Sea Traffic Management Validation Project

Final Report

Co-financed by the Connecting Europe Facility of the European Union

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1. Executive Summary

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Every day thousands of ships carry millions of tons of cargo worldwide. In complex logistics chains, minor decisions may easily have major consequences. The shipping industry suffers from a lack of shared data between ships and ports, which could lead to monetary loss when ships are delayed, fuel burned and sub-optimal routes are chosen. Operations in the maritime industry are characterized by infrequent interaction among an extensive number of actors. In many other industries, close partnerships have stimulated systems integration and general standardization of information exchange. In shipping, however, this has yet to happen. Sea Traffic Management, STM, is part of the solution!

STM establishes a global maritime digital infrastructure where standard messages can be sent and received. Interoperability is achieved by specifying not only WHAT format the data should have but also HOW the exchange should be done. When actors follow this design principle they can connect seamlessly even on their first encounter. Shipping is often a series of first-occasion encounters, as ships visit new terminals and ports most of the time. Data exchange among port actors can cut waiting times during port calls and assist in achieving just-in-time arrivals. In STM, information owners select the partners with whom they wish share data, thus avoiding business sensitivity issues.

The goal of the STM Validation Project was to develop and validate the infrastructure and the services using it, and to verify the functions and benefits. The benefits predicted in the previous projects defining and designing the STM concept include: common situational awareness among ships and shore actors, reduced administrative burden, green steaming and just-in-time operations.

The STM Validation project set up three test-beds. One test-bed was located in Northern Europe and another in the Mediterranean Sea. Apart from these operational test-beds, the European Maritime Simulator Network (EMSN) was used to validate complex cases involving many ships. EMSN tests using 30 manned bridges supplied data on the behaviour of mariners and to compile their feedback on STM. The test-beds were supported by the development of a maritime digital infrastructure.

The validation of the port functions took place in parallel with current operations, whereas the ships and shore centres implemented services, many of which will remain operational after the project. Examples of functions and services include winter navigation services in the Northern Baltic Sea, enhanced monitoring in the Strait of Gibraltar, port arrival synchronization in Limassol, Search and Rescue (SAR) and ship-to-ship route exchange among 311 ships wherever they meet around the world.

1.1 STM Port Functions

In the port test-bed, 92% of users agreed with the statement that the use of the STM sub-concept Port Collaborative Decision Making (PortCDM) is expected to contribute to a shared situational awareness during port calls, which more than half of them identified as the key to enhanced collaboration. Bringing people together in real life workshops induced 40% of the participants to begin to collaborate with actors they had never communicated with before. One conclusion from the port tests is that data sharing and collaboration is critical in creating more efficient port calls and operations. The project established the International PortCDM Council (IPCDMC)[1] to stimulate continuing progress after the project, and which has had an uptake of 36 active members and 34 observers, derived from ports, authorities, private companies and international organizations.

1 The International PortCDM Council aims for establishing the necessary overarching guidelines, processes and procedures to make PortCDM a successful international concept to improve maritime transport as it relates to Port operations and Ports interaction with ships.

1.2 STM Services in Use

The ship and shore centre test-bed implemented the following STM services:

- Nordic Pilot Route Service.
- Baltic Navigational Warning Service.
- SSPA Route Optimization Service.
- SMHI Route ETA (Estimated Time of Arrival) Forecasts.
- Winter Navigation Service.
- Ship-to-Ship route exchange.
- STM Search and Rescue.
- Enhanced Monitoring Service.

Each service has its own individual purpose and benefits, which have been validated. Combined, they contribute to the overall goal of STM to improve safety, increase efficiency and reduce the environmental footprint of shipping in line with the IMO Sustainability goals.

Some services will remain operative after the validation process. Examples are SAR, Navigational Warnings in the Baltic Sea, the sharing of Pilot Routes in Sweden, Finland and Norway and the Winter Navigation services. The functions in the Electronic Chart Display Information System, ECDIS, on board the ships will continue after the project duration. Ongoing and future implementation projects, e.g. STM BALT SAFE, are committed to supporting the existing ships while also implementing new services and engaging more ships.

A cross-industry Developers Forum was established during the project. Technical expertise from competing companies solved common problems and the forum has been instrumental in making STM operational and interoperable. The forum will continue under the governance of the implementation projects.

End-user feedback from navigation officers on board test-bed ships validates the hypothesis set up for the project. The results indicate that digital information sharing between shore-ship, ship-shore and ship-ship can improve situational awareness, increase operational safety and improve operations. For example, an average of 75% perceived operational safety to be increased and 74% thought STM supported tools and services assisted their ordinary bridge duties. The digital infrastructure and some services, for example SAR and the pilot route service, are considered mature for industrialization and to be taken into large-scale operation.

1.3 Simulator Tests

The European Maritime Simulator Network, EMSN, was used to validate scenarios that involved many STM-enabled ships. Qualitative analysis of the data from simulations suggests that, generally, the STM services promoted navigational safety and efficiency, as these services have the potential to improve communication, decrease bridge crew workload, and increase the time to respond, plan and act accordingly in challenging navigational and traffic conditions. The results from various quantitative analyses indicate that the STM services are valuable in areas in which strategic navigation is applicable, i.e. where there are fewer temporal and spatial constraints. However, in areas with dense and regulated traffic and less room for strategic navigation, the value of the available STM services in improving traffic safety could not be directly demonstrated.

1.4 Maritime Digital Infrastructure

During the project, leading system suppliers of on board navigation systems, e.g. ECDIS, as well as Ship Traffic Service (VTS) systems, maritime service providers and authorities agreed to adapt the standard formats used in STM. They joined forces to achieve interoperability in the exchange of ship voyage plans, time-stamps, such as estimated times of arrival to ports and navigational warnings, based on a common digital infrastructure.

The infrastructure provides solutions, such as a global, digital identity of users, ships and systems, which is a serious bottleneck in commencing a digital maritime revolution across different companies and individuals. This is a prerequisite just as global, unique telephone numbers or email addresses are required to enable human-to-human communication on a global scale.

The common digital infrastructure was tested successfully and was thoroughly evaluated during three years of operations. One important output is the recommendations on how to further develop and mature the infrastructure.

1.5 Analysis and Business Perspectives

The analysis has reconfirmed the potential savings in time, fuel and greenhouse gas emissions (GHG). This is based on deeper and wider data analysis both from within and outside the project. The environmental aspect is gaining increasing attention and STM can play an important role in reaching the IMO goal of reducing

GHG by 50% by 2050. However, to realize such benefits, business models need to change. One step in this direction is the new STM clause in the BIMCO standard contracts, developed and implemented during the project. The STM clause helps to distribute the value of fuel savings when ports and ships are better synchronized, stimulating more ships to adjust their speed and arrive just-in-time.

1.6 Next Steps

Four implementation projects have already commenced ahead of the completion of STM Validation. REAL TIME FERRIES will use the on board knowledge of ferry delays to inform passengers, goods handlers and public transportation about the changes. EfficientFlow will implement STM in two ports in the Baltic Sea. It will also help ships to plan encounters in narrow passages at an earlier stage, thus saving fuel and enhancing safety. STM BALT SAFE will increase tanker safety in the Baltic Sea, taking into account the cross-traffic of ferries for the most part. STM in the Eastern Mediterranean, STEAM, will establish a shore centre in Cyprus and implement STM in the port of Limassol, exchanging information with ports in neighbouring countries. Partners will continue collaboration with the SMART Navigation project in Korea and with SESAME Solution II in Singapore.

The overall project recommendation is that the concept and the infrastructure be made ready for implementation in the form of new and updated software, service and functions. However, continued support from public funding towards implementation would be useful in attaining a speedier adoption rate. Some of the benefits for the whole industry and individual users will be larger as the number of ships using STM reaches a critical mass.

The report also suggests continued work by project partners in international consortia and organizations, such as the IPCDMC. For the digital infrastructure, there is the Maritime Connectivity Platform Consortium and the non-profit industry group for STM. A new organization has been formed to develop and operate the European Maritime Simulator Network for future research, training and testing of new services. In order to facilitate a long-term sustainability of STM, it is proposed that a programme is established for STM and that a function for coordination of the programme is established.

The work on standards and on regulation must continue and intensify in IEC (International Electrotechnical Commission), IALA (International Association of Marine Aids to Navigation and Lighthouse Authorities) and IMO (International Maritime Organization). It is important to get many of the project partner countries to unite in various actions to speed up the development. Work on three new standards with a firm base in the STM Validation project has started. Transforming and enhancing the route exchange and port call message formats developed in the MONALISA 2.0 project into the S-421 and S-211 standards through IEC and IALA respectively. IEC has also taken up the SECOM work item to create a standard for transfer of S-100 products, based on the Voyage Information Service interface developed by the project.

2. Introduction

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2.1 Background

During the past decade, the development of technologies involved in compiling, processing and information exchange in real time has experienced a revolution, both in terms of capacity and functionalities, as well as in terms of the useful extension of this practice to multiple economic sectors. Along with the increasing corporate usage of the internet since the beginning of this century, the range of technologies, the interoperability among various elements and the greater connectivity reliability of all kinds of devices and platforms, have favoured the emergence of new applications and extraordinary added-value services for organizational competitiveness.

The maritime transport sector is no exception in the evolution and integration of new technologies in its business models. However, despite the great advances made in this industry – which is responsible for the conveyance of more than the 80% of goods in international trade – the challenges and new opportunities for improvement are still huge. Thus, digitalization is a key factor in the maritime industry evolution, having as an objective the optimization of the processes of secure interaction among the network of participants in the logistics chain.

Currently, the maritime transport sector is facing significant challenges that could have a major impact in the management and the infrastructure fields, such as: the increase in ship capacity, the imbalance among commercial flows between various geographical areas of producer and consumer countries respectively, the strategic alliances among ship-owners, the commercial impact of major accidents and the opening of new commercial routes, etc. These and other factors shape a sector in constant evolution, making it necessary to articulate tools that permit efficiency-enhancement, while simultaneously guaranteeing safety and environmental protection. For this purpose, various international authorities have activated numerous programmes and initiatives to foster innovation in the maritime industry in order to facilitate its competitiveness vis-à-vis other transport modes.

This is exemplified by initiatives such as the e-Navigation, which frames STM and its predecessor projects. The leading player in this development is the IMO, whose efforts are supported by the many organizations, among them: International Hydrographic Organization (IHO), International Committee Radio-Maritime (CIRM), IALA, International Chamber of Shipping (ICS), Baltic and International Maritime Council (BIMCO), and IEC. The involvement of such institutions reflects the general interest in these matters and indicates the issues that must be resolved.

The foundations for the further development of STM were established in the definition phase of Sea Traffic Management (within the MONALISA 2.0 project). Key Performance Areas and Key Performance Objectives were defined jointly using Key Performance Indicators to address various perspectives: business, institutional, legal, operational and technical. First concept approaches of central components of STM, such as Voyage Management or Port Collaborative Decision Making, were also depicted.

The MONALISA 2.0 project also contributed to a common route exchange format, elaborated and agreed by the manufacturers of navigational equipment with the aim of ensuring interoperability of ship-ship and ship-shore route exchange.

2.2 The Sea Traffic Management Validation Project

The Sea Traffic Management (STM) Validation project is a wide-scale European initiative under the Motorways of the Sea umbrella, focusing on implementing new digital information exchange services for the shipping and port industries. STM Validation comprises the third stage of this action, initially defined during the previous projects MONALISA and MONALISA 2.0, all of which were co-funded by the Trans-European Transport Network (TEN-T) through its Connecting Europe Facility Programme (CEF).

The aim of the STM initiative is to push the maritime industry towards more collaborative and digitalized operational environments, enabling the transition of the sector to the "Industry 4.0" paradigm, where digital and real time connectivity is the driver for increasing efficiency, safety and sustainability. STM has been greatly inspired by the aviation sector, where this evolution has demonstrated significant and measurable benefits.

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, as follows:

- **Port Collaborative Decision Making (PortCDM).** The overall goal of PortCDM is to support just-in-time operations within ports and vis-à-vis other actors coordinated by an efficient and collaborative port. It is a way of establishing not only a common view of all available information, but also of using this information as a tool to create a common situational awareness and support the particular actors in making efficient collective decisions. PortCDM relies on continuous interactions among the maritime actors involved in a port call.

- **Voyage Management (VM).** VM concerns strategic, tactical and operational decisions about a voyage, such as planned and executed routes of a certain ship and its interaction with nearby ships in a given position. It focuses on the initial planning phase of any sea voyage and the ability to monitor the execution of that plan. VM supports improved route planning, route exchange, and route optimization before and during the maritime voyage. Especially in this phase, VM connects ships, adds intelligent processes and new tools to enable all stakeholders to increase their situational awareness during the voyage, providing faster, more secure and transparent information exchange.

- **Flow Management (FM).** FM supports the optimal coordination of multiple ships in congested geographical areas. FM will support both VTS control and ships in optimizing overall traffic flow through areas of dense traffic or those with particular navigational challenges. FM's objective is to improve the overall flow of maritime traffic through superior information sharing and coordination. VM builds common situational awareness and enhances decision-making with information and advice about traffic and safety.

- **Sea System Wide Information Management (SeaSWIM).** SeaSWIM, or a maritime digital infrastructure, provides a framework for the harmonization of data formats and standards for information management and operational services. SeaSWIM includes the use of the newly established Maritime Connectivity Platform for identity and service management. SeaSWIM will support collaborative decision-making processes using efficient and end-user applications to exploit the power of shared information in STM operational services.

The project has demonstrated and validated the aforementioned target concepts by deploying large-scale test-beds in both the Baltic and Mediterranean seas involving 311 ships, 9 ports and 6 shore centres. Moreover, STM has demonstrated the benefits of capitalizing on the European Maritime Simulator Network (EMSN), a comprehensive network of ship bridge simulators that has performed specific exercises to assess operational, safety and human factor aspects in a controlled environment.

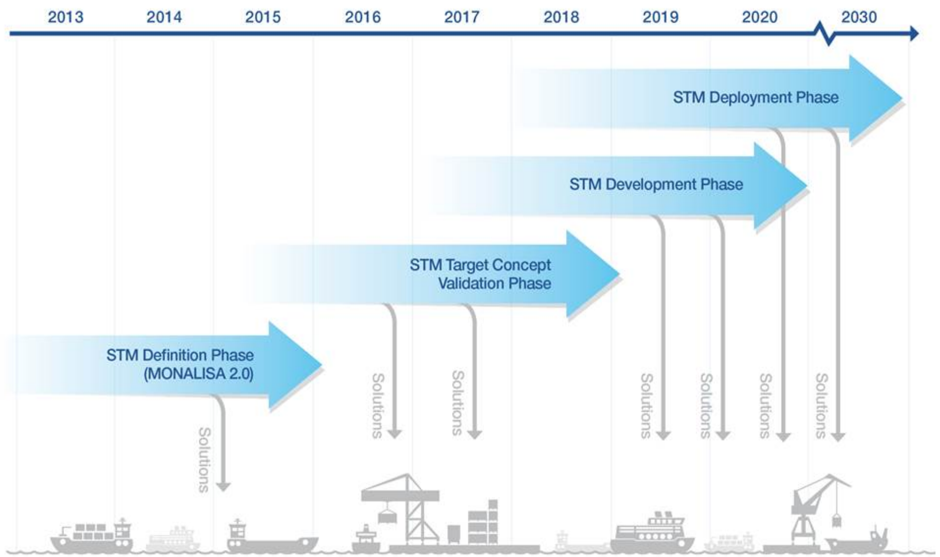


Figure 1. STM Implementation and Deployment Strategy

Sea Traffic Management offers a paradigm shift in the maritime sector in terms of information sharing. The development of Sea Traffic Management is the result of a European team effort that brings together industry, academia and a proactive public sector, as well as international intergovernmental organizations and key non-European stakeholders. The concept is inspired by the work in progress within aviation in developing the next generation of Air Traffic Management, but is adapted to the specifics and requirements of the maritime transport sector.

The STM concept becomes a reality through a set of standards and services that facilitate the information exchange among authorized users in a secure and real-time manner. This is endorsed by the setting of a common framework that confers standards for information exchange and access management to a set of interoperable services.

