Motorways of the sea

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ABSTRACT: In order to reduce road traffic many governments have tried to create the so-called "Motorways of the Sea (MoS)". The aim of the MoS is to reduce road traffic by using maritime transport to haul truck loads. The goal of the study is to trace the recent history of actions of the different governments to encourage MoS. This paper presents a brief overview of the situation worldwide. More details are provided concerning the actions of the European Community and more particularly the French government. Finally, the examples of the *Saint-Nazaire / Gijón* and *Saint-Nazaire / Vigo* links are examined to determine how these maritime links could reduce road traffic to an important extent.

The European Union has launched several funding programs to support the operation of these links. However, the actual effort is not sufficient to avoid the increasing traffic jams observed around the city of Bordeaux and at the border between France and Spain. A solution is proposed using six newly designed Ro-Ro vessels capable of transporting 110 semi-trailers each. The proposed logistics system implies that the tractor units will not be transported on board. Specialized Ro-Ro tractors will handle the installation of the semi-trailers on board whilst the tractor units are either coupled to newly arrived semi-trailers or returned to their base to fetch other semi-trailers.

The six vessels are necessary to ensure three departures per day from each port. A complete ship design loop has been performed to prove the feasibility of the project. The vessels satisfy the rules and regulations of the IMO. The proposed twin screw motorization would run on LNG and allow the vessels to travel at 19 knots in sea states up to 5 in order to meet winter conditions in the Bay of Biscay.

INTRODUCTION

The number of motorized vehicles in the world has exploded in the last 10 years to around 1.3 billion vehicles today (source: OICA). This very important number raises several questions from an environmental and economic point of view as well as the logistical point of view. Estimates in this area are not always reliable, but the environmental footprint left by road transport on the planet is estimated at 13% of the global $CO2$ emissions, i.e. 6.4 Gt of $CO2$ in 2010 [1], which corresponds to the consumption of 4.2 billion European households [2]. These hallucinatory figures are directly linked to the most important problem that road transport is facing today: *traffic jams*. Motorists spent "*9% of their driving time stuck in traffic jams in 2016* ", which is both a problem for our health and our economy. Indeed, a study by INRIX (a leading company in traffic data), aimed to raise "*the alarm bell to sensitize public awareness about the growing impact of traffic jams*"[3], shows that by 2030, traffic problems will cost Western economies 221 billion Euros a year, hence 70 billion more than in 2013.All these figures are intended to sensitize the various governments to the growing danger of the saturation of roads and to encourage them to facilitate traffic flows. Diverting part of the traffic flow by means of motorways of the sea or short sea shipping is one of the various solutions offered.

1 MOTORWAYS OF THE SEA, DEFINITION

Short sea shipping has been examined for decades as an alternative to road freight. Since Europe and the USA were the first concerned by massive traffic jams, they produced the largest share of these studies, however Asia is also examining the possibility of increasing short sea shipping in its coastal regions. The many studies conducted in the USA underline the benefits of short sea shipping but they will not really materialize until the government massively invests in such a solution [4]. Europe is now coming to the same conclusion.

Motorways of the Sea officially appear for the first time in the European Commission's White Paper on Transport Policy for 2010 [5]. This report was undoubtedly written as a consequence of the devastating fire of the Mont Blanc Tunnel in 1999, which was caused by a freight carrier. This report examines a program ending the same year, the Pilot Actions for Combine Transport (PACT) program [6].This program was a real start for the concept of MoS, in the sense that it "*encourages traffic to move from the road to other modes of transport in order to achieve a more balanced intermodal transport system*" [7]. Indeed, thanks to the PACT program, the European Union has finally become aware of the existence of a common program in terms of freight transport in the member countries "*to reduce external costs of freight transport, such as those imposed by environmental damage, accident and congestion*" [7].Thus, the main idea of the PACT program, which was to financially support intermodal transport projects in order to make them more eco-friendly, is reflected in the conclusions of the 2001 report, evidence that the MoS have their own place in this program. The idea of MoS, as advanced in 2001, seems relatively simple: create motorways of the sea that will be as close as possible to the image of a highway, an easy and quick way to get from point A to point B. The MoS will have to propose "*a real competitive alternative to land transport*", while taking into account the PACT program's objectives, and in particular the nodal transfer for the transport of freight and not of passengers. Indeed, the European Union has estimated that "*the effects on traffic congestion of a transfer of passengers from the road to the seaway were minimal compared to what a transfer of freight traffic could accomplish*" [8]. The European Union, by means of this White Paper and the introduction of MoS, seeks to raise the awareness among the various European players, while reiterating the desire to develop a real strategy for the use of transport means in Europe, in which the MoS could take part. However, no definition is clearly given to define the MoS: it was not until after 2004 that a real explanation of the terms "*motorways of the sea*" was provided [8].

