Rethinking transport
27–30 April 2020

Proceedings of 8th Transport Research Arena TRA 2020, April 27-30, 2020, Helsinki, Finland

VESSL as a tool for macro-analyses at European level. STM Validation Project results calculated by the use of Short Sea Shipping data mining

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Abstract

Shipping companies are constantly updating their ships' schedules to move cargo from shippers to end customers. The fuel consumption and GHG emissions of ships passing through European waters has always been an important metric to analyse. STM Validation Project proposes a scenario where ship-to-port communications would allow synchronizing port calls in a more efficient way, saving time at ports and allowing a more rational navigation. One of the objectives of the project has been to assess the impact of the implementation of the services at European level. For this purpose, the VESSL tool is able to extrapolate the main results obtained in the project to ships operating Short Sea Shipping and national *cabotage* lines from the main core and comprehensive ports of the European Union. This tool also contributes to another type of analyses for several projects where the real impact on the sector is measured from accuracy and reliability.

Keywords: Transport economics; Ports; Trans-European Networks, Externalities; Impact assessment; Big data.

1. Introduction

This paper presents the results of the theoretical implementation of STM Validation Project at European level and contains information about the tool Fundación Valenciaport European Short Sea Shipping Lines Database, hereinafter VESSL, developed in part during the Sea Traffic Management Validation Project developed within the framework of the Trans-European Transport Network, CEF Programme. This tool, owned by the Fundación Valenciaport because of 15 years of work, has been adapted for use in the analysis and evaluation of the project. Moreover, VESSL facilitates macro analyses that could provide data at European Union level on the impact that the implementation of the STM concept would have on all the regular lines operating in their waters.

Sea Traffic Management connects and updates the maritime world in real time, with efficient information exchange. Through data exchange among selected parties such as ships, service providers and shipping companies, STM is creating a new paradigm for maritime information sharing offering tomorrow´s digital infrastructure for shipping. The concept, which is somewhat inspired by the European programme for Air Traffic Management has a Master Plan for how STM will be implemented up till the year 2030. STM is a concept for sharing secure, relevant and timely maritime information among authorized service providers and users, enabled by a common framework and standards for information and access management, and interoperable services. STM relies on four concepts which are Port Collaborative Decision Making, Voyage Management, Flow Management and Sea System Wide Information Management.

This database provides an important value as it offers real information on Short Sea Shipping, cruises, deep-sea and *cabotage* services of the main European ports; compiled daily and used by the Valenciaport Foundation for the analysis of data for various external and internal projects.

The database has undergone a significant restructuring over time due to the needs that arose in relation to the topics of the projects that were being developed. Several of the needs that have been tried to cover have been the following:

- To know the capacity offered and to contrast the information with Customs information (export/import) by the services.
- To have real information of the ships that operate these services
- Precise information to make traffic forecasts for the Spanish Port Authorities
- Calculation of a connectivity index for container traffic
- Calculation of fuel consumption by ships thanks to the collected information on engines on-board ships.
- Calculation of emissions from such ships for specific routes
- Identification of the Motorways of the Sea in the TEN-T (Trans-European Networks) scheme
- Identification of transport flows with Northern Europe
- Information about the navigation and port times used to calculate the carbon footprint at ports and the impact of GHG emissions on the environment
- Identification of seasonality of cruises
- Financial analysis of the fleet for bunkering demand studies LNG
- Estimations related to onshore power supply (OPS)

This paper aims to explain the tool at a conceptual, quantitative and qualitative level throughout the different sections of the paper. The structure is as follows:

- Definition of Objectives
- Methodology and Structure
- STM Validation project macro-results
- Conclusions.

2. Definition of Objectives

VESSL database was born from the need to have a tool capable of providing real, accurate and standard information about the regular lines operating in the European Union. In addition, it offers an alternative information capable of meeting the needs of different port clusters as it provides continuously updated data on regular services operating in their areas of interest.