2.3 Sea Traffic Management Benefits

Instant exchange of information is a key facilitator for improved situational awareness in its role as a catalyst for improved navigational safety, optimized capacity utilization, and just-in-time operations. By providing ships with the ability to view each other's planned routes, navigators gain a more comprehensive picture of how ships in the vicinity will influence their onward voyage. The same functionality also provides opportunities for shore-based actors to enhance planning capabilities. Using this data, other services are able to produce valuable information and offer advice to ships on their routes, such as recommendations to avoid congestion in areas with high traffic density, avoidance of environmentally sensitive sea areas, and maritime safety information.

The information exchange among ships and port actors can improve planning and performance for arrivals, departures and turnaround times for ships. Sea Traffic Management adds interoperability to the information ecosystem, which lowers the threshold and cost for both users and service providers alike. It should be noted that ownership of the information determines the parties with whom is to be shared.

The STM Validation project represents a remarkable opportunity to join forces and make Sea Traffic Management a global concept with the aim of being fully implemented in 2030. This will not only improve efficiency and safety of navigation, but will also greatly benefit our seas and the marine environment.

Sea Traffic Management is a powerful driver for reducing maritime transport's environmental impact. The Baltic Sea is one of the Regional Seas that also have the status of Particular Sensitive Sea Area (PSSA). The HELSINKI Commission – consisting of the coastal states of the Baltic Sea, together with the European Commission – is in the process of recognizing Sea Traffic Management and the potential to exchange voyage plans in the Baltic Sea for greater navigational safety and improved environmental performance as well as for enhanced competitiveness of environmentally friendly maritime transport.

HELCOM[1] recommends the Governments of the Baltic Sea countries to further test the concept of voyage-plan exchange as well as other e-navigation services such as:

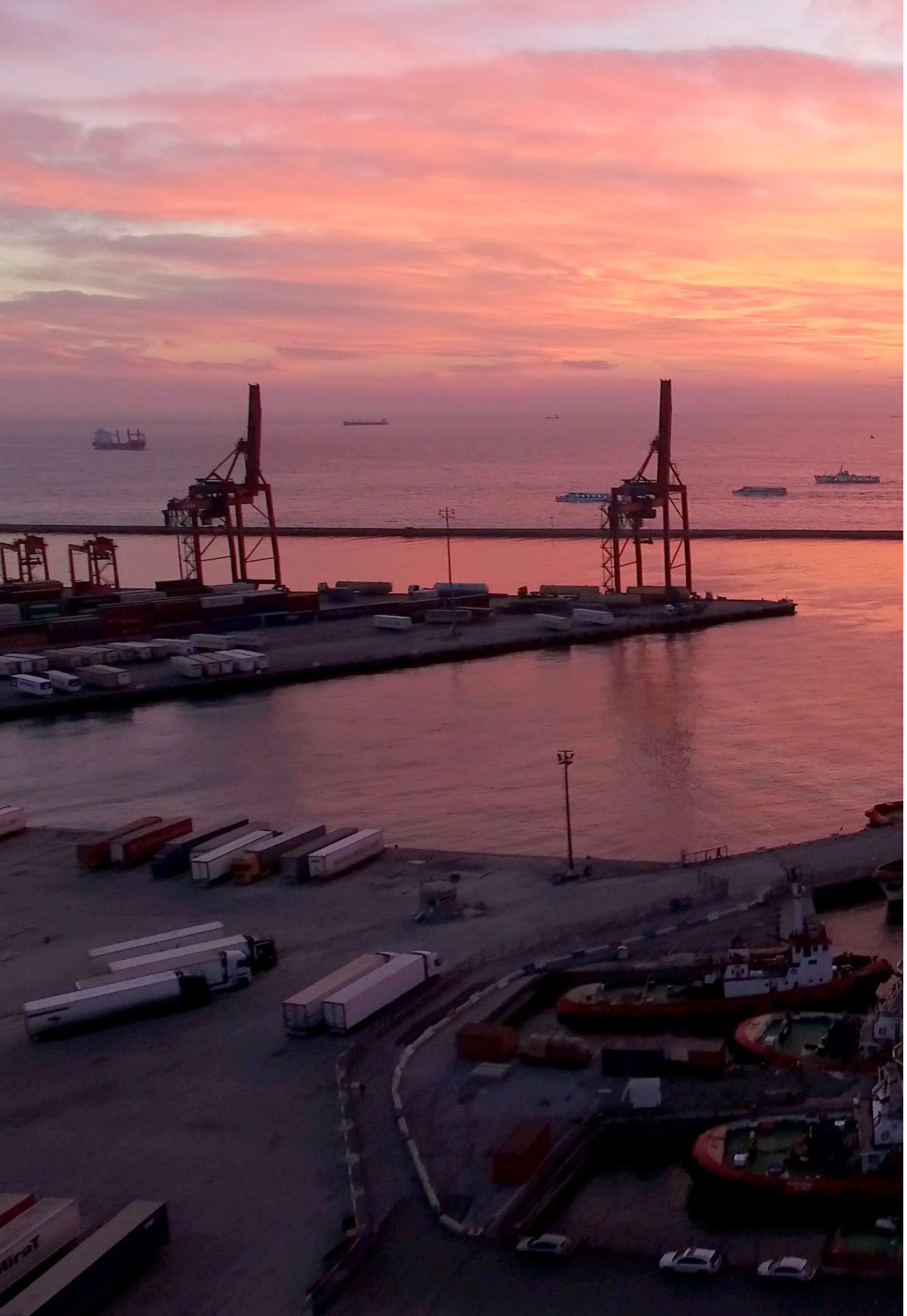
Maritime Safety Information (MSI)	Notice to Mariners	Ship to Ship Route Exchange	Route Optimization
Route Cross-check	Route and Port Monitoring	Ice Routeing	Port Call Optimization
Port Call Synchronization	Flow optimization	Facilitated reporting	Pilot Route Distribution
Efficient Exchange of SAR information			

Table 1: Helcoms recommendations on e-navigation services testing

2.4 International Cooperation

The STM Validation project has also served to strengthen international cooperation. Europe and the Republic of Korea have joined forces in collaboration between Sea Traffic Management and the Smart Navigation Project. This collaboration is

1 Revised HELCOM Recommendation 34E/2 on FURTHER TESTING AND DEVELOPMENT OF THE CONCEPT OF EXCHANGE OF VOYAGE PLANS AS WELL AS OTHER E-NAVIGATION SOLUTIONS TO ENHANCE SAFETY OF NAVIGATION AND PROTECTION OF THE MARINE ENVIRONMENT IN THE BALTIC SEA REGION, Adopted 3 October 2013 and amended 5 March 2018, having regard to Article 20, Paragraph 1 b) of the Helsinki Convention



aimed at harmonizing developments and testing global solutions. The results of the STM test-beds will be reported according to the guidelines for the e-Navigation test-beds of IMO and IALA.

In June 2018, five leading e-Navigation countries decided to continue and strengthen cooperation by signing a memorandum of understanding (MoU) on e-Navigation test-beds. Australia (AMSA), China (MSA), Denmark (DMA), Republic of Korea (MOF) and Sweden (SMA) will work together on standards and solutions.

The agreement means that the countries will test each other's solutions and provide international feedback, making sure that the solutions suit the global shipping industry. Through the growing cooperation with the MoU-Member States and others, the existing services will develop and new ones will emerge worldwide.

Sea Traffic Management is fully in line with the vision and strategic directions of IMO and addresses IMO's Strategy Implementation Plan (SIP) for e-navigation (as updated by NCSR 5 and approved by MSC 99). Sea Traffic Management addresses certain aspects of four of the five e-Navigation solutions, namely S1 (improved, harmonized and user-friendly bridge design), S2 (means for standardized and automated reporting), S4 (integration and presentation of available information in graphical displays received via communication equipment) and S5 (improved communication of VTS Service Portfolio).

Sea Traffic Management is also in line with a majority of national, regional and global policies protecting life at sea, property and the protection of the marine environment (MARPOL and HELCOM Conventions, OSPAR Commission).

As Sea Traffic Management is scaled up to the global level, a substantial contribution to the UN Sustainable Development Goals (SDG) will be expected through the protection of life, property and the protection of the marine environment. Of special relevance is SDG 14 on the preservation of the oceans and the marine resources, but there are also linkages to SDG 2, SDG 4, SDG 7, SDG 9 and SDG 13.

The STM Validation Project, (2015-2019) is one of the largest e-Navigational project ever. In this project, the Sea Traffic Management Concept has been taken from theory to practice and validation in the Nordic area and in the Mediterranean Sea. More than 50 partners from 13 countries have participated in the project with an overall budget of €43 million.

3. STM as Enabler for Ship-Ship and Ship-Shore Communication

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The goal of the voyage management test-bed was to operationalize and validate the concept of voyage management services based on digital information exchange. The information exchanged in the test-bed includes voyage plans, navigational warnings, port call messages and text messages. A total of 312,800 messages has been exchanged. In addition to these, route messages, a segment of a ship´s monitored route, have been sent on Automatic Identification System (AIS) as Binary Broadcast Messages (BBM) to other ships within AIS range.

In STM, interoperability has been achieved through a distributed service ecosystem approach, the Maritime Digital Infrastructure. The test-bed has proven this approach to be a suitable solution and the number of partners and systems that are now interoperable is a major result of the project. Accordingly, and as an outcome of the project results, a generic service interface, communication protection measures and service lookup functions have been accepted by the International Electrotechnical Commission (IEC) as a work task for standardization.

Leading market actors have integrated STM functionality in existing operational systems such as on board navigation systems, shore-side services, Ship Traffic Services (VTS) and in ports. As of 1st of June 2019, 311 ships, and six shore centres have been upgraded with STM capability.

In conclusion, end-user feedback from navigation officers on board test-bed ships, validates the hypothesis set up for the project. The results indicate that digital information sharing between shore-ship, ship-shore and ship-ship can improve situational awareness, increase operational safety and improve operations. For example, an average of 75% perceived operational safety to have increased and 74% thought STM-supported tools and services assisted their ordinary bridge duties. The digital infrastructure and some services, for example SAR and the pilot route service, are considered mature for industrialization and for introduction into large-scale operation.

3.1 Voyage Management Test-bed

The scope and objective of the voyage management test-bed were to validate and operationalize STM services, and to boost efforts by system manufacturers to develop STM functionality in prototype systems, such as on board navigation systems and shore-side services, as well as VTS centres. Another objective was to provide data for evaluating the effects on the maritime transportation system as a whole as well as benefits and costs for shipping companies when utilizing STM services. This evaluation was done with data from both the voyage management test-bed and from the simulated environment, the European Maritime Simulator Network (Sub-chapters 3.2 and 3.3).

Figure 2. Different aspects of STM were compiled from both voyage management test-beds and from simulations

The goal was to make 300 ships, six shore centres (See Figure 3) and a number of operational services STM capable. Two test-beds were established, one in the Mediterranean and one in Northern Europe.

To fulfil the goals mentioned above, the test-bed started by analysing the strategic concepts, operational services and enablers defined in the MONALISA 2.0 project. The concepts and operational services were broken down to operational needs expressed as use-cases. With these use-cases as a basis, a set of information needs, functional and technical requirements were designed. A Service Oriented Architecture (SOA) approach was proposed already in MONALISA 2.0 and the requirements indicated demands on the architecture itself in terms of authentication and access management, but also as regards the development of new information services and new/updated data formats.

Partners in the project developed the architecture, SeaSWIM, and information services, e.g. Voyage Information Service, while the parts that would affect ship's systems were discussed and analysed together with an industry group consisting mainly of ECDIS and VTS manufacturers. The jointly agreed technical and functional requirements were then used as a basis for the development of STM-capable maritime services ashore, e.g. VTS systems and in the equipment of STM-capable ship systems.

The goal was that major providers of maritime navigation systems would develop interoperable systems that support route exchange and other information exchange as defined within the STM concept. The on board installations would in-

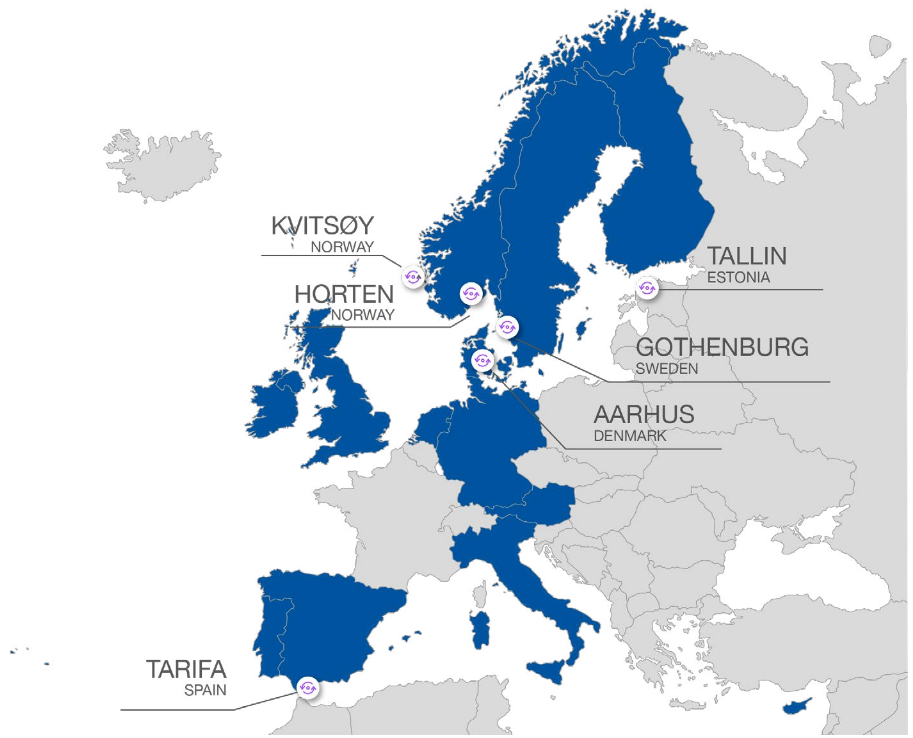

Figure 3. Shore Centres included in STM test-bed

clude either a software upgrade of an existing ECDIS or planning station to support the specified STM functionality and/or installation of a dedicated planning station for STM functions, which is connected to the on board ECDIS.

Furthermore, the goal was to reach as many manufacturers as possible in order to get as wide a market spread as possible to facilitate international acceptance of the proposed standards and formats. Consequently, the procurement of ship systems was open to all type-approved ECDIS manufacturers and eventually resulted in contracts with Transas, Wärtsilä SAM Electronics, Furuno and Adveto.

The actual realization of the functional specifications with regards to technical solutions, user interfaces, etc. was up to each system manufacturer to decide upon, even though it was recognized that some standardization in this area would be beneficial for both users and system providers.

After initial product development, Transas, Furuno and Adveto upgraded existing systems with STM capability during the latter part of the project. All their STM ship systems have been tested and approved according to the revised performance standards for ECDIS as reflected in IMO's Resolution MSC.232(82) adopted on 5 December 2006.

In addition to these ship systems, the cruise ship company Costa Crociere, part of Carnival Corporation, has developed interfaces to integrate STM features with the existing Neptune Platform, part of the Costa Group software suite since 2012.

The STM ship system installations were delayed. The delay was mainly caused by complex development, lengthy approval processes by the manufacturers' Classification Societies to ensure the systems comply with the revised Performance Standards for ECDIS as reflected in Resolution MSC.232(82). Furthermore, time-consuming installations caused the installation phase to take longer than expected. The delays in installations delayed the analysis and validation of the results from the test-bed ships too. This was one factor that compelled the overall project apply for and receive a time extension of six months. As a result, it proved possible to compile sufficient data and results from the test-bed ships.

Major providers of maritime navigation systems have developed interoperable systems that support route exchange and other information exchange as defined within the STM Concept.

3.1.1 Maritime Digital Infrastructure in the Voyage Management Test-bed

The STM voyage management test-bed includes ships, fleet operation centres, ports, shore centres and service providers. Information is exchanged via secure network on the Internet for all operational services but one. The existing AIS network is used for ship-to-ship exchange of AIS route messages.

