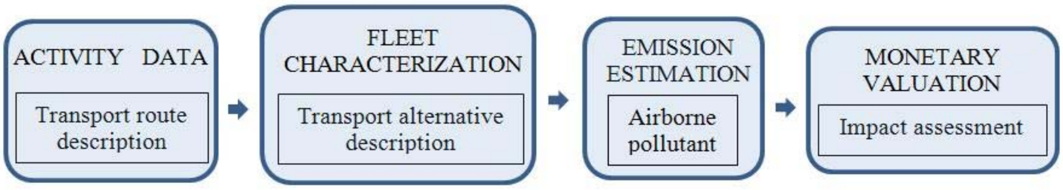


Fig. 1.
Calculation model breakdown
Source: Own

2.2. Main assumptions and methods

Tables 2 and 3 both the characterization and calculation procedures used for the environmental performance assessment of the considered transport chains. These tables gather emission and cost drivers together with main assumptions and methods used.

Table 2
Main assumptions and methods for the road transport model

ROAD TRANSPORT MODEL
Activity data: • Covered distance • Crossed countries • Affected inhabitants in the urban stage • Load factor • Route profile (flat, medium, highland) • Average speed
Fleet characterization: • Truck configuration: The articulated truck, i.e. a road tractor coupled to a semi-trailer, is considered representative of the truck fleet engaged in SSS services. A configuration responsible of the 73,9% of the total intra-European road freight transport in 2009 (Hill N. et al., 2011). • A review of allowed gross vehicle weights in articulated trucks within the EU27 is consulted (EU, 2011), identifying articulated trucks with maximum gross weights between 40 to 50 tonnes as the most representative category among the ones considered by the Tier 3 methodology. • Engine type: The fleet is considered to be evenly distributed along its eleven years of life cycle (Hill N. et al., 2011), what it means that for projecting purposes an annual replacement rate of 11,1% is assumed. Then depending on the scenario selected, 2012-2020, and taking into account the emission standards (Euro I-VI) enforcement dates, engine technologies present in the fleet are extrapolated.
Emission estimation: • Tier 3 methodology from the EMEP/EEA air pollutant emission inventory guidebook 2009. Technical report; No 9; 2009; Part B; chapter 1.A.3.b.
Impact valuation: • Local impact: Benefits Table Database: Estimates of the Marginal External Costs of Air Pollution in Europe (BETA), 2002. • Rural impact: Clean Air For Europe project (CAFE), 2005. • HICP regression model for external costs price update and projection, period 1990 – 2012.

Source: Own

Table 3
*Main assumptions and methods for the maritime transport model**

SSS TRANSPORT MODEL
Activity data: • Ship type • Sailing scenario (year + emission standard in force) • Covered distance • Sailing area (Mediterranean Sea, North East Atlantic, English Channel, North Sea or Baltic Sea) • Load factor (ship´s and average intermodal transport units (ITU) load factors) • Origin and destination ports details (country and inhabitants in port cities) for sensitivity assessment.
Fleet characterization: • Emission factors are engine type and power dependent, therefore these have to be identified for the considered ship types engaged in SSS services. In the marine industry diesel engines are the predominant form of power for both main and auxiliary engines, ME and AE from now on (Trozzi C. et al., 2010). Diesel engines, depending on their rated speed, are categorised into slow (up to 300 rpm), medium (300-900 rpm) and high (more than 900 rpm) speed diesel engines: SSD, MSD and HSD respectively. Moreover, emissions to air are also related to the fuel consumption or engine power; therefore besides the engine type, the average power for the different representative SSS ship types needs to be identified. • Emissions also depend on ship service speed and engine load factors in each of the sailing phases (at sea, manoeuvring and at berth). The ship service speed, determining the time spent at sea and hence total emissions, is the average value obtained from the SSS fleet survey. Engine load factors are directly obtained from the study carried out by Entec for the European Commission regarding emissions from ships associated with ship movements between ports in the European Community (Whall C. et al., 2002). • At sea, manoeuvring and at berth times are either estimated using the average service speed or taken from previous studies such as Whall C. et al. 2002, Whall C. et al. 2010 and Usabiaga et al. 2011. These data are necessary as emissions will be proportional to them. • The capacity tab together with the covered distance will enable the model to produce results (emissions or impacts) in transport work units (per tonne kilometre). Results in transport work units will enable the comparison between various transport alternatives. Capacities are given in units (TEUs or line meters) inherent to the ship type being considered.
Emission estimation: • Tier 3 methodology from the EMEP/EEA air pollutant emission inventory guidebook 2009. Technical report; No 9; 2009; Part B; chapter 1.A.3.d.
Impact valuation: • Local impact: Benefits Table Database: Estimates of the Marginal External Costs of Air Pollution in Europe (BETA); 2002. • Rural impact: Clean Air For Europe project (CAFE); 2005. • HICP regression model for external costs price update and projection, period 1990 – 2012.