The tool attempts to meet the following objectives:

- To have updated information of the regular routes offered by the shipping companies in EU ports.
- To standardize and to give uniformity to the information of the schedules of the shipping companies, that do not follow defined patterns.
- Collect contrasted information from different specialized sources of the sector, stakeholders involved in the operations, etc. giving solution to the scarce or dispersed information that exists nowadays in this sector.
- To offer a tool that not only gathers information but also is capable of calculating relevant variables for the different projects it serves.
- Provide content to a tool capable of providing inputs for reports at European Union level, analysing the impact of project activities in the sector.
- It offers accurate and truthful information that serves to make decisions at a strategic level for some of the actors in the sector.
- Collection of historical data to establish comparative bases of evolution of regular traffic.
- Data on ships calling at European ports for decisions on energy, logistics, operations, etc.

3. Methodology and structure

The planning methodology for the Trans-European Transport Network (TEN-T) structures a double layer network architecture, establishing a comprehensive and a core network (European Commission, 2013). As the multimodal basic level of the TEN-T includes all transport modes, for instance, maritime as well as their connecting points and their corresponding traffic information and management systems.

Figure 1: Comprehensive and core port network

The comprehensive network arises from updating and adjusting the TEN-T defined in Decision Nº 661/2010/EU of the European Parliament and the Council of 7 July on Union guidelines for the development of the trans-European transport network. The European Union selected those seaports, which are open for commercial traffic under the following criteria:

- Passengers – ports connected to the land component of the comprehensive network with an annual traffic volume exceeding 1‰ of the total annual EU maritime passenger traffic (calculated with average data from all Member States using EUROSTAT 2009, 2010 and 2011).
- Freight – ports connected to the land component of the comprehensive network with an annual traffic volume – either for bulk or non-bulk cargo handling – that exceeds 1‰ of corresponding total annual cargo handled in EU ports (using the same EUROSTAT statistics that represents 2.22 million tons per year for bulk cargo and 1.27 million tons per year for non-bulk cargo).
- Seaports located on islands, on condition that they provide accessibility at NTUS 3 or archipelagos level.
- Seaports located in outermost regions or peripheral areas provided their road-distance from another TEN-T port, is at least 200 km on road.

The core network is a subset of the comprehensive network. While for inland waterways the core network is identical to the comprehensive network, the following criteria apply on road and rail, only. The land-based core network links are complemented by the "Motorways of the Sea" to give due access to the insular Member States and to shortcut connections to or between peninsulas.

The connections between ports are not foreseen, but may be result from the overall itinerary of a core network link. VESSL provides a solution to this lack of maritime connections compiling that regular services calling at this comprehensive network.

Core network corridors were introduced to facilitate the coordinated implementation of the core network. The main challenges are remove bottlenecks; build missing cross-border connections and promote modal integration and interoperability

They also aim at:

- Integrating rail freight corridors
- Promoting clean fuel and enhancing safety
- Foster innovative transport solutions
- Advancing telematics applications for efficient infrastructure use
- Integration of urban areas into the network

Nine core network corridors are identified in the annexe to the CEF regulation (European Commission, 2014) based on their benefit for TEN-T development. These are Scandinavian-Mediterranean, North Sea-Baltic, North Sea-Mediterranean, Baltic-Adriatic, Orient/East-Med, Rhine-Alpine, Atlantic, Rhine-Danube and Mediterranean corridors.

The use of core and comprehensive ports as a selection criterion for the regular lines guarantees that data are representative and describe the current situation along Europe, as long as the network of core ports accounts for the majority of transport flows.

The scope of this database is to compile the information of the regular services along the Mediterranean and North Europe sea area that comply with the criteria used to define Short Sea Shipping. Short Sea Shipping is defined as 'the movement of cargo and passengers by sea between ports situated in Europe or between those ports and ports situated in non-European countries which have a coastline on the enclosed seas bordering Europe' (on the Mediterranean and Black Seas, etc.). As a result, short sea shipping also includes feeder services: a short-sea network between ports with the objective of consolidating or redistributing freight to or from a deep-sea service in one of these ports, the so-called hub port. The database also includes national services named *"cabotage"* for all the core ports in the European Union.