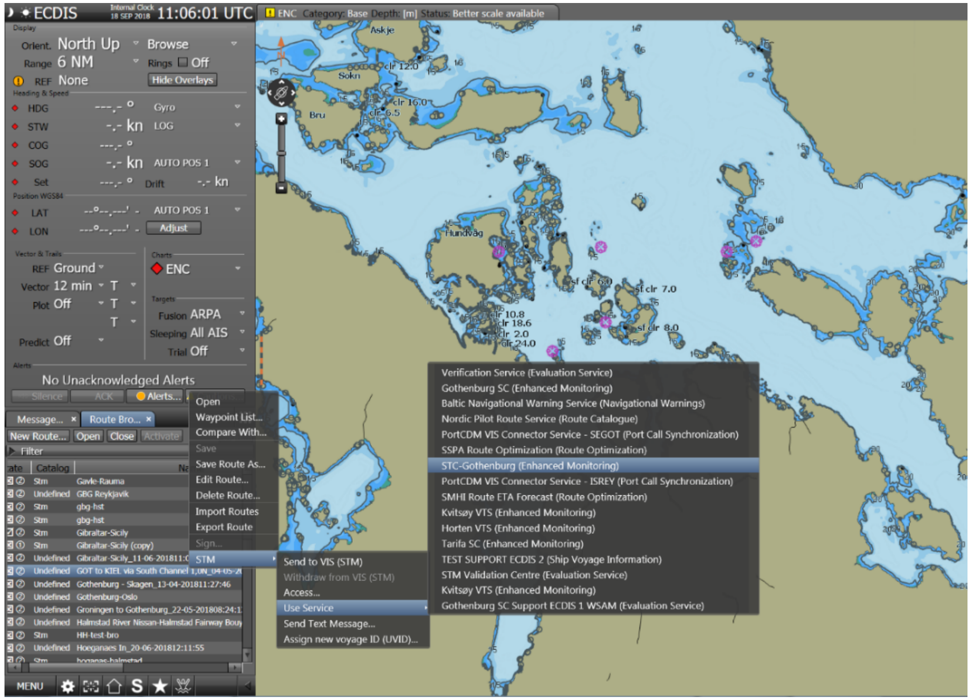

Figure 4. Example of ECDIS with STM Tools

All actors have been digitally connected through Internet and the dedicated security domain, SeaSWIM, where secure exchange of information is executed (for more information on SeaSWIM see chapter 5). In the STM test-bed, the Maritime Connectivity Platform (MCP) realizes the infrastructure part of SeaSWIM with its common registries for identities and service information lookups.

Figure 4 is an example where an operator on board uses the STM capable ECDIS application to search for enhanced monitoring services along the route, which the user will share the voyage plan with.

Interoperability between actors, which is one of the most important features of the STM concept, is established through the use of a limited set of common message formats and a common set of service interfaces (Service API).

The set of common message formats used are;

- *Route Exchange Format (RTZ).*
- *Area Format (S-124) for Navigational Warnings.*
- *Port Call Message Format (PCMF).*
- *STM Text Message Format (TXT).*

The set of common service interfaces used for sending data in these formats are:

- *Assisted Message Submission Service (AMSS).*
- *Message Broker (MB) for PCMF.*

Figure 5 shows the common infrastructure in the STM voyage management test-bed and the additional components added specifically for STM. The common MCP enables service and identity lookup but the actual exchange of information is done actor-to-actor directly in the STM test-bed, and no information is stored centrally other than identities and metadata regarding services.

3.1.2 Voyage Information Service (VIS)

The main purpose of VIS is to handle communication around voyage information and the main artefact Voyage Plan (VP) in RTZ format. VIS implements methods for exposing new and updated VP's, and to consume external VP's. VIS also supports subscription of voyage plans, see Figure 6.

In addition to voyage plans (RTZ), VIS also supports the exchange of STM Text Message and area messages (S-124). The Voyage Information Service interface is used by all actors in the voyage management test-bed for the exchange of voyage plans among ships, ports, shore centres and service providers.

The VIS interface has the potential to evolve into an international standard. It was proposed by the Swedish Maritime Administration to the Swedish section of TC 80 at the IEC and has been accepted as a new work item by IEC.

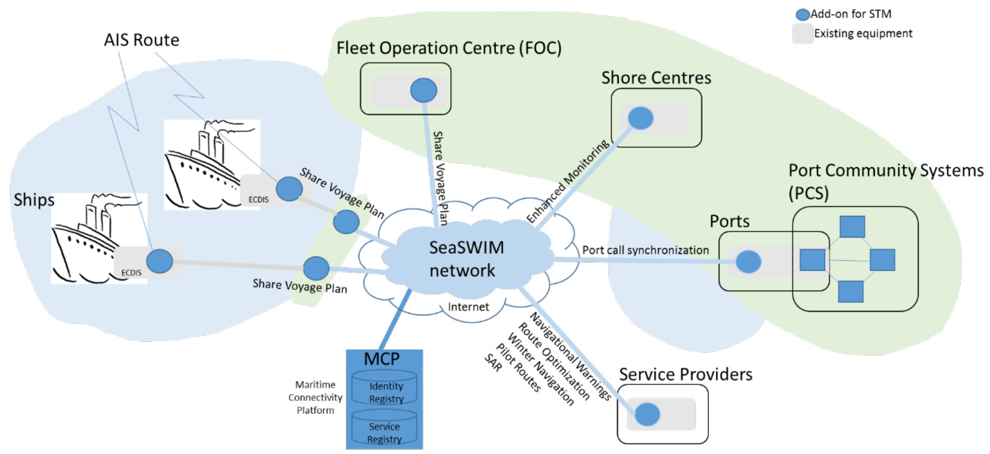

Figure 5. Overview of STM voyage management test-bed

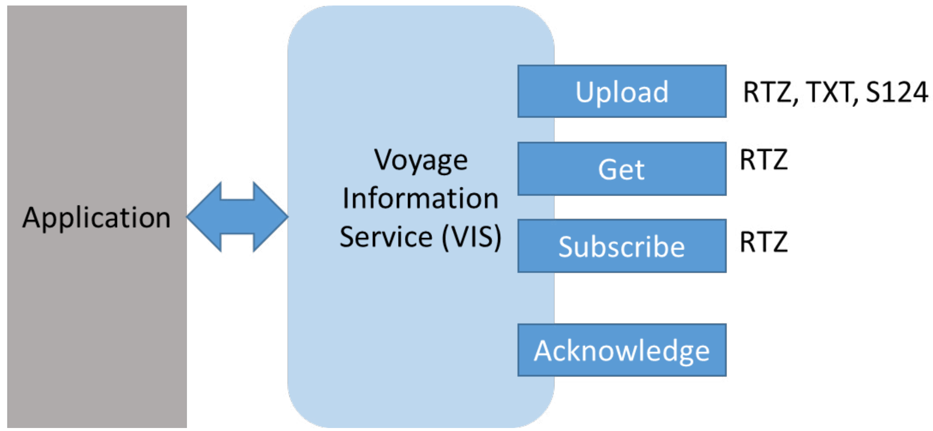

Figure 6. Overview on VIS interface

3.1.3 Information Exchange in the Voyage Management Test-bed

As of June 2019 311, see Figure 7, ships have been upgraded with STM capability.

Figure 8 gives the total number of exchanged messages for each message format. The statistics are obtained by collecting log files from all actors with active

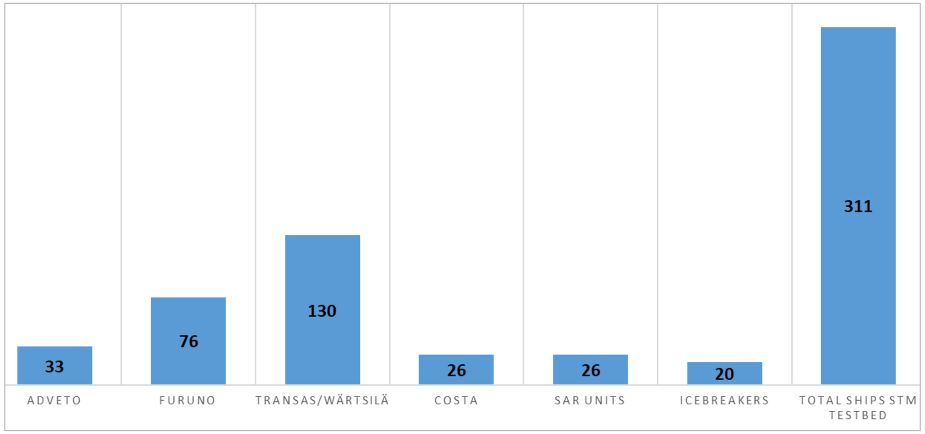

Figure 7. Number of STM capable ships in the test-bed

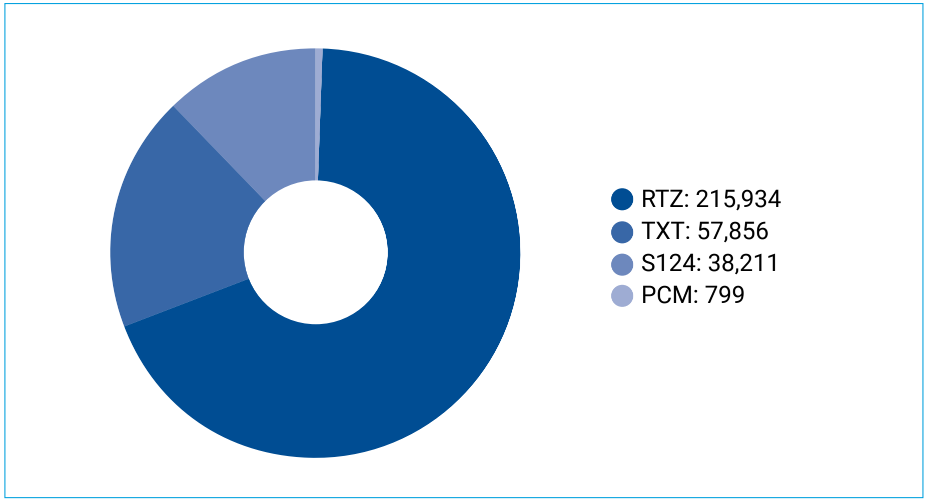

Figure 8. Number of exchanged messages among ships and between ship and shore in the voyage management test-bed

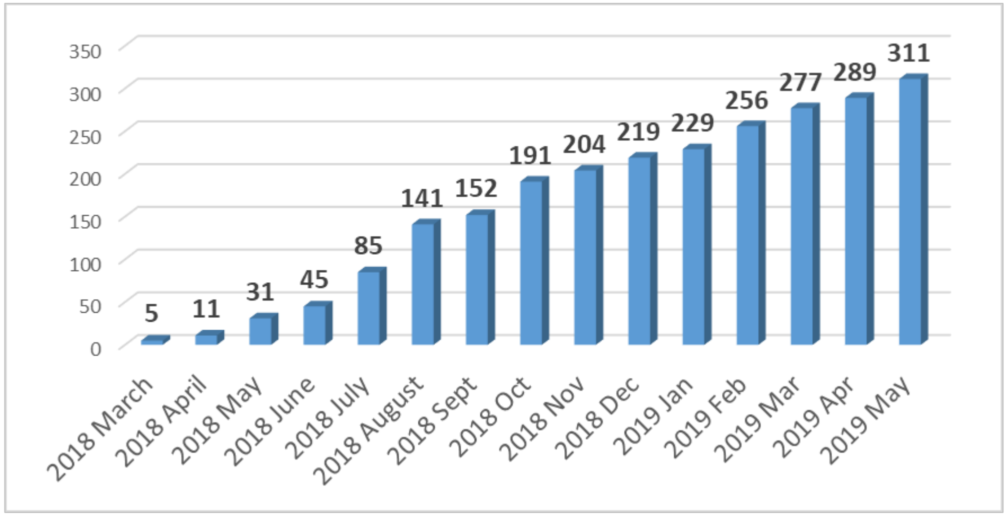

Figure 9. Number of STM capable ships per month during the voyage management test-bed

STM services that have been involved in the voyage management test-bed. As more ships joined the test-bed the level of activity increased.

216,000 RTZ messages represent a relatively high number, given the number of ships. One of the contributing factors to this is that the number comprises the total data exchanged e.g., a ship that shares its voyage plan with seven subscribers will generate seven exchanged messages. Normally, there are several updates of the route and changes to the status of the route during a voyage, generating seven messages each time in the example.

3.1.4 Operational Services in the STM Test-bed

STM is built on services that share a common infrastructure based on standards. There are two types of services: information and operational services. Information services, such as the VIS, are part of the architecture to support operational services that deliver value to its users. The operational services in STM have been developed and delivered by different service providers and will be presented in this chapter. All services in STM need to be registered in the Maritime Service Registry, part of Maritime Connectivity Platform.

The basic principle for using a service is that a ship shares its voyage plan with a service provider in the planning stage or during the voyage and receives requested service results in response, see Figure 10.

3.1.4.1 Nordic Pilot Route Service

The Nordic Pilot Route Service (NPRS) is an onshore service that exposes a route catalogue consisting of pilot routes in RTZ format. The NPRS service is intended for real time usage during the route-planning phase. End users (ships and shore centres) deploy the service either by sending their planned route or by sending a STM Text Message with an area included. For a submitted route NPRS will perform a geographical search for pilot routes based on the waypoint coordinates in the route solely, i.e. NPRS is not dependent on UN/LOCODE or any naming objects. For a submitted area, NPRS will return all pilot routes intersecting that area, which the user can merge into the existing voyage plan. NPRS includes pilot routes from Sweden, Finland and Norway (restricted to Bay of Oslo). The NPRS architecture enables connection to many databases and each request will merge the search for routes among all of these.

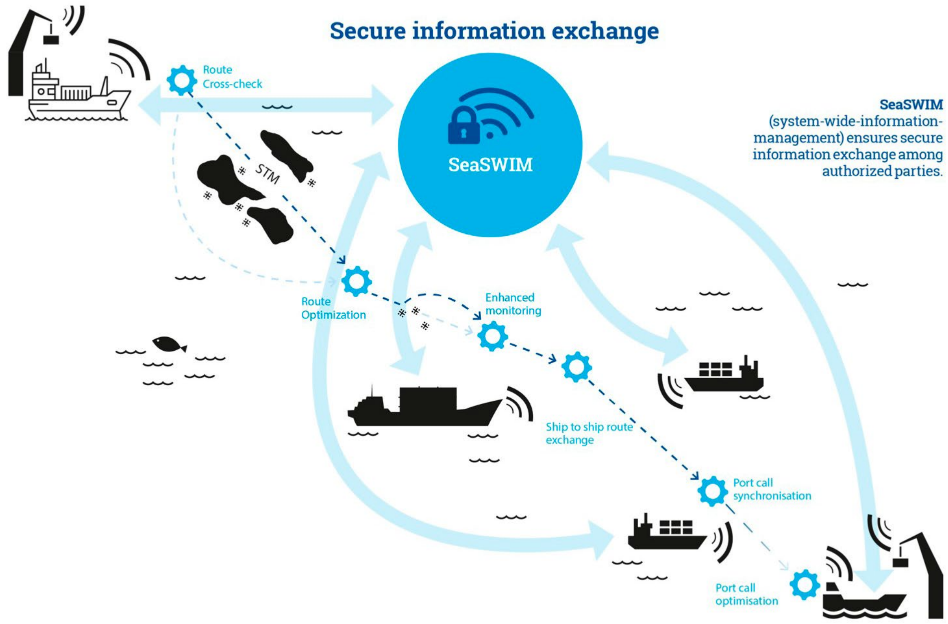

Figure 10. Services on a ship's voyage

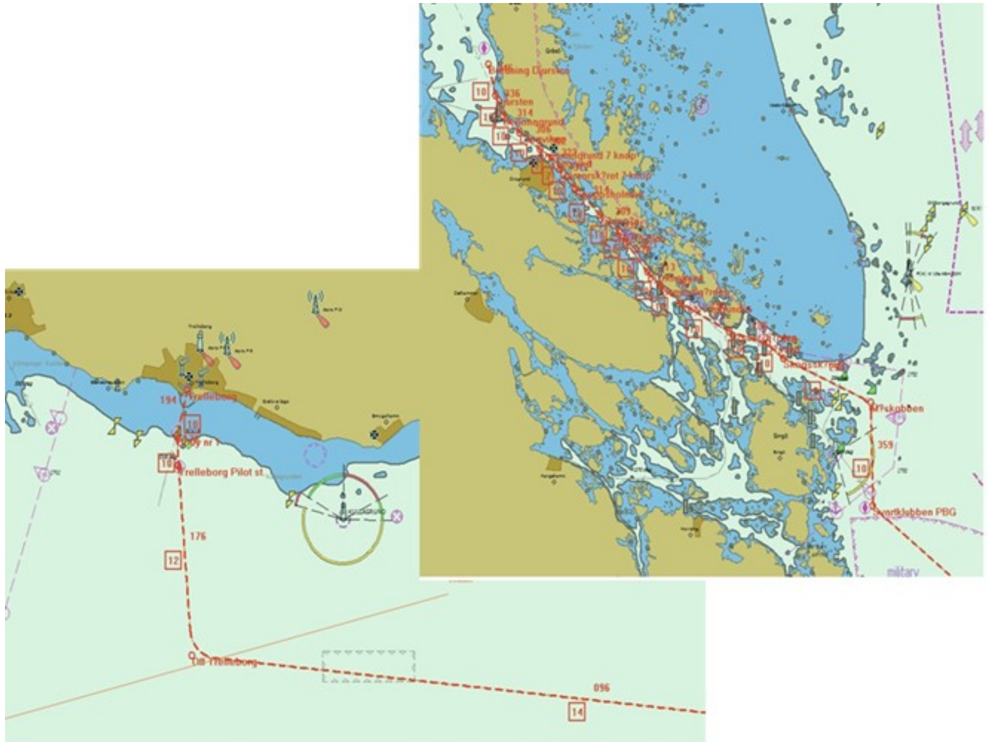

Figure 11. Pilot routes merged with existing voyage plan

3.1.4.2 Baltic Navigational Warning Service

The purpose of the Baltic Navigational Warning Service is to provide the service consumer, i.e. ships, with only those warnings that are relevant for the specific route that they intend to sail/are currently on and at the time specified in the route schedule. Moreover, the warnings will be displayed directly in the ECDIS, see Figure 11, and be automatically deleted when they expire and are no longer valid.