2 EVOLUTION OF MOS WITHIN THE EUROPEAN UNION

After various consultations – which lasted two years – carried out in the different countries of the European Union with regard to the concept of MoS, the European Commission completed the Guide of Customs Procedures for Short Sea Shipping in April 2003[8]. This Guide will serve to draw up a working document explaining the customs procedures to adopt in order to simplify the formalities for the transport of freight between two States of the European Union as much as possible. It is therefore within the framework of an improvement of maritime transit that a new program was presented in 2003 encouraging the different Member States to develop MoS: the Marco Polo program. With a budget of 115 million Euros for the period 2003-2006, this program provided financial support to European governments which, lacking confidence, did not believe in the economic viability of the MoS, and hence did not commit themselves. This was planned by the European Commission: "*these lines will not develop spontaneously. It will be necessary, on the basis of the proposals of the Member States, to "label them", in particular through the granting of European funds to encourage their take-off and ensure an attractive commercial dimension*". Thus, thanks to the Marco Polo aid program, many MoS projects were carried out, notably in four priority regions that we will discuss later. In April 2004, a decision of the European Parliament and the Council clarified the expectations of the MoS, while reaffirming their strong desire to promote their development: "*support for the development of motorways of the sea should be considered complementary to the provision of an aid to promote the development of short sea transport activities under the Marco Polo program*". They provide a lengthy definition (extending to 6 points in total), with more details for MoS in Article 12-bis of this decision:

1**.** *The trans-European network of motorways of the sea within maritime flows on maritime routes for logistics, so as to improve maritime links by establishing new ones, reduce congestion and / or improve access to States and peripheral and island regions. Motorways of the sea should not exclude the combined transport of persons and freight, provided that cargo is predominant.*

2. *The trans-European network of Motorways of the Sea consists of equipment and infrastructure relating to at least two ports in two different Member States. Such equipment and infrastructure shall include elements, at least in one Member State, such as port equipment, electronic logistics management systems, safety and security procedures and administrative and customs procedures (...)*

In addition, this 2004 declaration lists specific projects, "*thus making definitive the concept of Motorways of the Sea*". These different projects take place in four different regions, namely:

- South-East Europe (motorway connecting the Adriatic Sea to the Eastern Mediterranean);
- South West Europe (motorway connecting the western Mediterranean to France, Spain, and Italy);
- Western Europe (motorway connecting the western Mediterranean to the North Sea);
- Baltic Sea (motorway connecting the Baltic States to central / western Europe).

All four have different issues: a MoS in the Eastern Mediterranean has to develop maritime transport, while in the Western Mediterranean, a MoS has to respond to congestion in the Alpine and Pyrenean regions. In view of these new directives, the Marco Polo II program has succeeded the Marco Polo program, and has a larger budget (450 million Euros for the period 2007-2013). It offers a wider geographical coverage, i.e. the required presence of only one of the two ports in the European Union and the other port in a neighboring country [9].

The document also contains a new, clearer and more concise definition of MoS:

"*Any innovative action to directly transfer freight from the road to short sea shipping or a combination of short sea shipping with other modes of transport where road journeys are as short as possible; actions of this type may include the modification or creation of ancillary infrastructures necessary for the implementation of a very high volume and high frequency intermodal maritime transport service, preferably including the use of the modes of transport the most environmentally friendly, such as inland navigation and rail transport, for the transport of freight in the hinterland and integrated door-to-door services. If possible, the resources of the outermost regions should also be integrated.*"

The Marco Polo II program ended in 2013 and we can only underline the very positive assessment made by the UE of this program through the scheme proposed in Figure 1.