Thousands of data are being collected and compiled from different sources such as the different agents implied: Sea Carriers, Shipping Agents, Port Authorities, Specific Press, Private Databases, etc. Data accuracy is continuously verified with updated information provided by the actors concerned along the transport chain. The main groups of data are:

- Regular Shipping Services Data: name of the service, sea carrier, actual schedule, itinerary of ports, main ships operating the service, type of traffic, number of port calls, number of different countries where the service is being provided, frequency, seasonality, etc.
- Ports Data: The ports included in the different itineraries are characterised in detail by country, sea, coordinates, continent, geographic area, Ten-T Corridor comprised, UN Locode, among other details.
- Ships Data: IMO number, name of the ship, ship type, ship operator, shipyard, MMSI number, flag, GT, DWT, year of build, dimensions, cargo capacity, total power, group of engines configuration, service speed, median speed, average speed, maximum speed, fuel consumption, etc.

- Distances Data: port-to-port distance for every two ports in a service is calculated and registered. A smart selection of waypoints to cover the distance from port-to-port is included in the database.
- Times Data: figures like the navigation time, port call time, etc. are calculated and registered.
- Engine characteristics Data: data from prime and auxiliary engines of the ships operating in regular services are collected and registered.
- Bunkering Data: related to the ports. The market price of the different fuels including LNG (Liquefied Natural Gas), HFO (Heavy fuel oil), MGO (Marine gas oil), MDO (Marine diesel oil), etc. is estimated.

The type of services has been categorised based on the cargo transported by each service and the characteristics of the ships used. According to these criteria, services have been classified as car carrier, container, passenger, cruises, Ro-ro and Ro-pax services.

VESSL will collect a huge variety of information for more than 200 core and comprehensive ports in 23 Member States (Bulgaria, Cyprus, Croatia, Greece, Spain, France, Italy, Malta, Portugal, Romania, Slovenia, Belgium, Germany, Denmark, Estonia, Finland, Ireland, Lithuania, Latvia, Netherlands, Poland, Sweden and United Kingdom).

Collecting and validating information about regular services and their fleets operating for their inclusion in this tool is a complex and labour-intensive task because of the lack of uniform and comprehensive information. Data about the different aspects of SSS and cabotage is available from different sources, but this information is often incomplete and outdated.

The following search procedure has been followed:

A. Search on websites related to the ports under study: Port Authorities, Port Terminals, Shipping Agents, National Maritime Administrations, research studies, UNCTAD reports, etc.
B. Port-to-port monitoring of ship movements using AIS information, since AIS is compulsory standard for all ships that are part of the SOLAS Convention
C. Search for information on specialized ferry and containership websites, maritime press, etc.
D. Identification of ships, sea carriers and ship owners. Where ships are allocated to specific services by monitoring their movements and contrasting this information with the official players. Specific datasheets for each ship are elaborated using search engines, publications from several maritime entities, Equasis database, IHO Fairplay, classification societies' information, etc.
E. Identification of the sea carrier and downloading or requesting of the updated services' schedules. This information is treated, prepared and analysed to find out the way of modelling into the database. When the shipping companies share their services publicly and once the operator is identified, the most complete and reliable source of information is chosen and accurate information is collected.

4. STM Validation Project macro-results

Taking into account the results from the previous analyses, the percentages obtained have been extrapolated to apply to global fuel consumption and GHG emissions, calculated using the VESSL database, which estimates the potential impact assessment of STM at the European level (23 Member States of the European Union)

This unique, tailor-made tool code-named VESSL (Valenciaport Short Sea Shipping Lines database), features detailed and reliable information about all the regular services calling at all Core Ports and Mediterranean Comprehensive Ports of the Trans-European Transport Network in the European Union (TEN-T Network). The focus has been on these SSS regular lines and cabotage since these could be potential beneficiaries in the implementation of STM.

The large number of ports studied and the vast amount of information and variables to be considered in the database have resulted in an exhaustive information-monitoring process, which is essential for a reliable evaluation, and for meeting the expected objectives of the STM Validation Project. The results of this data compilation are based on a SQL database containing essential information about the morphology of the Short Sea Shipping situation in the European Union.