The hypothesis is that the following benefits are achieved:

- **Reduced workload** – no need to manually plot positions/areas received by NAVTEX/voice communication at Electronic Navigational Chart/paper chart. This allows the navigator to concentrate on safely navigating the ship.

- **Increased safety of navigation** – according to the London P&I Club, insurance inspections regularly find deficiencies in managing navigational warnings and notices to mariners, as officers fail to implement navigational safety notices. By providing the notices directly to a ship´s ECDIS manual, work and the risk of omitting important information is reduced.

- **Temporary and Provisional (T&P) Notice to Mariners in the ECDIS** – sent out before the ENC updates. In addition, some NAV AREAS do not send out T&Ps, which means that full ECDIS ships, sailing paperless, do not receive all notices.

- **Reduced human errors** - as warnings are provided digitally and seamlessly shown directly on ECDIS, possible human errors, errors in misunderstandings and manual plotting can be avoided.

- **Increased Navigational Warning focus** - since only notices relevant to the planned and/ or actual route will be sent to the ECDIS, the Officer of the Watch can concentrate on these and disregard warnings issued outside the adjacent areas.

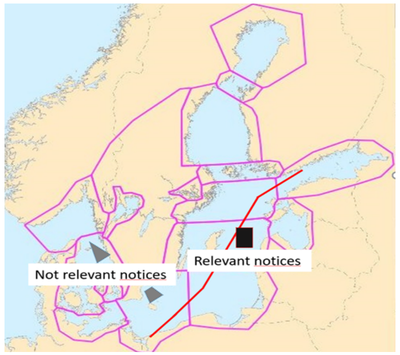

Figure 12. Service coverage area and example of relevant notices based on ships voyage plan and sub-area division

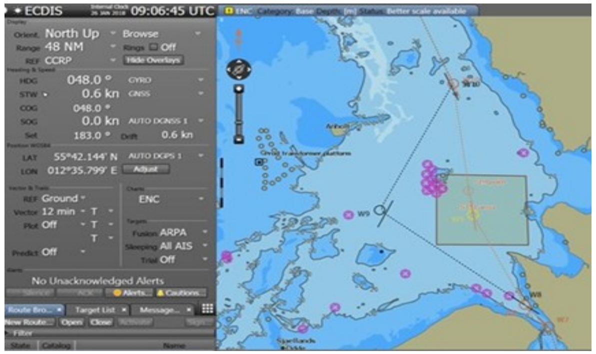

Figure 13. Example of a navigational warning displayed in the STM ship system where the ship used the geographically received area to re-plan its initial route

The Baltic Navigational Warning Service provides safety notices to ships in the S-124 format. The S-124 product specification is being developed by an IHO Correspondence Group for the purpose of submitting it for endorsement. Before being mature for endorsement, the STM Validation Project will serve as one of the test-beds to validate a draft version of the specification.

It is important to note that the service is not intended to relieve its users from the normal receipt of Maritime Safety Information (MSI) as part of the Global Maritime Distress and Safety System (GMDSS), with which every ship must comply while at sea.

How received notices are handled in each STM capable ship system is described in respective user manual but the common requirements are that the ECDIS/ bridge system should be capable of:

- Displaying received areas.
- Handling updated notice area.
- Deleting notices when expired/obsolete.

3.1.4.3 SSPA Route Optimization

The SSPA Route Optimization Service is an onshore service that provides optimized routes to ships when planning their voyages. The service requires a manually planned route as input, and returns an optimized route and a text message with information about potential savings and a liability waiver.

The service performs optimization based on bunker consumption/total ship resistance, i.e. the returned route aims to be the most efficient route from A to B. The service accounts for the following physical effects:

- water depth (resistance increase from shallow waters).
- wind.
- current.
- waves.
- ice (in terms of added resistance due to ice breaking).

Bathymetry data is sourced from the EMODnet EU-project (http://www.emodnet.eu/) and weather forecasts/hindcasts are sourced from DMI (Danish Meteorological

Institute). Note that weather is accounted for only during a period of 5 days ahead and 7 days prior to the current date, i.e. a rolling 12 day-period is covered. Submitted routes with scheduled legs.

Outside this period will be optimized without the influence of weather conditions

The route optimizer works in both the spatial and time dimension, and the optimized route may therefore differ from the input route in terms of:

- Number of waypoints.
- Waypoint spatial position.
- Waypoint Estimated Time of Departure.

For an example, see Figure 14.

Figure 14. Initial and optimized route

The returned route does not account for any navigational aspects such as Traffic Separation Schemes (TSS) and therefore the returned route has to be checked from a nautical perspective on board once received. This is a conscious design choice aimed at promoting the service as a support tool during the planning stage, instead of routing software that prescribes a ready-to-go voyage plan. The added benefit of this is the retention of the active involvement of the Officer on Watch in the planning stage.

3.1.4.4 SMHI Route ETA Forecast

SMHI Route ETA Forecast's main purpose is to combine information about the voyage with information about the weather, sea currents and ship characteristics. This information is used to calculate a more probable time of arrival for each waypoint on the route as well as a calculated time-window for the estimated arrival time. This window indicates any uncertainty of the estimated arrival time. The service uses the Swedish Meteorological and Hydrological Institute's (SMHI) vast knowledge about the weather and ship performance in different kinds of weather to support the voyage with more accurate estimates. The service should be viewed as an aid for navigators on ongoing voyages in being able to run multiple optimizations during long voyages to maintain a realistic ETA.

The gains from a more accurate calculation of the estimated time of arrival are significant in terms of efficiency. Being able to calculate the arrival time with greater accuracy, offers the ability to adjust engine settings for fuel efficiency, saving fuel at lower speeds in the knowledge that the destination will be reached at a given time. This is what the SMHI Route ETA Forecast provides. Adding to that, the service also gives a window of arrival based on the uncertainty of the weather to give the navigator a better understanding of the estimated arrival time based on the weather. Having an accurate arrival time also unlocks the possibility for ports to work more effectively in handling incoming ships. When it comes to saving fuel it is not only a monetary gain, the environment also clearly benefits when the ship is operating at lower engine settings, which in turn reduces Greenhouse Gas (GHG) emissions.

3.1.4.5 Winter Navigation Service

The Winter Navigation Service provides ships with information related to icebreaker assistance in the Northern Baltic. The service enables ships, icebreakers and shore centres to share routes and other operative information directly using machine-to-machine interfaces. The information is available to users directly on their operational systems, without a need for manual operations, see figure 15.

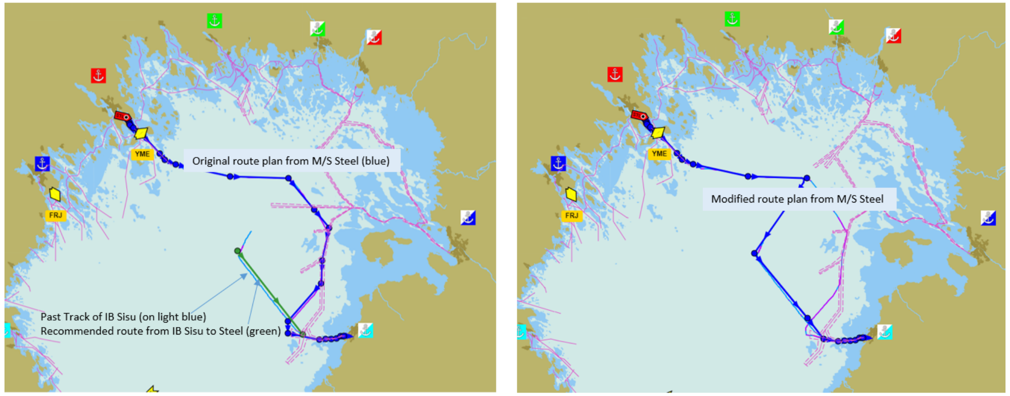

Figure 15. Example of route exchange between M/S Steel and Winter Navigation Service. The routes are displayed in the icebreaker coordination system IBNET

This enables information to become more precise and up-to-date, which reduces the number of manual tasks for information management which, which, in turn, leads to reduced risk of errors and misunderstandings. The service consists of two operational components, namely, information to assist route planning and up-to-date information to assist navigation during the voyage.

3.1.4.6 Ship-to-Ship Route Exchange

Each ECDIS-equipped ship has a monitored route, meaning the route the ship is sailing. In STM, this route is defined according to the RTZ format and exchanged using IP (Internet Protocol) communication.

Ship-to-Ship route exchange allows ships to broadcast their routes (seven waypoints) to all other ships in the vicinity. Shared intentions create a common situational awareness among all ships.

As part of the project, monitored route exchange formats for use via AIS and VDES (VHF Data Exchange System, the next level of AIS) have been developed as Binary Broadcast Messages (BBM) to facilitate safe navigation. These are denoted as AIS/VDES route messages and allow ships to exchange a fixed part of the monitored route with other ships in the same geographical area in a standardized format. Only AIS broadcasts have been used in the voyage management test-bed.

The route message broadcast is used as a means to indicate intended navigation and route information to nearby ships, allowing them to avoid ending up in a close-quarter situation. The route message information should be used as an aid to navigation and not interfere with existing watch-keeping practices of maintaining a proper lookout or compliance with the COLREGs.

3.1.4.7 STM SAR

The introduction of STM-supported digital tools in Search and Rescue (SAR) operations sets out to improve the Maritime Rescue and Coordination Centre´s (MRCC) and the On Scene Coordinator´s (OSC) overview and possibility to control SAR units in search operations. As per today, communications between these actors rely on voice communication, which can lead to misunderstandings and longer response time, as manual work is required to plot positions and search areas, for example. Supported by the digital infrastructure of STM, MRCCs will be able to send areas, search patterns and search routes to a SAR unit, a Vessel of Opportunity (VoO) and to other assets participating in the SAR operation. This information will be visualized directly in the on board units' navigation systems, e.g. ECDIS or portable tablet.

As part of the voyage management test-bed, the SAR management system at the Swedish Joint Rescue and Coordination Centre (JRCC) has been upgraded with STM capability. Moreover, 26 SAR units in Sweden have been made STM capable. The information exchanged between JRCC and SAR units includes:

- **Text messages** with the essential information, e.g. number of persons in distress and data identifying the missing object. etc.
- **Search area/distress position** where the units should be heading.
- **Search patterns or routes** that the SAR mission coordinator wants the units to follow during the search, to enable optimal coverage of the area to be searched, Figure 16.

3.1.4.8 Shore Centres and Enhanced Monitoring Service

The shore centre in the STM test-bed has its origin in traditional VTS. A VTS is a land-based station aimed at enhancing efficiency, safety and environmental protection through surveillance of ships´ movements using radar, AIS, CCTV, etc. When deemed necessary, the VTS operator can provide the Officer of the Watch on board with information regarding the traffic situation, port operations, and adverse weather conditions, etc.

The shore centre is similar to the VTS in that it is a land-based station with an operator communicating with ships at sea. There are also significant differences between a traditional VTS and a shore centre equipped with STM functionality. The main difference is that the shore centre covers much larger areas than a VTS. The level of automation is higher in the shore centre and it relies on ships to share information, i.e. their route and schedule, well in advance, for the shore centre to review the ships' intentions and then act proactively.

Monitoring is basically what the VTS has been doing since the 1950s. An on-shore operator monitors a ship and if it appears to be running into a potentially dangerous situation, e.g. heading for shallow waters, the operator will alert the ship. The difference between the basic VTS service and the Enhanced Monitoring Service (a term used in conjunction with STM and shore centres, not in VTS) is that the STM shore centre receives the route from the ship in advance, analyses it and uses it for monitoring. It is also important to note that this route, sent from the ship, states the ship´s intentions. This gives the shore centre operator the possibility to review the ship´s planning of its approach to shore.

The distributed service eco-system approach selected in the project has proven a suitable solution in the voyage management test-bed, enabling episodic tight-coupling between maritime actors. Accordingly, and as an outcome of the project results and findings, the service interface, the communication protection measures and the service lookup functions are proposed to IEC as a new work item for standardization.

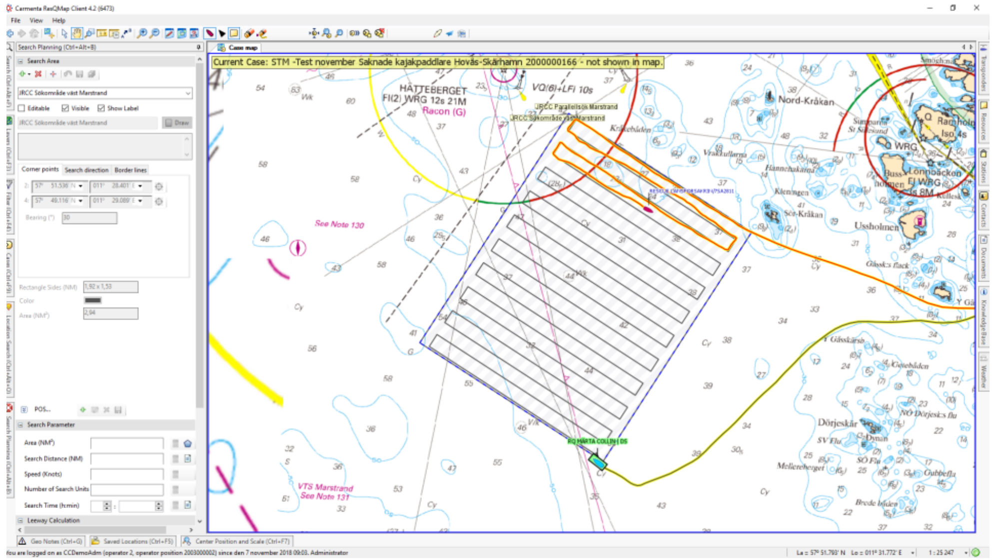

Figure 16. JRCC SAR management system displaying two SAR units conducting a search according to a search pattern sent by SAR management

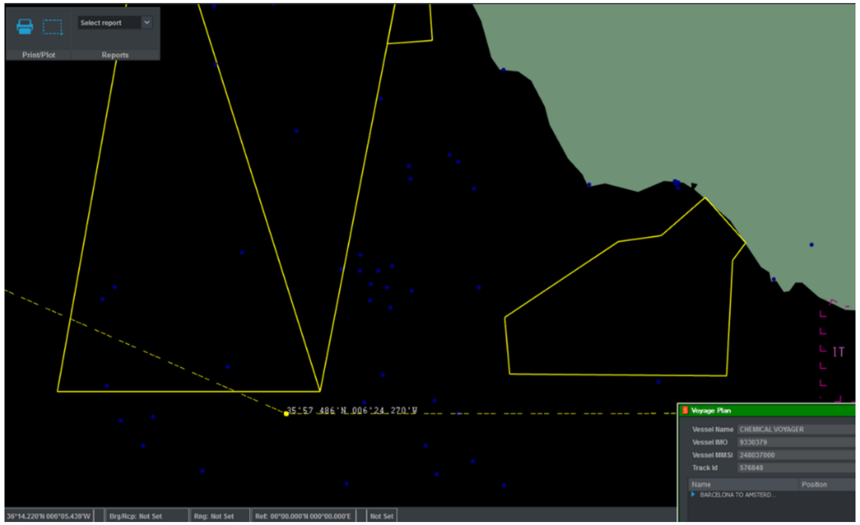

Figure 17. Enhanced monitoring service. The figure is a screenshot of a voyage plan shared with Tarifa SC. The route passes through a firing exercise area in force. The dotted line is the ship route and the solid lines indicate the boundaries of the firing exercises