Figure 1. Results of the Marco Polo program (*according the UE, http://ec.europa.eu/transport/marcopolo/index_en.htm*)

This program was submitted for study to the European Commission and at present the last European plan promoting the MoS, the *Trans-European transport network* (TEN-T), has started. TEN-T is a program to improve the infrastructure of the European Union to transform all railways, roads, airports and shipping routes into a perfectly unified network. Its main goal will be to eliminate the fact that every day, "*7500 km of motorways are paralyzed by traffic jams*"[10] in Europe. It is therefore in May 2013 that the European Union agreed on 30 priority projects for 2020, representing an investment of 225 billion Euros by 2020. The MoS are part of these 30 projects (the 21st) and are included in the section "Maritime transport infrastructure and motorways of the sea" and can be qualified as "*Maritime leg of the Trans-European transport network*". A new definition, much shorter than the previous ones, is given and reinforces the idea of nodes and connections within the European Union: *"They (i.e. MoS) shall consist of short sea routes, ports, associated maritime infrastructures and equipment, and facilities as well as simplified administrative formalities enabling short sea shipping or sea-river services to operate between at least two spots, including a hinterland connection."*

Thus since the 2000s, the European Union has implemented a policy to encourage interconnections between different types of traffic (road, maritime, rail ...) and in particular in the case of freight transport. The MoS are part of a true European policy and are intended to accelerate until 2020 with the TEN-T plan. But what about countries like France, which are directly concerned by this European policy?

3 THE FRENCH CASE

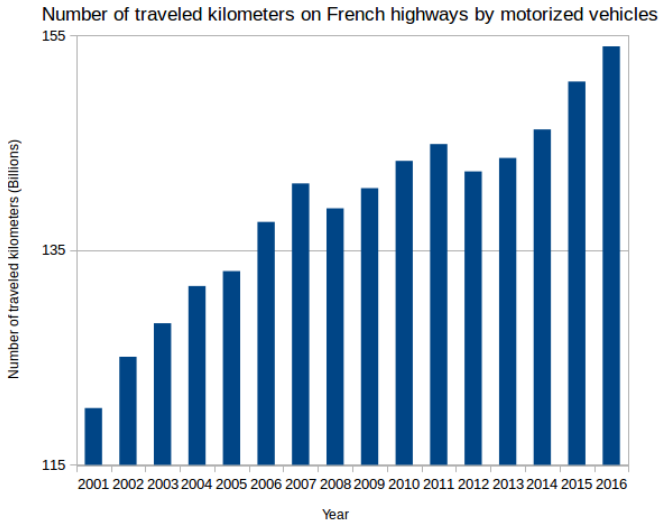

Figure 2. French road traffic.

France, like the rest of the European Union, has seen an explosion in the presence of vehicles on motorways, (Figure 2). Indeed, various axes are saturated like the Alps and the Pyrenees (natural obstacles), but also the Bordelaise region which ensures the transition between the North and South-West of France. France is therefore obviously at the heart of the various regions mentioned above, so it must participate in the different initiatives for the development of motorways of the sea. France aligns itself with the European policy in order to reduce the congestion of its motorways. Therefore, as expected, the desire to use motorways of the sea in order to smooth road traffic appeared in the objectives of the Grenelle of the sea (equivalent of the Grenelle of the environment for the maritime domain) in 2009, [11]. As a reminder, the aim of the Grenelle of the sea is to propose new actions to be taken in the maritime sector, in order to ensure its economic and sustainable development. The Grenelle commits France, in the sense that it sets "*the objective to reroute from 5 to 10%*" the road traffic of the Alps and the Pyrenees towards a Mediterranean and Atlantic network of motorways of the sea. To this end, France joined forces with Spain, Italy and Portugal in 2015 "*to study*

the feasibility of an incentive for shippers using motorways of the sea" (*Med Atlantic Ecobonus project*).