The basis for calculations using VESSL, from which the main results of the project have been extrapolated, is delimited and shown in the following figure (2017):

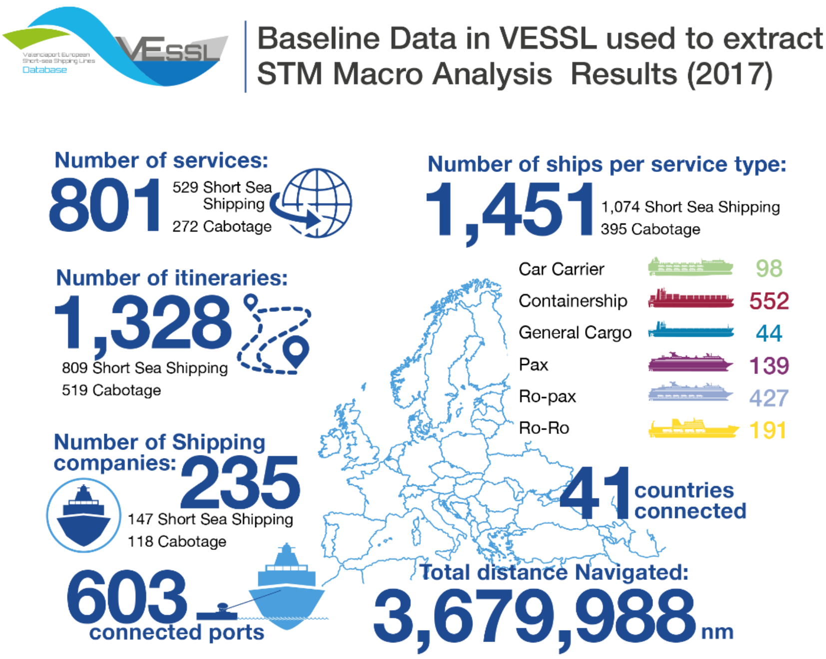

Figure 2: Baseline data in VESSL used to extract STM Macro Analysis Results (2017)

The assumptions for the calculation of savings derive directly from the results obtained in the use-cases, which also take into account some of the findings from the various results of the project, in line with conservative criteria.

The most significant results of the extrapolation of STM findings using VESSL are shown below, structured as savings in time, fuel consumption and GHG emissions for ports and navigation phases. The calculations are expressed in a MGO 2020 scenario that will comply with the 0.5% of sulphur content of fuels used in maritime sector recently approved by the IMO.

Impact of the potential improvement in the port call phase

The estimation of potential savings during port calls for the various types of ships analysed has been extracted from the results of the project. However, a more conservative percentage has been taken for the extrapolation of results. Thus, a 1% time saving in ports resulting from the implementation of STM concept has been established as the pessimistic scenario, a 5% saving as the moderate (most probable) scenario and a 10% saving as the optimistic scenario. Consequently, the global results are obtained from a total of 217,127 hours at ports for 1,097,544 port calls analysed, operated by 1,451 different ships included in the database and applying aforementioned percentages.

4.1.1.1. Potential Time Savings at Ports

In the moderate scenario, the average time saved in minutes per call would be 7.5 minutes as a result of the total time saved in minutes

Table 1 divided by the total of 1,097,544 port calls. However, it is important to note that the potential savings in time at port for container ships, general cargo and car carriers are superior to the time savings of passenger-related traffic, due to the latter's priority access to the port. The results are expressed in days, hours and minutes for all the scenarios, as follows:

Table 1: Time saving in port estimation for 1,097,544 port calls in 2017

Time Savings	Pessimistic scenario	Moderate Scenario	Optimistic Scenario
Total time saving (days)	2,169	5,730	10,183
Total time saving (hours)	52,056	137,520	244,392
Total time saving (minutes)	3,123,360	8,251,200	14,663,520

4.1.1.2. Potential Fuel Consumption and GHG Emission Savings at Ports

As a result of the reduction in time at port, there is a consequent reduction in fuel consumption and GHG emissions. The following tables summarize the potential fuel savings in the different scenarios on the basis that the total consumption of all ships included in the database amounts to 1,246,809 tons of MGO; 3,995,887 tons of CO_2; 78,500 tons of NO_x; 2,500 tons of SO_x and 1,637 tons of PM_x at ports. As observed in Table 2 the moderate scenario adds up to savings of more than 100,000 tons of GHG, while in the most optimistic scenario it amounts to more than 180,000 tons of GHG.