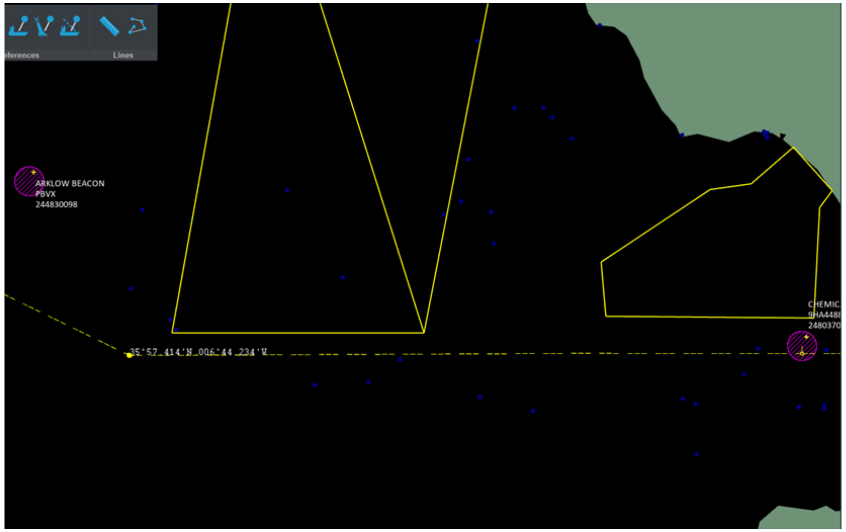

Figure 18. Enhanced monitoring service. Tarifa SC sends several area messages to the ship regarding firing exercises in force. The figure shows how the ship has changed her route according to information received from Tarifa SC

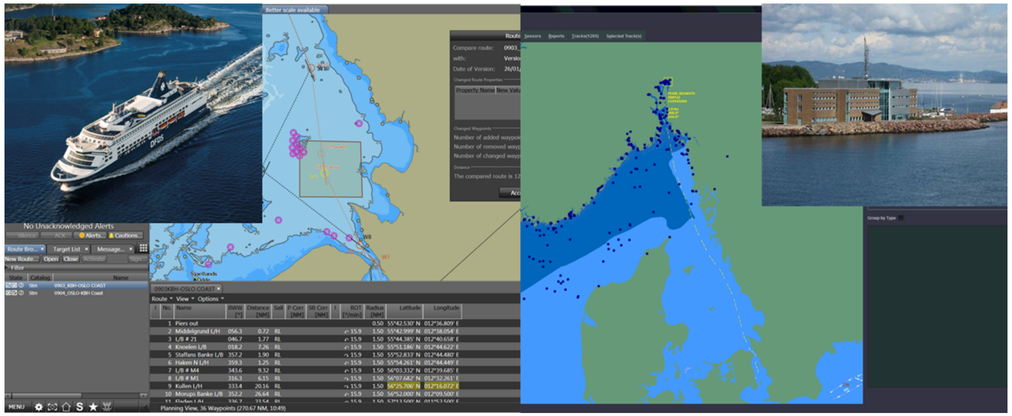

Figure 19. During the e-navigation underway conference in early 2018 the voyage plan from DFDS cruise ship Pearl Seaways was shared with Horten VTS, which could monitor the ship's progress according to her plan. The voyage plan was at the same time shared with the Baltic Navigational Warning Service that provided Pearl Seaways with navigational warnings along her route, which were displayed directly in the ECDIS.

The Enhanced Monitoring Service can also be used to foresee dense traffic situations. Supposing that all, or nearly all, ships in, e.g. Dover Strait or Strait of Gibraltar are STM equipped. A prediction can be made well in advance of the time and position of complex traffic situations. Furthermore, shore centres can transmit information regarding temporarily restricted areas, such as those for military exercises, SAR operations etc. Figure 17 and Figure 18 gives examples of enhanced monitoring service in the Strait of Gibraltar.

3.1.5 Results

The distributed service eco-system approach selected in the project has proven a suitable solution in the voyage management test-bed. The eco-system enables episodic tight-coupling between maritime actors, for example ship-shore communication between systems from different manufacturers. Accordingly, and as an outcome of the project results and findings, the service interface, the communication protection measures and the service lookup functions are proposed to the IEC as a new work item for standardization.

In the voyage management test-bed, primarily existing services have been digitalized and distributed by new means in order to facilitate service discoverability, consumption and visualization for the stakeholders concerned. The operational services implemented during the test-bed are to be considered as initial examples of potential future services.

Findings from end-user feedback indicate that digital information sharing between shore-ship, ship-shore and ship-ship can improve situational awareness and improve operations on board, in shore centres, maritime rescue and coordination centres and VTS centres. These improvements are created by operational services such as optimized routes, pilot routes, ice routes, SAR search areas and patterns, selected navigational warnings and synchronized arrival times. The responses as to whether STM has reduced workload are more varied. Some services are viewed as reducing workload, while others are not. This was expected, since not all services are aimed at reducing workload; instead, the benefits of these services are related to safety effects or enhanced operations on shore-side, for example. In addition, future usability refinements can hopefully further stimulate utilization of the various services.

According to 165 questionnaire respondents and 6 interviews with navigation officers on test-bed ships and shore centres, the exchange of voyage plans directly from the ship´s ECDIS, see Figure 20, has been valuable. For navigation officers, the benefits of integrating information of higher quality (i.e. accuracy and timeliness) are similar for most services. For example, the route optimization services have been found useful in getting the optimized routes directly into the ECDIS without having to use stand-alone applications. This is also the case for winter navigation where ice waypoints and ice routes are made available directly in the navigation system. The operational benefits are related to easier route planning, which enables reduced administrative burden, misunderstandings and human errors.

In addition, other services such as the Nordic Pilot Route Service, the Baltic Navigational Warning Service and Enhanced Monitoring from shore centres, demonstrated improved situational awareness and operational safety. These conclusions come from practical end-to-end usage of the different test-bed services. Figure 21 gives some example of the perception of the services among navigation officers who responded to the questionnaires.

The responses as to whether STM has reduced workload are more diversified, see Figure 22. Some services are viewed as reducing workload while others are not. This was expected, since not all services are aimed at reducing workload on board; instead, the benefits of these services are related to safety effects or enhanced operations on shore-side , such as enhanced monitoring and port-call synchronization. The services with the highest ratings in reduced workload are the winter navigation service and the Nordic pilot route service. One possible reason for this could be that these services are similar to existing services and procedures and, thus, moving on to using a new but similar service presents few obstacles. In addition, it is hoped that future usability refinements will further reduce the effort required to use all the services.

Looking at the VTS part of the Shore Centres, no absolute conclusions can be drawn from the voyage management test-bed, since a sufficient number of ships did not appear to have used the same VTS area at the same time. However, the STM services that could be useful for VTS operations have been tested in a simulated environment.

The results from the simulations, can be found in the project report STM_ID3.3.6. EXTENSION_EMSN Test Report_Evaluation of STM services_Human Factors_Including_VTS_SC

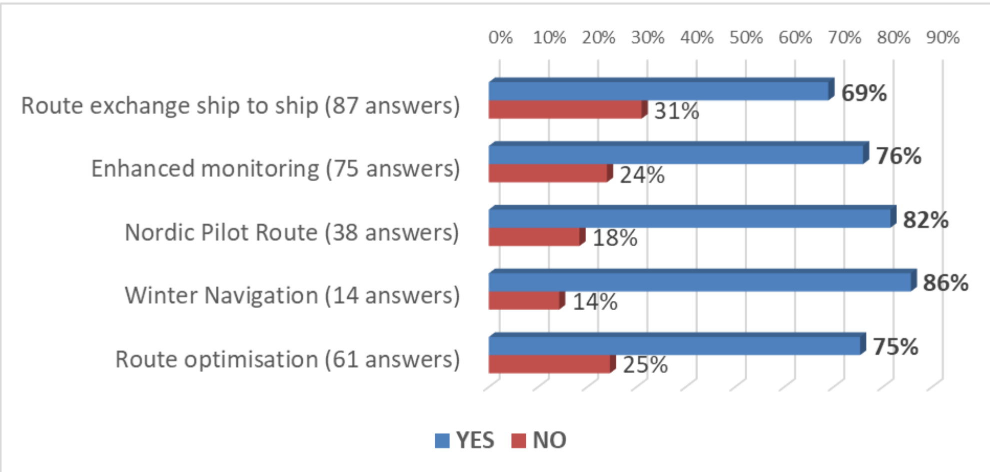

Figure 20. Rating by navigation officers on test-bed ships as to whether STM services made them feel safer. Note: actual safety is difficult to measure and the question therefore focused on the perception of safety

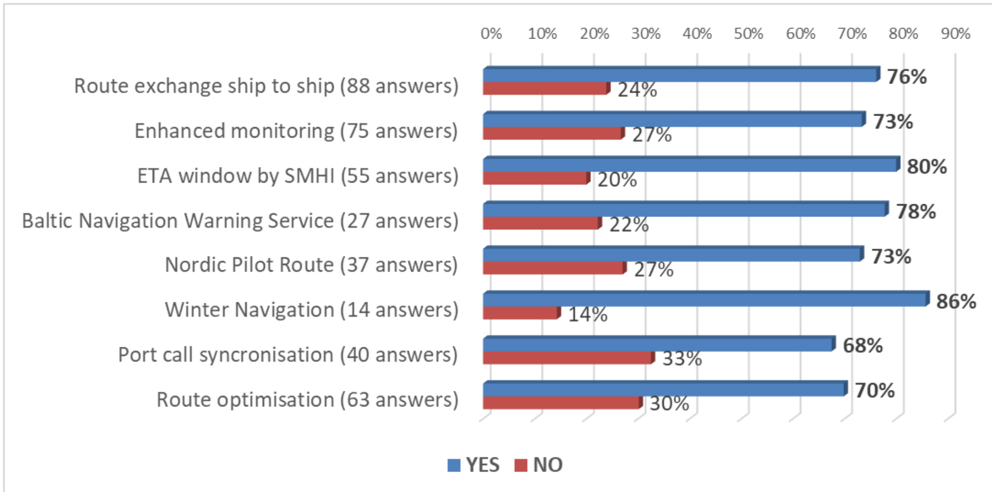

Figure 21. Rating by navigation officers on test-bed ships as to whether STM test-bed services and STM-supported tools assisted ordinary bridge duties

The results from the simulations clearly indicated a change in the work of the VTS. Given the possibility to review the intentions of the ships well in advance before entering the surveillance area of the VTS, allowed the VTS to work more proactively than is currently possible.

Ship-to-ship exchange of route messages, containing up to seven route legs, was a "test within the test" as it did not use the digital infrastructure for exchange but, instead, deployed the on board AIS equipment. The feedback on its usefulness and effect on situational awareness and safety was positive from the voyage management test-bed ships. However, refinement is necessary in terms of human-to-machine interface HMI-related aspects and how/when routes are to be presented to the OOW (Officer of the Watch).

3.1.6 Considerations and Recommendations for STM Development and Implementation

On a general level, the implemented services indicate support for the goals set up for STM. However, it should be remembered that they do not encompass all functionalities needed to cover the overall STM concept as defined in MONALISA 2.0. In the coming phases of STM, more and new kinds of operational services, based on new message formats and information services/APIs are needed. Additional focus needs to be directed towards the refinement of the operational services and components related to the architecture, such as information services and cyber-security precautions and solutions. These refinement findings have been compiled and noted in technical notes to make sure they can be taken into account in further STM development.

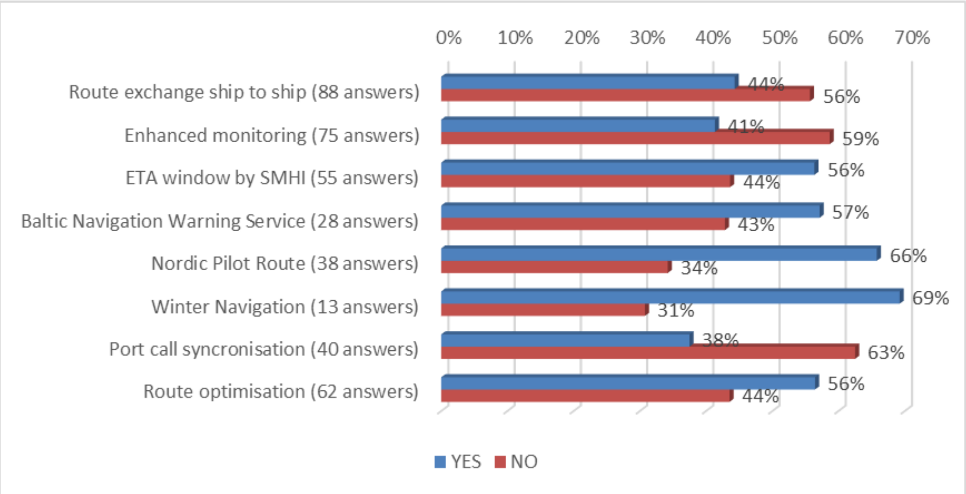

Figure 22. Rating by navigation officers on test-bed ships as to whether STM test-bed services had decreased their workload

To attain a more long-term sustainable use, the new functions and services need to be included in ships´ ordinary operational routines and procedures, such as voyage planning procedures. In order to reach this stage, the services need to create enough value for the shipping company to encourage and maintain their deployment. Even though end-user feedback through questionnaires indicates positive effects, it is anticipated that the value and number of existing services are not yet sufficient to sustain operations without further enhancement, initiatives or other incentives. In some cases, a higher degree of automation – to reduce the need for operator action or input – might be possible due to the greater insight that has been gained from the project. In addition, more user-friendly systems are needed to make service deployment easier and more intuitive and to further decrease the workload and administrative burden.

A mandated capacity to share voyage plans, according to defined standards, could also be a means to speed up adoption on board ships and ensure long-term sustainable deployment. This would require regulatory changes. Examples of relevant resolutions and regulations for a mandated capacity to share voyage plans include but are not limited to:

- IMO Assembly Resolution A.893 (21) on Guidelines for voyage planning.
- Revised Performance Standards for Electronic Chart Display and Information Systems (ECDIS) – Resolution MSC.232 (82).
- SOLAS regulation V/34.

This requires a careful review and further investigation.

3.2 EMSN Simulations

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Extensive simulations using the European Maritime Simulator Network (EMSN) were organized as part of the STM Validation Project to assess the Sea Traffic Management (STM) concept in various traffic scenarios in open and confined waters, ice conditions and search and rescue exercises to collect quantitative and qualitative data for comparative analyses. The operational STM services used in the simulations covered areas such as traffic coordination through simulated Shore Centre(s), enhanced monitoring by a Shore Centre, area management, enhanced on board navigation supported by route exchange (ship-shore and ship-ship including Rendezvous) and enhanced communication by Chat service.

Qualitative analysis of the data from simulations suggests that, in general, the STM services promoted navigational safety and efficiency, as these services have the potential to improve communication, decrease bridge crew workload, and increase the time to respond, plan and act accordingly in challenging navigational and traffic conditions. However, further rigorous user-interface testing and operator training of the users is needed to realize the full potential of the services.

The results from various quantitative analyses indicate that the STM services are valuable in areas where strategic navigation is applicable, i.e. where there were fewer temporal and spatial constraints. However, in areas with dense and regulated traffic and less room for strategic navigation, the value of the available STM services in improving traffic safety could not be directly demonstrated.

The simulations highlighted the many benefits, challenges and risks associated with the implementation of the STM services from the point of view of experienced seafarers. The introduction of new technologies to already complex systems is one of the most challenging aspects in any work environment. Additional testing is required to understand if there is a shift of workload to other components of the maritime decision chain, and how the services may make it necessary to adapt current regulatory, organizational and management structures in the shipping domain.