The Med Atlantic Ecobonus project has an estimated cost of approximately 1.5 million euros, half of which will be borne by the different countries of cooperation; the rest will be financed by the European Union. France is in charge of "*technical, environmental, economic and financial, regulatory, operational and technological specifications*". France is therefore a player in the development of motorways of the sea, shown by the Nantes-St-Nazaire / Gijón link.

4 THE MOTORWAY OF THE SEA NANTES-SAINT-NAZAIRE/GIJÓN

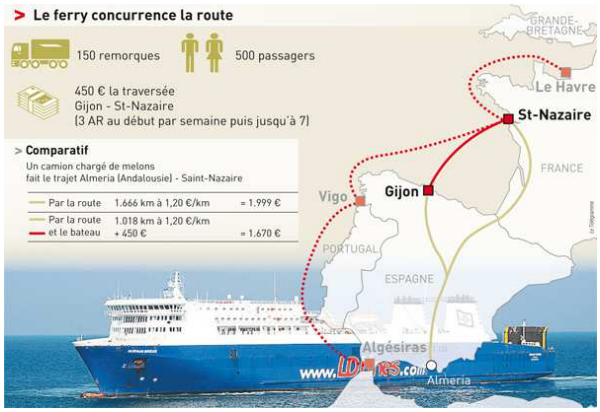

Figure 3. Ferry versus Road.

As part of the Marco Polo II project, the French and Spanish governments decided in 2009 to open a maritime link between the Montoir-de-Bretagne (Saint-Nazaire port) and Gijón terminals. This line aimed to unclog the motorway of Aquitaine as well as those crossing the Pyrenees, given the extreme traffic of trucks on these express ways: indeed, not less than 5.97 million trucks crossed the Pyrenees in 2010, according to the statistics of the Office of the General Commissioner General for Sustainable Development. It was not until September 2010, however, that this project could bear the "*MoS*" label, previously refused by the European Commission (EC), to allow the allocation of corresponding funding, and thus ensure the viability of the project. The refusal of the EC was based on the fact that the guidelines posted for this shipping line were directly linked to strict national requirements, in spite of the requirements of regional integration and innovation of the required transport model. To be as competitive as possible, the MoS Nantes-Saint-Nazaire / Gijón (see Figure 3) has to offer an attractive financial, economic, and ecological offer, otherwise all-road transport remains the preferred type of transport. To start the line, the French and Spanish States provided a cumulative aid of 30 million Euros (15 million for each country). The ship owner in charge of this line with a grant of more than 4 million Euros, provided by the European Union (EU) under the Marco program Polo II, commits itself to embark 150 trailers and 500 passengers with a frequency of 2-3 return trips / week to improve the Pyrenean and Atlantic road traffic.

To establish its economic model, the ship owner opted for the technique of the mixed ro-ro goods and passenger vessels. Indeed, ro-ro vessels (abbreviation of Roll-On, Roll-Off), are suitable for the transport of trucks, semi-trailers, tractors, agricultural machinery, construction equipment... They may also be suitable for containers or swap bodies. In particular, this type of vessel can ship heavy weights, the ship owner's core target for this MoS; this has allowed it to be able to offer two services for road carriers of all types: an escorted and an unaccompanied service. Detailed numbers are given in Dang's thesis [11]. He came to the conclusion that: *a company that uses the MoS instead of traditional road transport would see its cost drop by **42.17%**! The saving of time is also substantial: **0.83 days**.*

Dang also underlines that MoS offer road carriers an efficient way to reduce their CO2 emissions. This judicious alternative makes it possible to significantly reduce the road distances traveled and, what's more, get rid of CO2 emissions, especially when transport vehicles are in traffic congestions. The studies have in fact been carried out by taking a constant CO2 emission over the entire duration of the road trip, which, in view of the previous elements, is certainly not the case. As a result, established rebates of 20 to 100% are very likely underestimated. The use of MoS Nantes-Saint-Nazaire / Gijón is a success from the ecological point of view: it amounts to reducing the CO2 emissions released into the atmosphere compared to the terrestrial way by **64.01%**. The MoS could therefore stress the environmental aspect to attract new partners.