Table 2: Potential saving tons at ports

Savings at Ports	Pessimistic scenario	Moderate Scenario	Optimistic Scenario
Tons of Fuel (MGO) saving in Ports	12,468	31,757	55,869
Tons of CO_2 saving in Ports	39,945	101,743	178,990
Tons of NO_x saving in Ports	976	2,486	4,374
Tons of SO_x saving in Ports	25	63	111
Tons of PM_x saving in Ports	19	47	83

The second table rates the GHG emissions on the basis of the following reference values for externalities:

- The monetary value in Euros of fuel (MGO) is based on the spot price in the Mediterranean, which amounts to €568/ton (Piraeus bunkering price, 2019 according to estimated values in www.bunkerindex.com)
- CO_2 emissions - €25.89/ton (Sartori, Davide, et al., 2015)
- NO_x emissions - €3,790/ton (Gibson G., et al, 2014)
- SO_x emissions - €17,240/ton (Gibson G., et al., 2014)
- PM_x emissions - €6,080/ton (Gibson G., et al., 2014)

Table 3: Monetary savings in ports estimation

Monetary Savings at ports	Pessimistic scenario	Moderate Scenario	Optimistic Scenario
Amount of Fuel saving in Ports	7,081,873 €	18,038,119 €	31,733,425 €
Amount of CO_2 saving in ports	1,034,171 €	2,634,120 €	4,634,056 €
Amount of NO_x saving in ports	3,699,138 €	9,422,013 €	16,575,605 €
Amount of SO_x saving in ports	428,813 €	1,092,221 €	1,921,482 €
Amount of PM_x saving in ports	113,224 €	288,391 €	507,349 €
Amount of emission savings in ports	5,275,346 €	13,436,745 €	23,638,492 €

In the moderate scenario, the estimated potential value of the tons of MGO fuel saved in port for the total calls amounts to €18 million, with €13.43 million of GHG emission savings valued according to the reference values in the previous section for the same scenario. The potential emission savings at ports in the optimistic scenario would double the figures expressed in the previous table.

Impact of the potential improvement in navigation phase

In this section, the results obtained in the use-cases have been extrapolated to the VESSL database. Taking into account the varying levels of maturity of the systems included in STM Validation project, a simulation process was conducted to obtain estimates of the potential impact on fuel consumption and GHG emissions that the implementation of STM could have. To represent these various maturity levels, we have devised a number of scenarios with different assumptions that reflect an increasingly mature deployment of STM in the shipping industry and ports. Note that all these scenarios are built on top of the AIS data, adapting the figures to the corresponding assumptions. For this purpose, we have used the time and fuel savings estimations for the following scenarios:

A. Scenario 1: the first scenario assumes that ports, thanks to STM in Ports, can provide more accurate recommended times of arrival; that ships, thanks to the use of STM services, can avoid congestion or risks that otherwise would have affected their speed and, thus, meet their ETAs, and that both agents can communicate smoothly. Consequently, anchoring times are minimized or eliminated. The port assures that it will be let in upon its arrival. The ship adapts its cruising speed and arrives at port at the time they commenced its anchoring. According to the recommended time of arrival, the speed would be adapted to meet the port just in time.
B. Scenario 2: In scenario 2, it is assumed that ports have fully deployed STM and its use is already raising port efficiency. STM in Ports will not only improve communication between agents in the port, but also allow the gathering, processing and analysing of more data on port operations. This will result in superior resource planning, avoiding congestion in ports and increasing their efficiency reducing the time at berth.
C. Scenario 3: Scenario 3 is the most ambitious one. In this case, in addition to the assumptions of the previous scenarios, the effect on fuel consumption and GHG emissions of having the ships navigating at different speeds are analysed. Ships adopt optimal navigation speeds and ports adapt to them seamlessly. In particular, three different speeds are used,
    a. Lower Speed
    b. Median Speed
    c. Maximum Speed

Table 4: Results from STM use cases in the different scenarios (percentage of MGO fuel)