3.2.1 The European Maritime Simulator Network (EMSN)

As conceptualized in MONALISA 2.0 and further developed in the STM Validation Project, the European Maritime Simulator Network (EMSN) is a unique test-bed that enables the introduction and testing of new technologies in complex and large-scale traffic situations without exposing seafarers to any risks. The EMSN

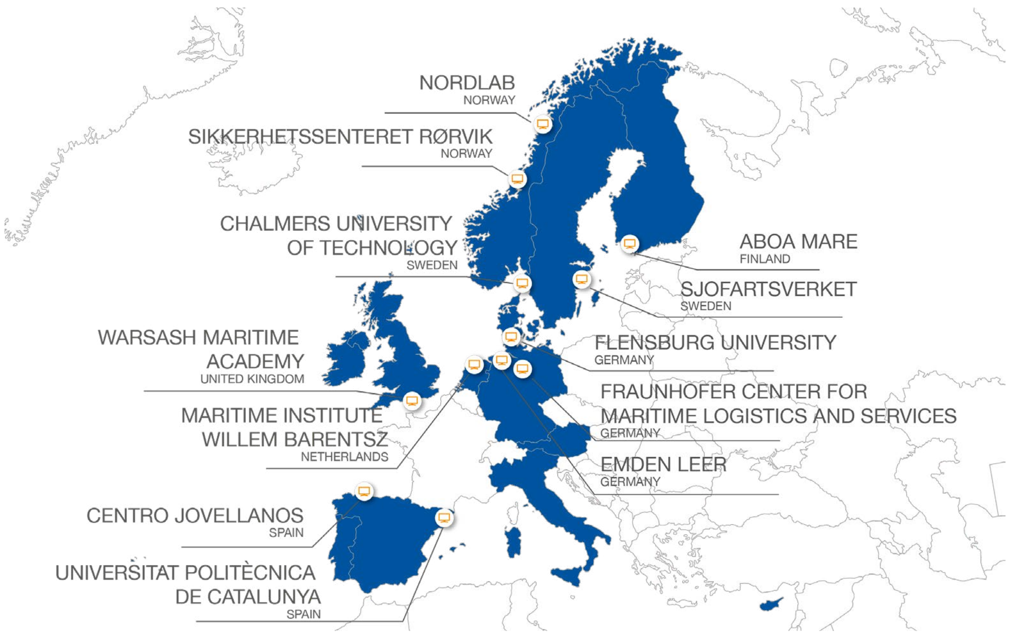

Figure 23. EMSN Simulation Centres

currently consists of 13 connected Ship Handling Simulators (SHS) based in seven EU countries with the possibility to run scenarios using over 30 manned simulated ships. To enable a realistic evaluation of STM's potential, a minimum set of services had to be established within the EMSN:

- **Exchange of simulation data:** Consists primarily of published entity data, which represents the participating simulated ships (ground truth).
- **Exchange of voice communication data:** Emulates real world radio communication (VHF) between SHS among each other and between them and the shore centre.
- **Exchange of STM data:** Shall provide the exchange of data between STM equipment established on each SHS and shore centres.

The exchange of simulation and voice communication data is conducted within a Virtual Private Network (VPN). Therefore, each site is connected with the internet by a VPN router that establishes the virtual EMSN subnets between hubs and spokes.

Since simulation management systems are considered to be manufacturer-specific, the widespread Distributed Interactive Simulation (DIS) protocol was introduced to provide a corporate mechanism for distribution of simulation data and to hide proprietary simulation protocols. (Poschmann & Burmeister, 2016)

The scope and purpose of the EMSN simulations were to reflect the STM concept in simulation scenarios and to collect quantitative and qualitative data. Comparative numerical and Human Factors analyses of the simulations with and without STM services were performed to serve as a basis for forming recommendations to support a future decision-making process regarding implementation of such services.

3.2.2 Simulation Exercises

Five simulation weeks were organized as part of the project, with two 90-minute simulation sessions per day over four days and two days of simulation exercises in ice conditions using 2 centres only.

> **Further information** STMVal_D3.14 - EMSN Management and Coordination Plan

In addition, a simulation study was performed locally at two centres to specifically evaluate the Ship to Ship Route Exchange (S2SREX) function and how it may affect the actions taken by the navigator in various traffic situations including the risk of misusing or placing over reliance on its functionality.

> **Further information** STM_ID3.3.8 -Test Report: Ship to Ship Route Exchange (S2SREX) - Controlled simulation trials

Simulations	
EMSN STM Baseline Simulations: Baltic and English Channel scenarios	
Pilot runs	2017-10-23 to 2017-10-27
Session 1	2017-11-13 to 2017-11-17
Session 2	2018-02-05 to 2018-02-09
EMSN STM Simulations with services: Baltic and English Channel scenarios	
Session 3	2018-03-12 to 2018-03-16
Session 4	2018-06-11 to 2018-06-15
EMSN STM Simulations: SAR (with and without services)	
Session 5	2018-10-22 to 2018-10-26
EMSN STM Simulations: Ice (with and without services), 2 centres only	
	2018-10-08 to 2018-10-09
Ship-to-ship route exchange Simulations	
At Chalmers	2018-09-04 to 2018-09-07
At Warsash	2018-10-02 to 2018-10-05

Table 2. Simulation exercises

3.2.3 Scope and Purpose of the EMSN Simulation Exercises

The scope and purpose of the EMSN simulations were to reflect the STM concept in simulation scenarios and to collect quantitative and qualitative data. Comparative numerical and human factor analyses of the simulations with and without STM services were performed to serve as a basis for forming recommendations to support a future decision-making process regarding implementation of such services.

3.2.4 STM Services Used in Simulations

Following the initial technical development and establishment efforts, several available STM services were implemented and used during the EMSN simulations. The operational services covered areas such as:

- Traffic coordination through simulated shore centre(s);
- Enhanced monitoring by a shore centre;
- Area management;
- Enhanced on board navigation supported by route exchange (ship-shore and ship-ship including Rendezvous);
- Enhanced communication by Chat service.

The specific services used are further described in the next section.

Shore Centres will be able to detect if a planned schedule is not kept or if a ship deviates from the monitored route.

3.2.4.1 Route Crosscheck by Shore Centre

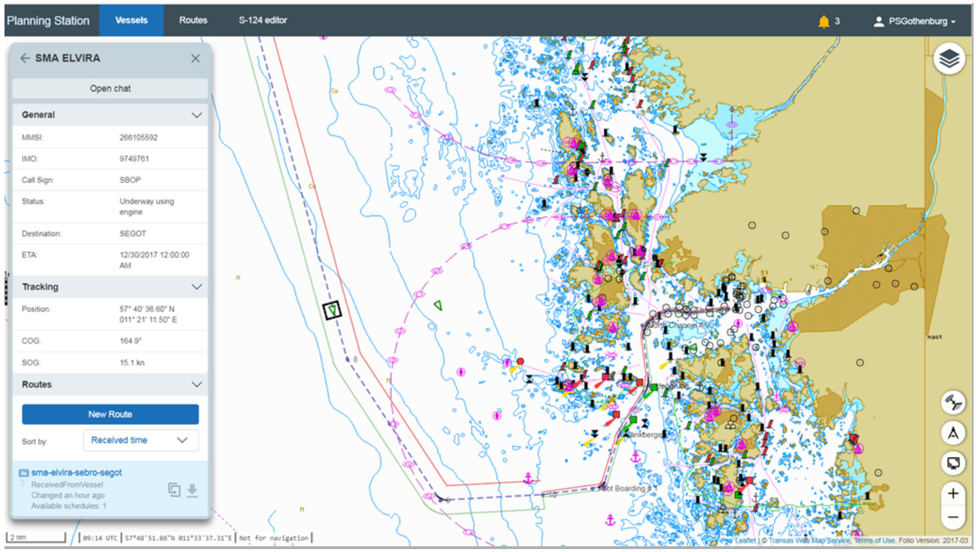

Figure 24. Route Crosscheck by Shore Centre

Ships may send any routes and schedules in their library to a shore centre. A shore centre can receive any planned route, have it displayed on their screen and crosscheck it against any navigational dangers and if necessary send a route suggestion back to the ship.

3.2.4.2 Enhanced Monitoring

Ships may share their monitored route with a shore centre of their choice. After having received a ship's monitored route and schedule, shore centres will be able to detect if the planned schedule is not being observed or if the ship deviates from the monitored route. Receiving routes and schedules from ships also enables the shore centre to predict potential traffic congestion points.

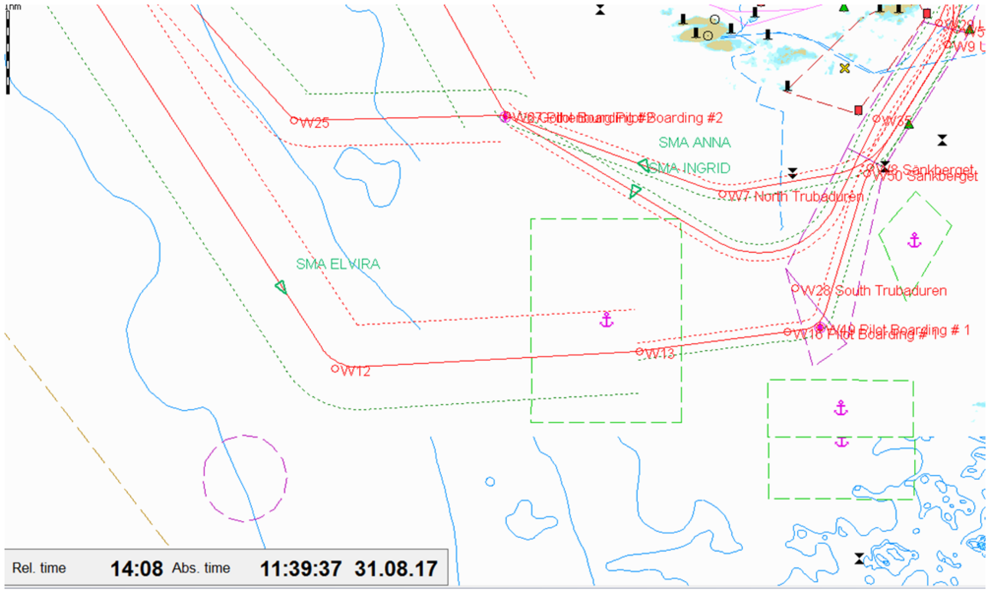

Figure 25. Enhanced Monitoring

3.2.4.3. Shore-to-Ship Route Exchange (Receiving Route suggestions from shore)

This service allows the shore-centre to send a suggested route to the ship's ECDIS, to be reviewed by the bridge team and then either accepted or rejected. This service can be used in various situations; for example, if several ships are warned to avoid a certain area, the shore centre can plan a route based on all available information and directly send this route to the ship.

The shore centre can plan a route based on all available information and directly send this route to the ship.

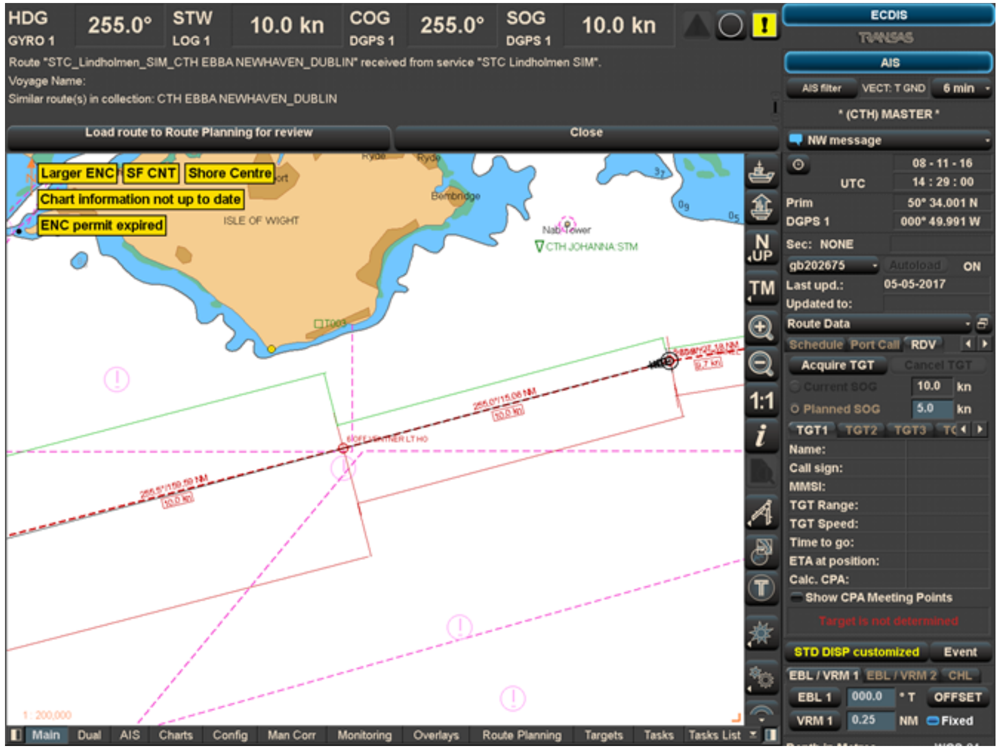

Figure 26. Route Suggestion

3.2.4.4 Receiving Navigational Warnings

This service provides a notification which overlays a Navigational Warning Message directly on the Electronic Chart Display and Information System (ECDIS). If the navigational warning involves a geographical area to avoid or be aware of, this will be automatically plotted onto the ECDIS.