**Assumptions and methods for the road transport leg in the multimodal transport chain are those presented in table 2.*
Source: Own

3. Scenarios

3.1. Emission standards

In the last two decades road transport has improved significantly its environmental performance regarding emissions to air (CO, NOx, HC and PM), Table 4. A set of emission standards known as the Euro standards have been progressively introduced since 1993. The next and more stringent standard, so called Euro VI, will be implemented by the end of 2013 reducing even more road transport's emissions to air. Moreover road transport has also improved in sulphur emissions to air by limiting the sulphur content on diesel fuels (Directive 2009/30/EC and Directive 98/70/EC). Currently and since 2009 the limit is in 10 ppm which is considered to be effectively "zero" content. With regards to CO2 emissions road has not achieved significant improvements as this GHG emission is proportional to the fuel consumption and the carbon content in the fuel and neither of these have been significantly reduced.

Table 4
Heavy duty vehicle emissions standards development

Euro Standards	Emissions to air			
	CO (g/kWh)	HC (g/kWh)	NOx (g/kWh)	PM (g/kWh)
Euro I (October 1993)	4,9	1,23	9	0,4
Euro II (October 1996)	4	1,1	7	0,15
Euro III (October 2001)	5,45	0,78	5	0,16
Euro IV (October 2006)	4	0,55	3,5	0,02
Euro V (October 2009)	4	0,55	2	0,02
Euro VI (December 2013)	4	0,16	0,4	0,01

*Euro I and II emissions standards are not directly comparable with those for Euro III or the later because of changes to the duty cycle used for each of these standards.
Source: Own, based in directives 88/77/EC, 1999/96/EC, 2005/55/EC, 2005/78/EC and 2007/46/EC

Unlike road transport, maritime transport has not been regulated with regards to emissions to the air until recently. Was the MARPOL 1973/1978 convention which through its Protocol of 1997 including the Annex VI introduced for the first time standards to prevent the air pollution from ships in May 2005. In this first version of the Annex VI a global sulphur cap limiting the sulphur content in the fuel to 4,5% was introduced. NOx emissions resulted also limited through the adoption of the NOx Technical Code (Tier I and Tier II standards), figure 10, and a more stringent SOx emission control area (ECA) was established in the Baltic Sea where the sulphur content in the fuel was limited to 1,5%. In July 2005 the MARPOL Annex VI resulted amended and new North Sea and English Channel SOx ECAs were introduced, although these were not fully enforced until November 2007. The last review of the MARPOL Annex VI took place in 2008 when a progressive reduction of SOx emissions from ships was planned and introduced to the annex: reducing the global sulphur cap to 3,5% by January 2012 and to 0,5% by 2020 subject to a previous feasibility review; and reducing the sulphur content in fuels used in SOx ECAs to 1% by July 2010 and to 0,1% by January 2015. Moreover same amendments also introduced new NOx emission limits for the so called Tier III engines, applicable to ships constructed after January 2016 and operating in NOx ECAs. Finally the revised Annex will also allow to designate ECAs for SOx, PM and NOx.