USE CASE	Scenario 1	Scenario 2	Scenario 3 Low	Scenario 3 Med	Scenario 3 High
CS1	7.10%	9.10%	16.19%	6.56%	1.12%
CS2	19.62%	21.87%	22.66%	12.82%	1.24%
CS3	-0.90%	2.03%	20.00%	3.99%	-8.12%
PAX1	14.33%	16.10%	18.42%	18.84%	17.41%
RPX1	2.86%	7.14%	8.49%	4.67%	1.35%
RPX2	2.41%	6.53%	9.34%	3.57%	-1.67%
RPX3	5.62%	8.32%	10.05%	4.17%	-1.95%
RO1	9.03%	13.03%	13.50%	7.78%	2.91%
RO2	5.53%	8.14%	12.18%	5.24%	-1.95%
RO3	12.47%	16.94%	18.42%	8.15%	-1.71%

The specific segmentation offered by Fairplay and by prestigious publications from the maritime world has been taken into account to select the use cases are summarised in the following table:

Table 5: Relationship between use case and main characteristics of the ships

USE CASE	*VESSL*	*VESSEL TYPE*	*HSC*	*UNIT*	*From*	*To*	*Range*
CS1	CONTAINER	CONTAINERSHIP	N	TEU	0	999	<=999 TEU
CS1	CONTAINER	CONTAINERSHIP	N	TEU	1000	1999	1000 - 1999 TEU