Despite these promising prospects and the transport of more than 14,000 trucks in 2010-2011 alone, the MoS Nantes-Saint-Nazaire / Gijón was only able to maintain itself until September 2014, following the cutting off of European public subsidies.

Reasons for failure: The increased use of the line, due in part to the freight of Renault vehicles between the Spanish plant and France, was not enough to earn the six million Euros needed for the sustainability of the project. On the one hand, the filling rate was only 70%, which did not allow to reach the economic equilibrium and to face the very strong competitiveness of all-road transport. On the other hand, the line suffered from legal and political considerations intrinsic to the concept of MoS: a report of the European Parliament of December 2014 made "*the threefold finding that the concept is insufficiently known, including interested actors, that it is not viable without public funding and that cooperation between stakeholders is not necessarily present*" [12].

Does that mean that we should give up and let road traffic continue to increase until total saturation? The main reason for failure is probably the timidity of the program.

To be permanently successful and to set an example to be followed, the Motorway of the Sea must show a significant reduction of the traffic. The statistics of the Marco-Polo programs bear witness to its efficiency but the public does not significantly perceive its effects and

statistically it has been proved that the fluctuations of the economy are far more perceptible. To impact the traffic jams, it is estimated that the MoS must absorb at least 5% of truck traffic. In 2017, the ring road of Bordeaux is used by 12.000 transit trucks per day. The MoS must therefore be capable of transporting 600 trailers per day in each direction.

5 TWO SOLUTIONS

The most compact solution is to transport freight containers. The other solution is to transport the trailers using Ro-Ro vessels. To optimize these solutions, both types of vessels fitting the requirements are designed.

5.1 Container ship design

To transport the freight of 600 trailers per day in each direction, four container ships with a transport capacity between 300 and 360 TEU are needed. Larger container ships are not appropriate since they would require important harbor infrastructure modifications and with two departures per day in each direction we have less chance to run half empty ships. For the motorization, despite the fact that it uses more room, LNG is chosen because it generates far less pollution than Diesel. The main dimensions of the container vessel are given in Table 1.

Type	Container vessel 300-360 TEU
Crew	12
LOA	102 meters
BOA	18.20 meters
T	5.95 meters
L_{wl}	100.60 meters
B_{wl}	18.20 meters
C_b	0.74
C_p	0.80
Δ	8341 metric tons
S_w	3416 square meters
V_{design}	14.5 knots

Table 1: Main dimensions of container vessels

The GA and capacity plans are given in Figure 4. The plans show where the containers are located; they also show the longitudinal and transverse bulkheads, the ballast tanks and the LNG propulsion system.

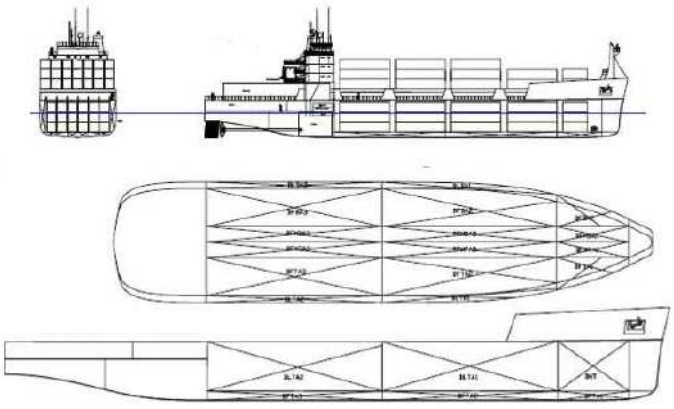

Figure 4.Container vessel's plans.

Stability calculations have been performed for two load conditions to verify that the vessel satisfies the IMO2008 and the SOLAS2009 rules. The scatter diagram of the Bay of Biscay weather conditions indicates that a sea state 4 should be considered for the design condition. In order to reach the 14.5 knots design velocity in sea state 4, the chosen engine must have a power of more than 6 Mwatts. The characteristics of the propulsive system are summarized in Table 2.