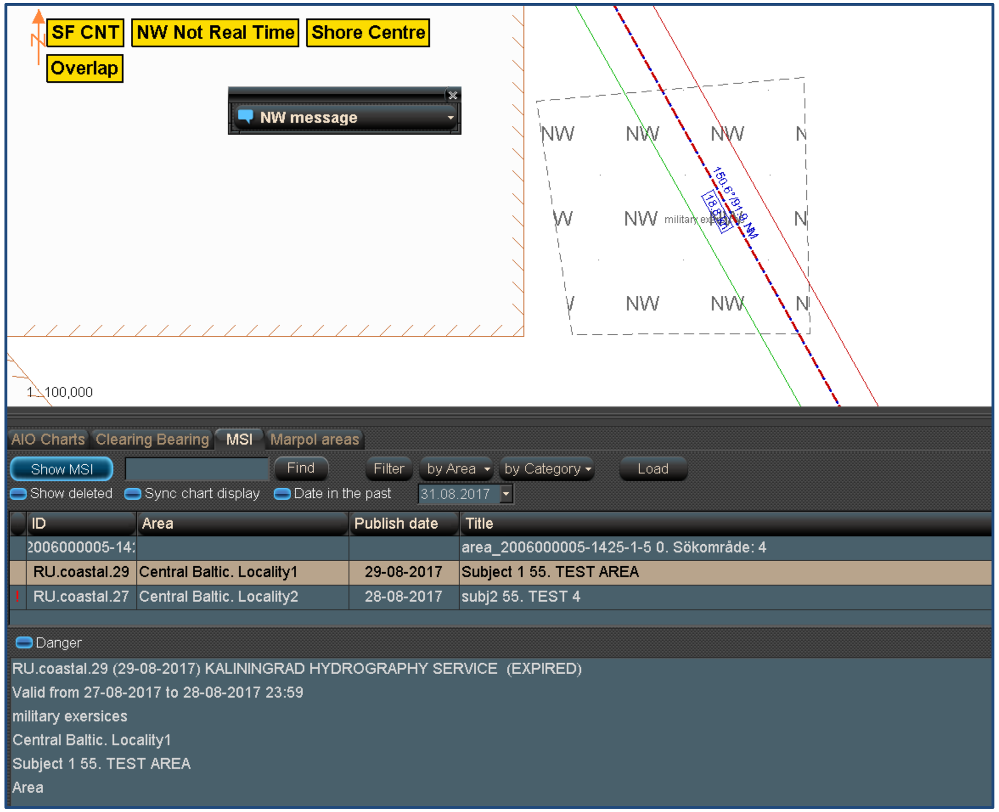

Figure 27. Navigational Warnings

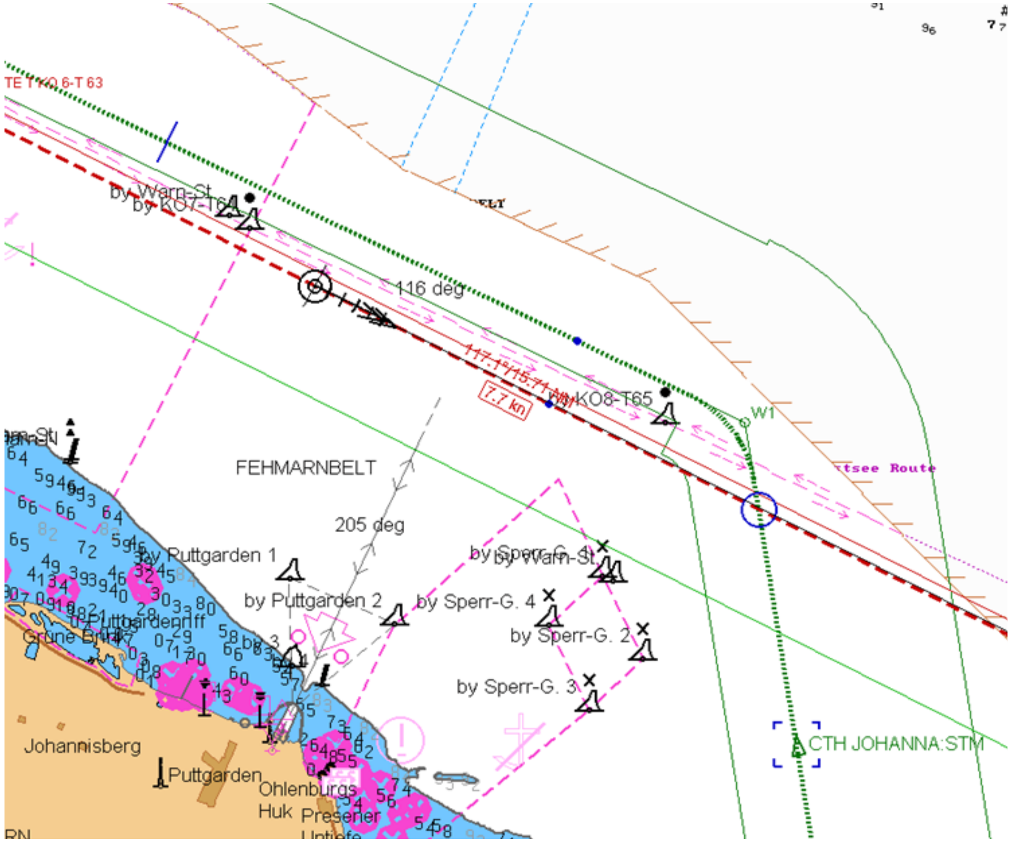

Figure 28. Ship-to-Ship Route Exchange and Rendezvous

3.2.4.5 Ship-to-Ship Route Exchange (S2SREX) and Rendezvous (RDV) Function

This service provides the navigator with a route segment consisting of the next seven waypoints of the monitored route of another ship. Route segments are broadcasted through the Automatic Identification System (AIS) and give additional information to the presently available data obtained by radar/ARPA and AIS. Nothing in the S2SREX information exonerates the navigator from applying the International Regulations for Preventing Collisions at Sea (COLREG) and, rather than being used in a close-quarters situation, the S2SREX may be used as a tactical tool for supporting decision-making and situational awareness when ships are at a longer range from each other. Additionally, as an integral part of the S2SREX, the Rendezvous function allows navigators to view where their own ship will meet a target ship if both ships continue along their monitored broadcasted route at the present speed over ground. This function provides route-based Closest Point of Arrival (CPA) and Time to Closest Point of Arrival (TCPA) based on AIS information.

3.2.4.6 Chat Function

Stand-alone software such as Skype or Messenger, was integrated into the same station as the ECDIS. Text communications with other stations with STM-enabled tools such as Shore Centres and ships.

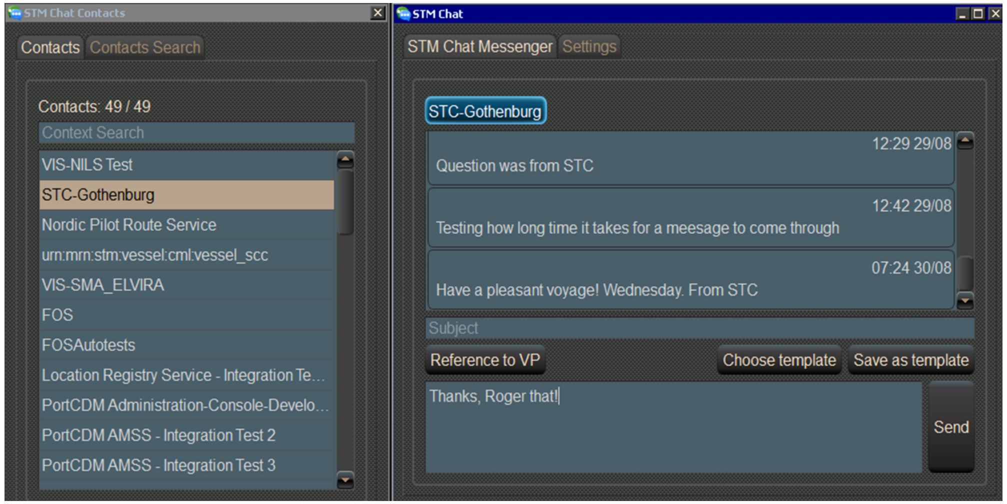

Figure 29. Chat Function

3.2.5 Methodology Used to Assess the Possible Effects of STM services on Traffic Safety

To determine whether the STM services had measurable effects on maritime traffic safety, the following methodologies were used:

- Specification of a set of maritime traffic scenarios to be implemented in EMSN simulations.
- Executing the scenarios with and without the STM services (STM runs and Baseline runs).
- Assessment of the traffic safety in each of the scenarios with and without the STM services using a quantitative and qualitative methodology.
- Comparison of the assessments.

3.2.6 Data Collection

As part of the process of data tracking, various simulation-relevant information was recorded. This information includes numerical and qualitative data, as well as audio files.

3.2.6.1 Numerical Data

All numerical data were recorded and stored centrally at one network site and consisted of:

Ship data

General information describing specifications of the ships used in the simulation scenarios, such as length overall, beam overall, IMO number, MMSI (Maritime Mobile Service Identity), etc.

Motion data

Variety of information describing direction and speed of the ships considered, such as heading, speed over ground, engine order telegraph, AIS, etc.

Environmental data

Environmental information with influence on the ship's motion, such as wind direction and speed, current direction and speed as well as visibility.

General data

General information and identifiers for the assignment of simulation centres and ships, such as simulation ID, site ID, time-stamp, etc.

Further information on the recorded numerical data can be found in STM 3.2.1. EMSN Technical Specifications.

Data were collected using web-based questionnaires during and after the simulation runs and openended debriefings after the simulation sessions at each centre.

3.2.6.2 Qualitative Data

The aim of the data collection was to gather purposeful data, which were later analysed employing qualitative data analysis procedures. Data were collected using web-based questionnaires during and after the simulation runs and open-ended debriefings after the simulation sessions at each centre.

> **Further information** is found in STM_ID3.3.2 EMSN Test Person and Data Collection Management

3.2.6.3 Audio Data

The VHF communication between the bridges and VTS/Shore Centres involved was logged through Teamspeak.

3.2.7 Participating Simulator Centres

A multitude of simulation centres spread throughout Europe participated in the simulation runs (see figure 23). The following table, Table 3, shows not only the location but also the simulator manufacturer and the number of bridges used during the exercises for each simulation site.

512 people participated in the simulator sessions. The majority of the participants were male (87.89%). More than half of the participants (56.64%) were younger than 40, with the 20 to 29 year old representing the largest group in the sample (29.69%) accounting many years of experience.

Simulation Site	Abbre-viation	Country	City	Simulator Type	Number of Bridges
Aboa Mare	AM	Finland	Turku	Transas	3
Centro Jovellanos	CJ	Spain	Gijón	Kongsberg	4
Chalmers University of Technology	CTH	Sweden	Gothenburg	Transas	2
Flensburg University of applied Sciences*	FUAS	Germany	Flensburg	Transas	3
Fraunhofer Center for Maritime Logistics and Services	CML	Germany	Hamburg	Rheinmetall	2
				Transas	1
Maritime Institute Willem Barentsz	WB	Netherlands	West-Terschelling	Kongsberg	2
Sikkerhetssenteret Rørvik	SSR	Norway	Rørvik	Transas	5
Swedish Maritime Administration	SMA	Sweden	Norrköping	Transas	3
Universitat Politècnica de Catalunya	UPC	Spain	Barcelona	Transas	2
Warsash Maritime Academy	WMA	UK	Southampton	Kongsberg	2
Emden Leer*	EL	Germany	Leer	Transas	3
NORDLAB*	NL	Norway	Bodø	Kongsberg	1

*not participating in all EMSN simulations

Table 3: Simulation Sites

3.2.8 Test Participants

A total of 512 people participated in the simulator sessions. The majority of the participants were male (87.89%). More than half of the participants (56.64%) were younger than 40, with the 20 to 29 year olds representing the largest group in the sample (29.69%). The portion of participants older than 60 years was 6.25%.

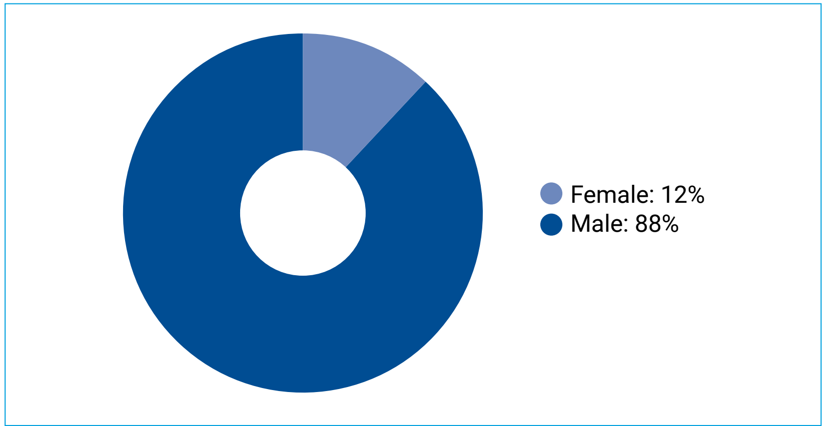

Figure 30. Participants demographics: Gender

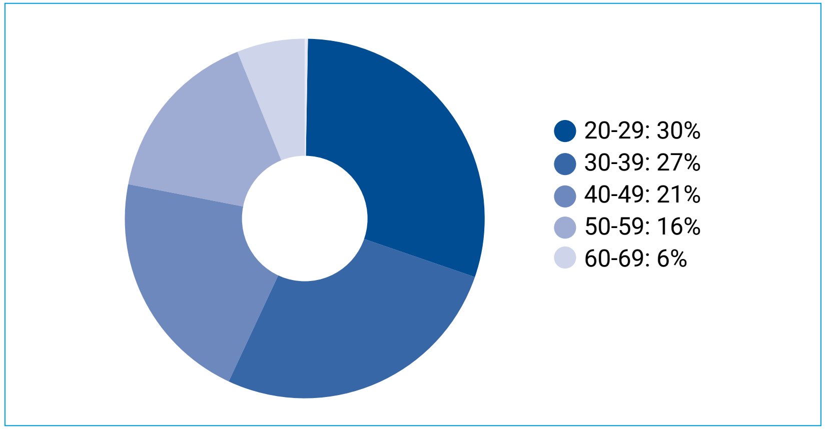

Figure 31. Participants demographics: Age

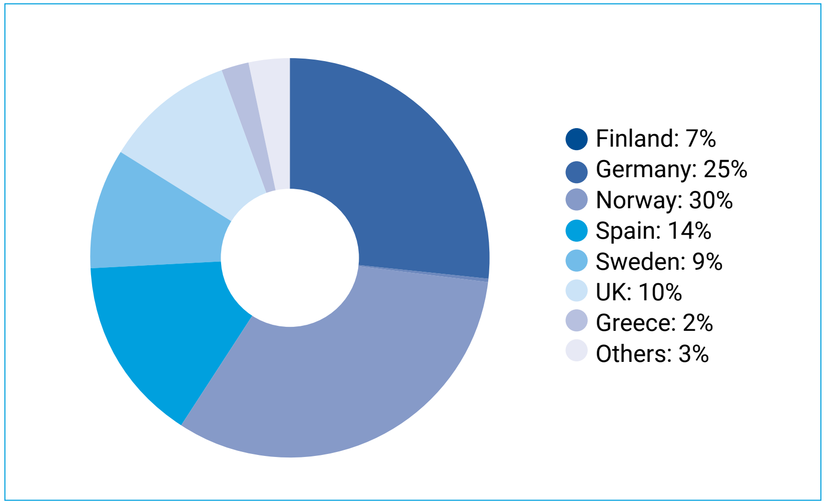

Figure 32. Participants demographics: Nationality

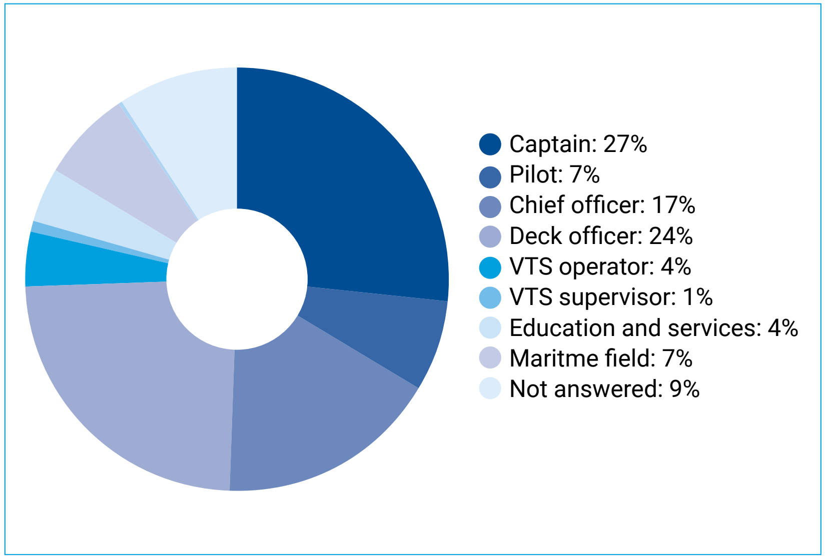

Figure 33. Participants demographics: Current Professional Position

Regarding the county of residence, the largest number of participants derived from Norway (29.88%), Germany (25.00%) and Spain (14.06%). The other countries, ranked according to the same criterion, were the UK, Sweden, Finland, Greece, Italy (and others), which accounted for a share of 31.05%.

As regards the participants' current professional employment, over half (50.78%) of the participants were employed either as captain or deck officer.

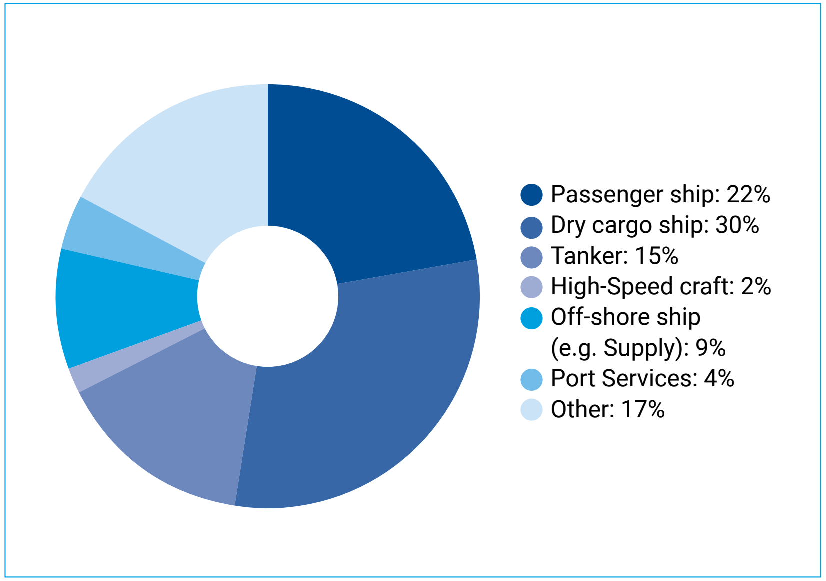

Figure 34. Participants demographics: Type of ship most served on

Passenger ships, dry cargo ships and tankers accounted for 2/3 (67.58%) of the types of ships on which the participants most frequently served.