CS1	CONTAINER	CONTAINERSHIP	N	TEU	2000	2999	2000 - 2999 TEU
CS2	CONTAINER	CONTAINERSHIP	N	TEU	3000	5399	3000 - 5399 TEU
CS2	CONTAINER	CONTAINERSHIP	N	TEU	5400	9999	5400 - 9999 TEU
CS3	CONTAINER	CONTAINERSHIP	N	TEU	10000		> 10000 TEU
CS1	CONTAINER	GENERAL CARGO	N	DWT	0	4999	<= 4999 DWT
CS1	CONTAINER	GENERAL CARGO	N	DWT	5000	9999	5000 - 9999 DWT
CS1	CONTAINER	GENERAL CARGO	N	DWT	10000	14999	10000 - 14999 DWT
CS1	CONTAINER	GENERAL CARGO	N	DWT	15000	19999	15000 - 19999 DWT
CS1	CONTAINER	GENERAL CARGO	N	DWT	20000	29999	20000 - 29999 DWT
CS1	CONTAINER	GENERAL CARGO	N	DWT	30000		> = 30000 DWT
CS1	CONTAINER	RO-RO	N	Lane Meters	0	499	<= 499 lane metres
CS1	CONTAINER	RO-RO	N	Lane Meters	500	999	500 - 999 lane metres
CS1	CONTAINER	RO-RO	N	Lane Meters	1000	1499	1000 - 1499 lane metres
CS1	CONTAINER	RO-RO	N	Lane Meters	1500	1999	1500 - 1999 lane metres
CS1	CONTAINER	RO-RO	N	Lane Meters	2000	2999	2000 - 2999 lane metres
CS1	CONTAINER	RO-RO	N	Lane Meters	3000		>= 3000 lane metres
RPX1	RO-PAX	RO-PAX	N	GT	0	9999	<= 9999 GT
RPX1	RO-PAX	RO-PAX	N	GT	10000	19999	10000 - 19999 GT
RPX2	RO-PAX	RO-PAX	N	GT	20000	49999	20000 - 49999 GT
RPX3	RO-PAX	RO-PAX	N	GT	50000	69999	50000 - 69999 GT
RPX3	RO-PAX	RO-PAX	N	GT	70000		>= 70000 GT
RPX1	RO-PAX	RO-PAX	Y	GT	0	9999	<= 9999 GT
RPX1	RO-PAX	RO-PAX	Y	GT	10000	19999	10000 - 19999 GT
RPX2	RO-PAX	RO-PAX	Y	GT	20000	49999	20000 - 49999 GT
RPX3	RO-PAX	RO-PAX	Y	GT	50000	69999	50000 - 69999 GT
RPX3	RO-PAX	RO-PAX	Y	GT	70000		>= 70000 GT
RO1	RO-RO	RO-RO	N	Lane Meters	0	499	<= 499 lane metres
RO1	RO-RO	RO-RO	N	Lane Meters	500	999	500 - 999 lane metres
RO2	RO-RO	RO-RO	N	Lane Meters	1000	1499	1000 - 1499 lane metres
RO2	RO-RO	RO-RO	N	Lane Meters	1500	1999	1500 - 1999 lane metres
RO3	RO-RO	RO-RO	N	Lane Meters	2000	2999	2000 - 2999 lane metres
RO3	RO-RO	RO-RO	N	Lane Meters	3000		>= 3000 lane metres
RO1	RO-RO	GENERAL CARGO	N	DWT	0	4999	<= 4999 DWT
RO1	RO-RO	GENERAL CARGO	N	DWT	5000	9999	5000 - 9999 DWT
RO2	RO-RO	GENERAL CARGO	N	DWT	10000	14999	10000 - 14999 DWT
RO2	RO-RO	GENERAL CARGO	N	DWT	15000	19999	15000 - 19999 DWT
RO3	RO-RO	GENERAL CARGO	N	DWT	20000	29999	20000 - 29999 DWT
RO3	RO-RO	GENERAL CARGO	N	DWT	30000		> = 30000 DWT
RO1	RO-RO	RO-PAX	N	GT	0	9999	<= 9999 GT
RO2	RO-RO	RO-PAX	N	GT	10000	19999	10000 - 19999 GT
RO3	RO-RO	RO-PAX	N	GT	20000	49999	20000 - 49999 GT
RO3	RO-RO	RO-PAX	N	GT	50000	69999	50000 - 69999 GT
RO3	RO-RO	RO-PAX	N	GT	70000		>= 70000 GT
PAX1	PAX	PAX	N	Passengers	0	199	< 200 passengers
PAX1	PAX	PAX	N	Passengers	200	499	200 - 499 passengers
PAX1	PAX	PAX	N	Passengers	500	1199	500 - 1199 passengers
PAX1	PAX	PAX	N	Passengers	1200	1999	1200 - 1999 passengers
PAX1	PAX	PAX	N	Passengers	2000		> 2000 passengers
PAX1	PAX	PAX	Y	Passengers	0	199	< 200 passengers
PAX1	PAX	PAX	Y	Passengers	200	499	200 - 499 passengers
PAX1	PAX	PAX	Y	Passengers	500	1199	500 - 1199 passengers
PAX1	PAX	PAX	Y	Passengers	1200	1999	1200 - 1999 passengers
PAX1	PAX	PAX	Y	Passengers	2000		> 2000 passengers
PAX1	MIXED PAX AND RO-PAX	PAX	N	Passengers	0	199	< 200 passengers
PAX1	MIXED PAX AND RO-PAX	PAX	N	Passengers	200	499	200 - 499 passengers
PAX1	MIXED PAX AND RO-PAX	PAX	N	Passengers	500	1199	500 - 1199 passengers
PAX1	MIXED PAX AND RO-PAX	PAX	N	Passengers	1200	1999	1200 - 1999 passengers
PAX1	MIXED PAX AND RO-PAX	PAX	N	Passengers	2000		> 2000 passengers
PAX1	MIXED PAX AND RO-PAX	PAX	Y	Passengers	0	199	< 200 passengers
PAX1	MIXED PAX AND RO-PAX	PAX	Y	Passengers	200	499	200 - 499 passengers
PAX1	MIXED PAX AND RO-PAX	PAX	Y	Passengers	500	1199	500 - 1199 passengers