The regulatory framework established by the MARPOL Annex VI was transposed into EU law by Directive 2005/33/EC in July 2005. This directive known as the " Low Sulphur Fuel Directive" does not only transpose what Annex VI establishes, but complements it introducing more stringent limits for passenger ships (1,5% sulphur content limit in the fuel) and ships at port (0,1% sulphur content limit in the fuel).

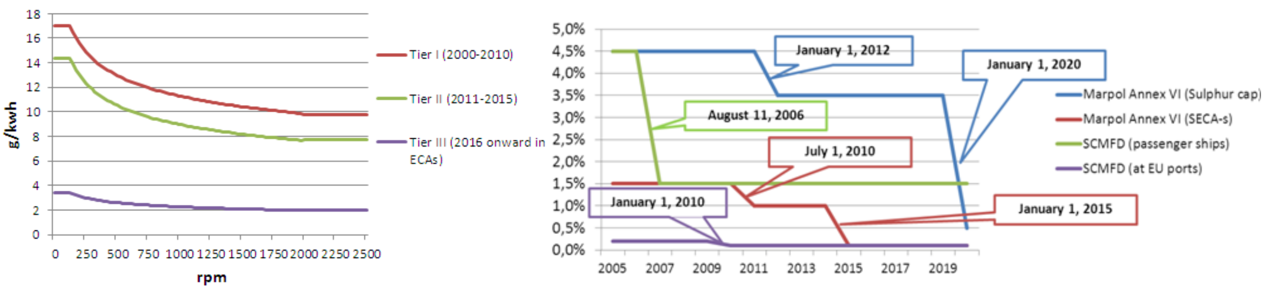


Fig. 2.
NOx Technical code and sulphur caps
Source: Own

3.1. Modelling current and future scenarios

According to current and future regulatory frameworks for road and maritime transport, the scenarios in table 5 and 6 were created for environmental performance assessment. These scenarios extend from 2012 (baseline year) until 2020 and include also specific scenarios representing ship types (passenger ships) and areas (SOx or/and NOx ECAs) in which due to their higher sensitiveness more stringent regulations are applied.

Table 5
Marine scenarios

Scenario	Year	Regulatory framework	Sulphur content in the fuel	NOx emission standard
2012 baseline	2012	MARPOL (Annex VI - Global sulphur cap)	3,50%	Tier 0 (52%)/Tier I (44%)/Tier II (4%)
2012 ROPAX	2012	Directive in Sulphur Content of Marine Fuels (DSCMF) - passenger ships	1,50%	Tier 0 (52%)/Tier I (44%)/Tier II (4%)
2012 SECA	2012	SOx ECA	1%	Tier 0 (52%)/Tier I (44%)/Tier II (4%)
2015 baseline	2015	MARPOL (Annex VI - Global sulphur cap)	3,50%	Tier 0 (40%)/Tier I (44%)/Tier II (16%)
2015 ROPAX	2015	DSCMF - passenger ships	1,50%	Tier 0 (40%)/Tier I (44%)/Tier II (16%)
2015 SECA	2015	SOx ECA	0,10%	Tier 0 (40%)/Tier I (44%)/Tier II (16%)
2016 baseline	2016	MARPOL (Annex VI - Global sulphur cap)	3,50%	Tier 0 (36%)/Tier I (44%)/Tier II (20%)
2016 ROPAX	2016	DSCMF - passenger ships	1,50%	Tier 0 (36%)/Tier I (44%)/Tier II (20%)
2016 SECA	2016	SOx ECA	0,10%	Tier 0 (36%)/Tier I (44%)/Tier II (20%)
2016 NECA	2016	NOx ECA	3,50%	Tier 0/I/II (0%)/Tier III (100%)
2016 SECA/NECA	2016	SOx and NOx ECA	0,10%	Tier 0/I/II (0%)/Tier III (100%)
2016 ROPAX/NECA	2016	DSCMF - passenger ships and NOx ECA	1,50%	Tier 0/I/II (0%)/Tier III (100%)
2020 baseline	2020	MARPOL (Annex VI - Global sulphur cap)	0,50%	Tier 0 (20%)/Tier I (44%)/Tier II (36%)
2020 SECA	2020	SOx ECA	0,10%	Tier 0 (20%)/Tier I (44%)/Tier II (36%)
2020 NECA	2020	NOx ECA	0,50%	Tier 0/I/II (0%)/Tier III (100%)
2020 SECA/NECA	2020	SOx and NOx ECA	0,10%	Tier 0/I/II (0%)/Tier III (100%)