Engine	WARTSILA 6L46F
Fuel	LNG
η_P	55%
1-w	0.72
1-t	0.83
D	3.67 meters

Table 2. Container vessel propulsive characteristics

5.2 Ro-Ro vessels design

The ship is designed almost exclusively for the transportation of trailers without tractor. There is a gain of 20% in storage capacity compared to trucks. Because the vessel only transports trailers without drivers, it is far less complicated as there is no need for passenger accommodations. The unloading plus loading times will totalize no more than 6 hours using Ro-Ro tractors [13]. The boarding of cars should remain exceptional and the number of passengers should not exceed 12 to avoid regulatory constraints of passenger ships amended by the SOLAS.

The target of the postponement of 600 trailers of the road to the sea (in both directions) will be made after a period of 3 years. Ultimately there will be six Ro-Ro vessels that will carry out the shuttle with three daily departures from each port. The main dimensions of the Ro-Ro vessels are given in Table 3.

Type	Ro-Ro
Crew	15
LOA	150 meters
BOA	25 meters
T	6.15 meters
L_{wl}	149 meters
B_{wl}	25 meters
C_b	0.57
C_p	0.60
Δ	13923 metric tons
S_w	4149 square meters
V_{design}	19 knots

Table 3: Main dimensions of ro-ro vessels

The GA and capacity plans are given in Figure 5.The ship has three main decks. The lowest deck is located above the ballasts, 1.40 meters above the baseline. Furthermore, the gained space between the lowest deck and the next one offers enough room for the engine room, LNG tanks, MDO bunkers and other capacities. All ballasts are placed in the double bottom and double hulls. The two upper decks are reserved for the trailers. A retractable bridge is linking these two decks.

As previously, a complete design spiral procedure has been performed including stability, strength, maneuvering and seakeeping. The design speed in sea state 4 is taken to be 19 knots to achieve the same goal. It can also

reach 18.3 and 17.5 knots for sea states 5 and 6 respectively. The ship is propelled by 2 dual fuel LNG engines with two fixed pitch propellers which offer better maneuvering capabilities. The propulsive system characteristics are summarized in Table 4.

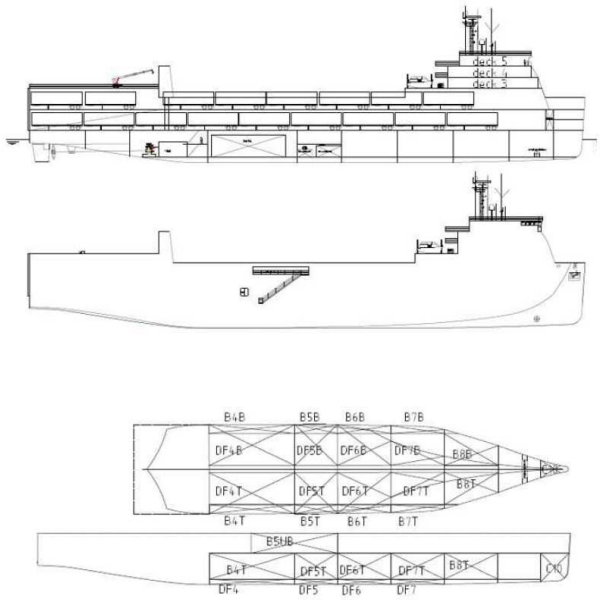

Figure 5. Ro-ro vessel plans

Engine	WARTSILA 8L46DF
Fuel	LNG
η_P	60%
1-w	0.88
1-t	0.87
D	3.67 meters

Table 4. Ro-ro vessel propulsive characteristics

6 CONCLUSION

The previous Bay of Biscay Motorway of the Sea did not succeed in achieving a modal transfer of road to sea traffic to a significant extent. They failed in their target of decongesting the Bordeaux ring road and did not manage to establish a dominant position in the highly competitive freight transport market.

The primary suspect cause of failure is the lack of ambition of the project. Two solutions have been predesigned and pre-dimensioned to reduce road traffic between the South-West of France and the North of Spain by at least 5%.

The most relevant solution seems to be transport by ro-ro vessels. The operating prices for this line are reduced by the attractive LNG fuel prices and reduced port charges due to regular and intense port traffic. By combining these regular departures (3 per day from each port) and attractive LNG prices, road transport companies should use this solution and gradually prefer it to classical road transport.

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