PAX1	MIXED PAX AND RO-PAX	PAX	Y	Passengers	1200	1999	1200 - 1999 passengers
PAX1	MIXED PAX AND RO-PAX	PAX	Y	Passengers	2000		> 2000 passengers
RPX1	MIXED PAX AND RO-PAX	RO-PAX	N	GT	0	9999	<= 9999 GT
RPX1	MIXED PAX AND RO-PAX	RO-PAX	N	GT	10000	19999	10000 - 19999 GT
RPX2	MIXED PAX AND RO-PAX	RO-PAX	N	GT	20000	49999	20000 - 49999 GT
RPX3	MIXED PAX AND RO-PAX	RO-PAX	N	GT	50000	69999	50000 - 69999 GT
RPX3	MIXED PAX AND RO-PAX	RO-PAX	N	GT	70000		>= 70000 GT
RPX1	MIXED PAX AND RO-PAX	RO-PAX	Y	GT	0	9999	<= 9999 GT
RPX1	MIXED PAX AND RO-PAX	RO-PAX	Y	GT	10000	19999	10000 - 19999 GT
RPX2	MIXED PAX AND RO-PAX	RO-PAX	Y	GT	20000	49999	20000 - 49999 GT
RPX3	MIXED PAX AND RO-PAX	RO-PAX	Y	GT	50000	69999	50000 - 69999 GT
RPX3	MIXED PAX AND RO-PAX	RO-PAX	Y	GT	70000		>= 70000 GT

Once the potential savings percentages from the Table 4 have been applied, the following figures are the MGO fuel and GHG emissions valued in tons that can be potentially saved with the progressive implementation of STM.

As can be seen in the following table, Scenario 3 Low yields the most favorable results, accounting for 2.1 million tons of MGO and 6.8 million tons of CO_2 in potential savings. These amounts express the greatest potential for implementation of the STM concept in Short Sea Shipping and cabotage navigation across the European Union, taking into account the data for the base-year, 2017.

Table 6: Savings in Navigation estimation

Savings in Navigation	**Scenario 1**	**Scenario 2**	**Scenario 3 Low**	**Scenario 3 Med**	**Scenario 3 High**
Tons of Fuel (MGO) saving in Navigation	1,179,439	1,660,993	2,135,070	974,828	-37,862
Tons of CO_2 saving in Navigation	3,778,646	5,321,430	6,840,262	3,123,120	-121,302
Tons of NO_x saving in Navigation	92,329	130,026	167,137	76,311	-2,964
Tons of SO_x saving in Navigation	2,353	3,314	4,259	1,945	-76
Tons of PM_x saving in Navigation	1,762	2,481	3,189	1,456	-57

Table 7 summarizes the monetary value in Euros of the MGO fuel, based on the spot price in the Mediterranean, as noted above. In Scenario 3 low, the estimated potential value of the tons of MGO fuel saved in navigation amounts to €1,212 million, with €903 million of GHG emissions savings, valued according to the reference values in the previous section for the same scenario.

Table 7: Monetary savings in Navigation estimation

Monetary Savings (€) in Navigation	**Scenario 1**	**Scenario 2**	**Scenario 3 Low**	**Scenario 3 Med**	**Scenario 3 High**
Amount of Fuel (MGO) saving in Navigation	669,921,549€	943,443,891€	1,212,719,733€	553,702,303€	-21,505,761€
Amount of CO_2 saving in Navigation	97,829,149€	137,771,823€	177,094,378€	80,857,565€	-3,140,502€
Amount of NO_x saving in Navigation	349,926,143€	492,797,526€	633,450,797€	289,220,300€	-11,233,297€
Amount of SO_x saving in Navigation	40,564,238€	57,126,215€	73,431,064€	33,527,078€	-1,302,189€
Amount of PM_x saving in Navigation	10,710,603€	15,083,636€	19,388,777€	8,852,507€	-343,831€
Amount of GHG saving in Navigation	499,030,134€	702,779,201€	903,365,015€	412,457,451€	-16,019,820€

5. Conclusions

The VESSL tool offers a solution for analysis of macro results for the main ports of the European Union as well as providing updated and verified information for any project that requires impact analysis in the EU maritime sector. In the future, accurate information about the retrofitting of ships and the use of scrubbers in VESSL could help to estimate the impact of these solutions implemented to comply with IMO emissions reduction in 2050 and the deviations under the calculations done in this study.

Finally, the implementation of the STM concept across the European Union would contribute to meeting the European Commission's goals regarding environmental issues in the maritime sector. This would offer a feasible solution to some of the concerns related to growing intra-European and international trade and the impact of shipping on climate change and society.

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WEBSITES: More than 300 websites of short-sea and sea carriers as well as of port authorities have been consulted to elaborate the study.

WEBSITES: Several websites of engine manufacturers and classification societies as well as tank manufacturers have been consulted to elaborate the study.