Source: Own

Table 6
Road scenarios

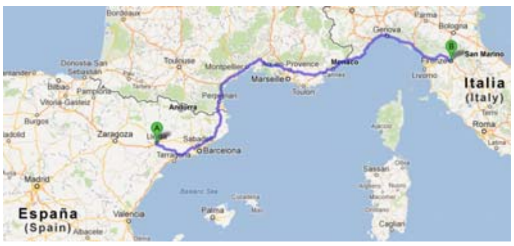
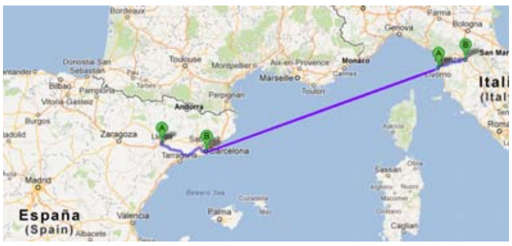
Scenario	Engine technology in the fleet
2012	Euro II (6,8%) Euro III (45,5%) Euro IV (27,3%) Euro V (20,5%)
2015	Euro III (25%) Euro IV (27,3%) Euro V (29,5%) Euro VI (18,2%)
2016	Euro III (15,9%) Euro IV (27,3%) Euro V (29,5%) Euro VI (27,3%)
2020	Euro IV (6,8%) Euro V (29,5%) Euro VI (63,6%)

Source: Own.

4. Case study

In this section the transport link between Lleida and Firenze is presented for analysis. Two transport alternatives are considered: an unimodal transport chain using only road transport and a multimodal transport chain combining road and maritime transport. The table below summarises the parameters inherent to each transport chain.

Table 7
Route parameters

UNIMODAL (road only)		MULTIMODAL (road +SSS)	
			
LOADED LEG			
ROAD		ROAD	
Origin:	Lleida	**Origin:**	Lleida
Destination:	Firenze	**Destination:**	Firenze
Loaded distance:	1239 km	**Loaded distance:**	267 km
Spain	315 km	**Pre Haulage:**	173 km
France	531 km	**Spain:**	173 km
Italy	393 km	**Post Haulage:**	94 km
TOTAL DISTANCE:	1239 km	**Italy:**	94 km
		SSS	
		Sea distance:	380 nm
		Port of origin:	Barcelona
		Port of destination:	Livorno
		TOTAL DISTANCE:	971 km

Source: Own.

Moreover only considering ship types competing for cargo with road transport, the ship types listed in the table below are used for calculation purposes. These ship particulars correspond to real ships considered representative of each type and range of sizes. This data derives from a comprehensive review of the Lineport Database (years 2010 and 2011), made available by the Valenciaport Foundation, and a complementary research task carried out consulting the Seaweb ships database.

Table 8

SSS fleet characteristics

	Container ships (LOA<155)	Container ships (LOA≥155)	Car Carrier (LOA<155)	Car Carrier (LOA≥155)
Length Over All	129,6	216,9	126,9	176,7
Breadth	20,9	32,2	18,8	31,1
Draft	7,4	12,25	6,2	8,8
GT	7545	30166	11591	38651
DWT	8168	35082	4442	12292
ME type	MSD	SSD	MSD	SSD
ME power	7000	31920	9840	11060
AE type	MSD/HSD	MSD/HSD	MSD/HSD	MSD/HSD
AE power	1540	7022	2952	3318
Average service speed	15,9	22,4	20	20,5
Capacity (TEU-s)	698	2833	na	na
Capacity (line meters)	na	na	448	3600
Capacity (trailers or CEU-s)	na	na	107	867
Capacity per TEU (tm)	21,5	21,5	na	na
Capacity per trailer(tm)	na	na	na	na
Total capacity (tm)*	8168	35082	107	867

*The unit for total capacity is CEU for car carriers

	Ro-Ro MSD	Ro-Ro SSD	Ro-Pax ships	Con-Ro
Length Over All	141,3	200,9	199	165,8
Breadth	21	26,5	26,6	23,4
Draft	6	7,5	6,4	7,3
GT	15222	32647	25518	15586
DWT	4695	10773	7500	11407
ME type	MSD	SSD	MSD	MSD
ME power	12960	20070	25200	15000
AE type	MSD/HSD	MSD/HSD	MSD/HSD	MSD/HSD
AE power	3888	6021	8820	4500
Average service speed	18,5	22,3	24	20
Capacity (TEU-s)	na	na	na	484
Capacity (line meters)	1500	3810	2600	2155
Capacity (trailers or CEU-s)	100	254	173	143
Capacity per TEU (tm)	na	na	na	21,5
Capacity per trailer(tm)	26,0	26,0	26,0	26,0
Total capacity (tm)	2600	6604	4498	11407

Source: Own.

5. Results discussion

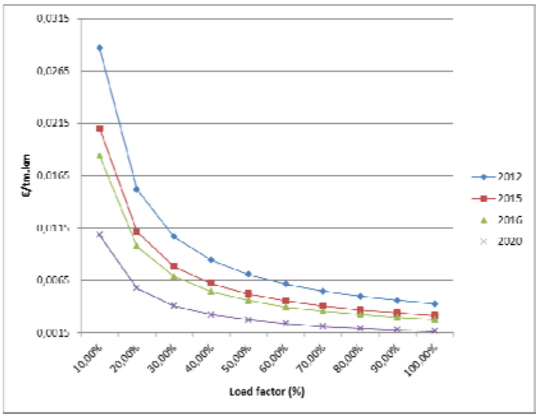
The results given in this section correspond to the trade link between Lleida (Spain) and Firenze (Italy). Table 9 presents the results for the road only transport alternative, linking the environmental performance of the transport alternative and the ITUs load factor. Main assumptions with regards to the type of ITU, empty distance, etc. are also listed. For comparison purposes results given in figure 3 correspond to a 60% load factor of the ITU, the rest of the assumptions are coincident for both transport alternatives.

Table 9

Road transport performance

UNIMODAL OPTION (road only)	
ITU	Semi-trailer
Empty trip distance (km)	100
Urban segment	10%
Rural segment	15%
Highway segment	75%
Urban (km/h)	40
Rural (km/h)	65
Highway (km/h)	80

Source: Own.



Looking into figure 3 the environmental performance of multimodal transport chains, combining road and maritime means of transportation, may also be called into question. For instance the environmental performance of transport chains using RoPax and RoRo ships expressed in €/tm.km is far more damaging than that of road transport. However those transport chains combining road transport with ConRo and container ships, perform better than road transport solely.

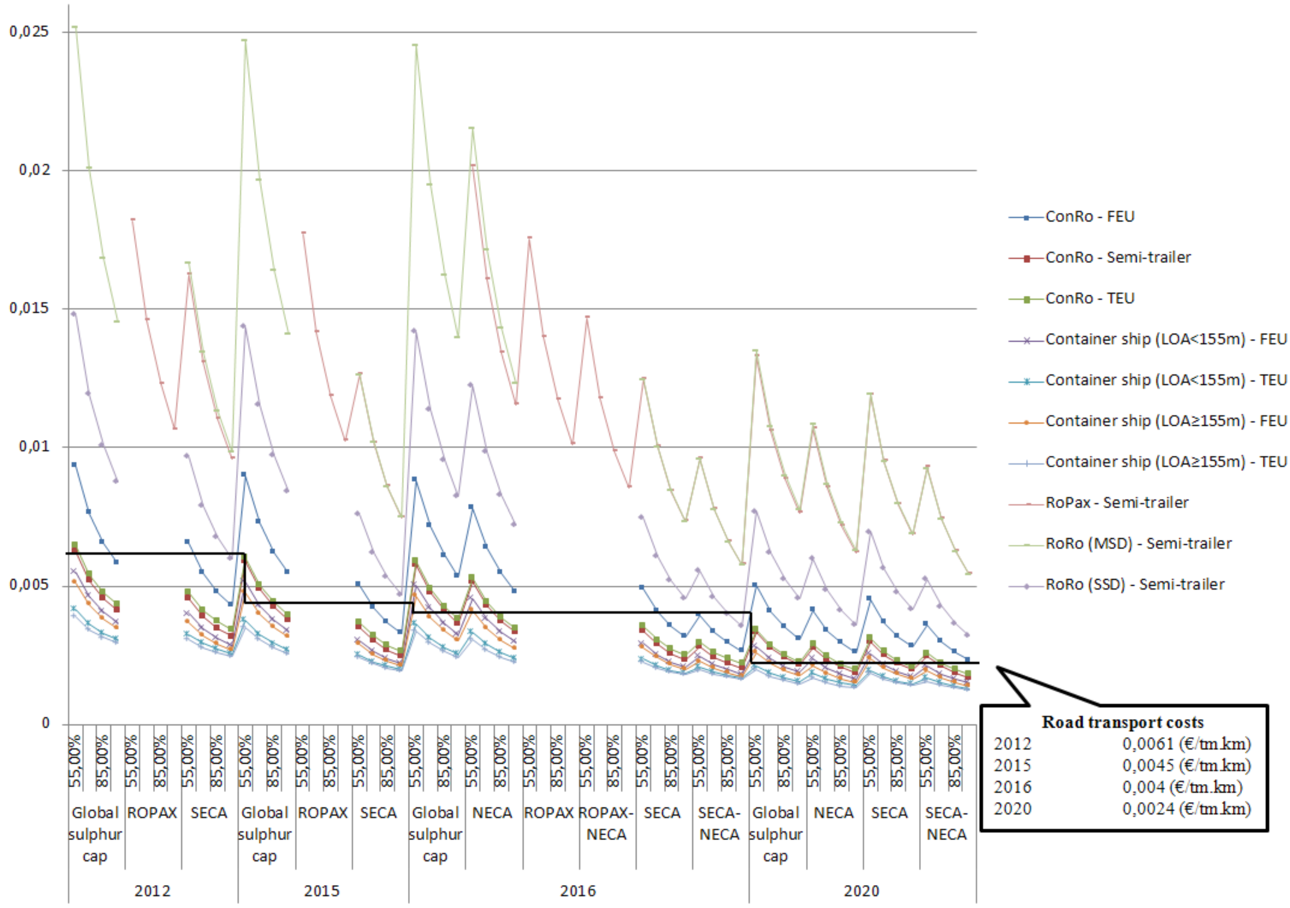


Fig. 3.
Multimodal and unimodal transport chains environmental performances comparison
Source: Own

6. Conclusions

Obtained results demonstrate that especially in certain types of maritime transport, improvement is needed to compete in environmental terms when talking about air pollutants and GHGs emissions and their impacts. However results are given in €/tm.km and thus do not represent the geographical characteristics of each trade link, where often the detouring between road only and multimodal alternatives is significant, especially in the Mediterranean. This benefits multimodal transport chains crossing seas, instead of land based alternatives going all the way around the Tyrrhenian, Aegean and other Mediterranean seas. Moreover not only the mean of transport, as the ship type, is a decisive variable: factors such as the load factor and ITU make all the difference between unimodal and multimodal transport chains.

Finally if similar environmental performances are going to be demanded to road and maritime transport in Europe, it is necessary, as in the North and Baltic seas, to implement more stringent measures also in the Mediterranean. Otherwise in the years to come, road transport will displace maritime transport regarding environmental friendliness. Although maritime transport will always have a competitive advantage in comparison with land based transports due to the Mediterranean geography and the consequent detouring between land and maritime transport alternatives.

In this respect an ECA proposal by a Mediterranean country is all the more essential keeping in in mind that since its proposal, around five years are needed until its adoption. On the contrary by 2017 road transport will have swept away maritime transport.

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