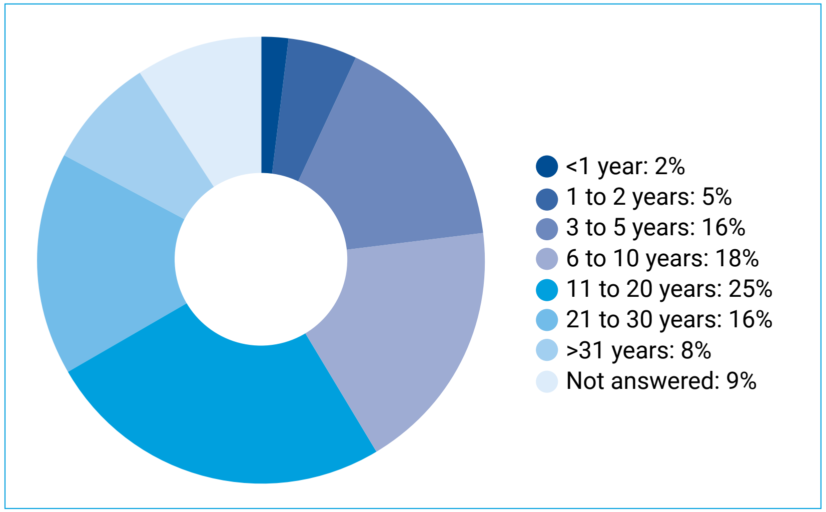

Figure 35. Participant demographics: Experience

Most of the participants had many years of maritime experience. Only 23.44% of the respondents had fewer than 5 years working experience in the maritime domain. Most of the participants, or 26.37%, had 11 to 20 years of professional experience. Note that 9.18% of the respondents did not provide any indication of their experience.

For the full report refer to STMVal_D3.16 EMSN Summary Simulation Test Report

3.2.9 Delimitation

The EMSN simulations did not attempt to make a comparative analysis of the possible effects of each individual STM service on traffic safety separately. Rather, the EMSN simulations tried to capture the possible combined effects of several STM services being available at the time of the simulation runs, based on qualitative and/or quantitative data collected during five weeks of simulation trials in the EMSN. The services may have been used individually by the test participants or in combination with other services. Other factors which may have an influence when analysing possible effects of introducing STM services such as usability of ECDIS in general, the familiarization and training in the use of the services, the experience of the test participants were noted but not further analysed.

3.3 Simulations Exercises

3.3.1 EMSN Simulations: English Channel and Southern Baltics Scenarios

3.3.1.1 Description of Exercises

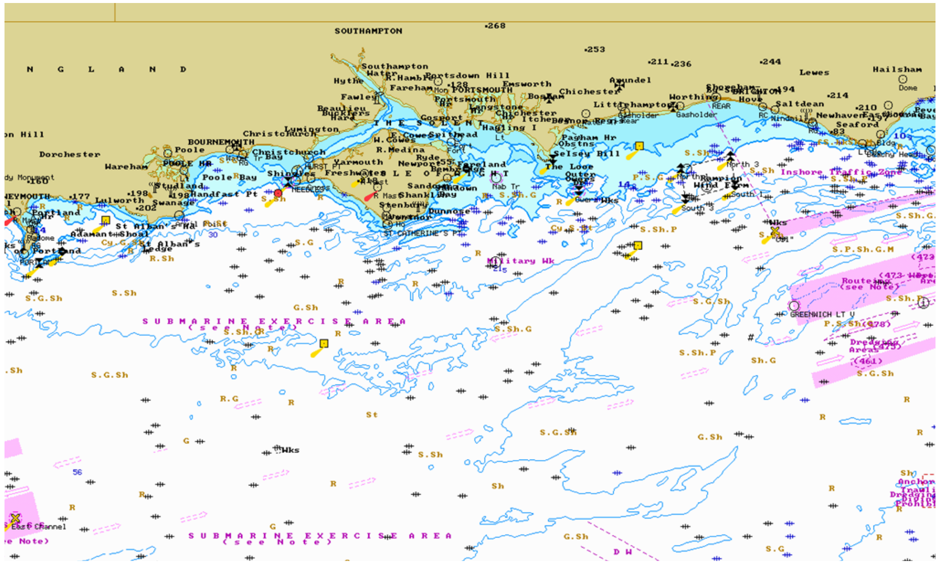

Figure 36. Area: English Channel Scenario

The English Channel and the Southern Baltic were selected as good examples of heavily trafficked areas. The Baltic scenario was created for the Fehmarn Belt, representing one of the world's busiest traffic corridors with numerous recommended routes, junction areas and ferry routes crossing the main corridors.

The English Channel scenario was created for the south coast of England with the port of Southampton as the major port of interest. The English Channel scenario focused more on port approach and less on dense traffic conditions in confined waters compared with the Baltic scenario.

Each geographical area also had a respective shore centre (SC), one located in Southampton, UK for the English Channel scenarios and the other in Gothenburg, Sweden for the Southern Baltic scenarios. Presently, there is no common consistent agreement on the definition, roles and tasks of a shore centre. For the purpose of the exercises, the SCs functioned as typical VTS centres with additional access to STM services.

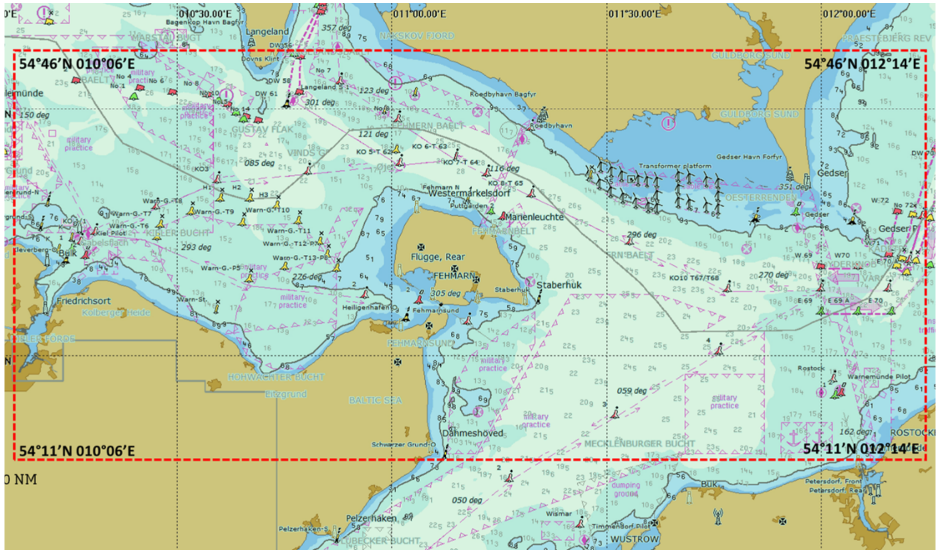

Figure 37. Area: Baltic scenario

Eight scenarios were specified, based on the combination of three variables: location, time of day and visibility. Each scenario was executed several times with and without the availability of STM services.

> **For the full report** refer to STM_ID3.2.4_EMSN_Pilot Test Plan and Exercise Specification

3.3.1.2 Human Factors Analysis and Results (Bridge Teams)

3.3.1.2.1 Methodology

A grounded theory approach (Corbin & Strauss, 2008) was used to compile and analyse the qualitative data from the debriefing sessions. A qualitative and mixed methods software programme was used to organize, visualize and analyse the open-ended debriefing responses. The coding process was continuous as new themes and relationships emerged between data, this is also known as axial coding.

Once it was established that the data were saturated, memos explaining the phenomena were recorded. The memos were written to help understand and support the observed findings.

3.3.1.2.2 Results

The simulations highlighted the many benefits, challenges and risks associated with the implementation of the STM services from the point of view of experienced seafarers. The research suggests that, in general, the deployed STM Services promoted navigational safety and efficiency.

These services have the potential to improve communication, decrease bridge crew workload, and increase the time to respond, plan and act accordingly in challenging navigational and traffic conditions. However, rigorous user-interface testing is needed to realize the full potential of the services. Additional testing is also required to understand if there is a shift of workload to other aspects of the maritime decision chain.

Seafarers are generally eager and supportive of the further development and implementation of STM services if proper training is provided, and shipping companies are willing to put safety above costs. Even in the earliest stages of development of the STM services, the participants recognized the potential benefits.

Further testing, including numerical testing of the traffic situations of the STM and similar services, is needed to ensure that the safety of crewmembers is prioritized. The EMSN and live test-beds offer a safe place to test and validate this transition to an e-Navigation-based shipping industry.

For the full report, refer to STM_ID3.3.6. EXTENSION_EMSN Test Report_Evaluation of STM services_Human Factors_Including_VTS_SC

3.3.1.3 Human Factors Analysis and Results (VTS/SC Participants)

3.3.1.3.1 Methodology

During the exercises, the shore centres were manned by professional VTS operators who, like the bridge teams, went through a familiarization process ahead of the scenario.

The data compiled at the shore centre were both qualitative and quantitative. The VTS/SC operators filled out post-scenario questionnaires that posed questions related to the usability, user-friendliness, and overall experience of the STM services. In addition, a VTS supervisor completed observational assessments during the simulations in each scenario to quantify the frequency, type, and quality of interactions between the ship and shore. The data were recorded in Excel sheets for further analyses.

3.3.1.3.2 Results

From the VTS operator perspective, the overall results indicate that, although the communication between ship and shore will increase, the STM Services will promote navigational safety and efficiency through the availability of additional navigational information, monitoring services, and communications resources. The STM services provide the opportunity to visualize (e.g. on a ship´s ECDIS or a VTS system) the traffic situation hours in advance, encouraging a proactive approach to safety. The participants were positive towards the further development and integration of the services.

However, from an operational perspective, the observed shift in communication patterns could also have an unintentionally negative impact on situational awareness, and information overload for the VTS operators. The use of alternative means of communication, instead of VHF radio, is an interesting finding that may have implications for surrounding traffic and miscommunication of the intentions of other ships. Therefore, it is important to study further the communication patterns between ship and shore to understand how workload, training, and procedures in the VTS station will be affected by STM. Moreover, because this study was conducted in a controlled simulated environment, there are many factors to consider that must be further investigated to fully understand how the STM services will impact the overall VTS operations.

For the full report, refer to STM_ID3.3.6. EXTENSION_EMSN Test Report_Evaluation of STM services_Human Factors_Including_VTS_SC

3.3.1.4 Quantitative Analysis

3.3.1.4.1 Methodology

Three different numerical models were developed to assess the possible impact of STM services on traffic safety:

a) A maritime collision safety index method was developed based on in-depth interviews with 13 experienced officers evaluating the safety in various angles of a two-ship traffic scenario taking the CPA (Closest Point of Approach) and TCPA (Time of Closest Point of Approach) into consideration. This was the basis that was used in a multi-ship traffic scenario by splitting up the multi-ship scenario to each traffic encounter and choosing the collision safety index from the least safe encounter (Olindersson & Weber, STM_ID3.3.4_EMSN_Test Report_Numerical Analysis_Safety_Index_, 2019).

b) The traffic safety (or risk) of the scenario simulations was assessed through a method based on the analysis of the "instant risk" of each of the ships throughout the simulation (Sanchez & Weber, STM_ID3.3.3_EMSN Test Report_Evaluation of STM Services through Traffic Risk Assessment, 2018).

c) The level of safety of different traffic situations was measured and evaluated based on a fuzzy logic approach. Overall, this safety index consists of a collision index, a grounding index, an environmental index and the manoeuvrability of the corresponding ship (Scheidweiler & Weber, STM_ID3.3.7_EMSN Numerical Data Analysis_Southern Baltic Scenario, 2018).

3.3.1.4.2 Results

To summarize, there are several uncertainties that make it difficult to provide an objective answer as to whether the implementation of STM services will improve maritime traffic safety. No separate analysis of the effect of individual STM services on maritime traffic safety has been made and there are several other uncertainties that make it difficult to give an objective answer, as their effects could not be measured. For instance, the fact that STM services were novel solutions for all the test participants and, thus, inexperience in how to use the services and usability issues may have an effect that could not be accounted for in the analyses.

All numerical analyses concluded that the runs with and without the available STM services were safe according to the parameters used in the models. There are indications that the STM services are valuable in areas where strategic navigation is applicable, i.e. where there were fewer temporal and spatial constraints. The English Channel scenario – focusing more on port approach and less on dense traffic conditions in confined waters – allowed ships and VTS/SCs more time to plan and solve potential situations pro-actively. One indication supporting this was that when the STM services were available in the English Channel scenario, the number of minor incidents decreased by 27% and the number of major incidents by 11% (Olindersson & Weber, 2019).

However, in areas with dense and regulated traffic (for example traffic separation schemes), and less room for strategic navigation, i.e. the Southern Baltic scenario, the value of the available STM services in improving traffic safety could not be directly demonstrated. Whereas the model based on instant risk calculations indicated an improvement in maritime traffic safety if STM services were available (Sanchez & Weber, 2018), neither the analysis based on a fuzzy logic approach (Scheidweiler & Weber, 2018) nor the analysis based on a maritime collision safety index (Olindersson & Weber, 2019) could confirm this. On the contrary, both methods showed a decrease in their respective safety index and an increase in minor and major incidents. However, no separate numerical analysis of the effect of the individual STM services on maritime traffic safety has been made. Some services may have a positive effect on traffic safety and the results reported here should be compared with the results of other evaluation methods to gain a deeper understanding and possibly more conclusive answers (Scheidweiler & Weber, 2018).

For the full report refer to STM_ID3.3.4_EMSN_Test Report_Numerical Analysis_Safety_Index (Olindersson & Weber, 2019)

For the full report refer to STM_ID3.3.3_Evaluation of the STM services through a traffic risk assessment (Sanchez & Weber, 2018)

For the full report refer to STM_ID3.3.7_EMSN_Test Report_Numerical Analysis_Southern Baltic Scenario (Scheidweiler & Weber, 2018)

3.3.2 EMSN Simulations: SAR Scenarios

3.3.2.1 Description of Exercises

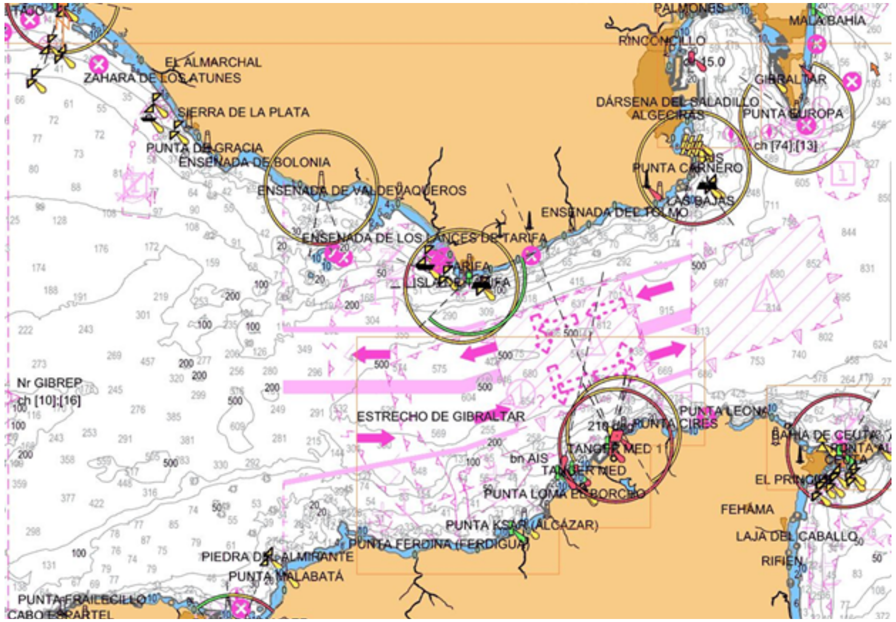

Figure 38. Area: SAR exercises

Up to 30 ships with manned bridges were participating in exercises with several SAR scenarios in the Strait of Gibraltar, including a simulated Tarifa MRCC. The area is not only known for its dense traffic but also, unfortunately, for its daily intensive SAR activities.

The primary objective of the simulation was to simulate scenarios with several SAR emergencies and traffic situations to evaluate if the use of the following STM services may improve the efficiency and effectiveness of SAR operations:

- Sending S-124 Areas depicting the search area
- Route exchange between shore and ships enabling the display of search patterns on the ECDIS on board
- The addition of the Chat service to the available communication
- Ship-to-Ship Route Exchange and Rendezvous

3.3.2.2 Human Factor Analyses and Results

The results indicate that most of the test participants evaluated the STM services in a positive manner. The overall SAR coordination performance using STM services was improved mostly because of the holistic approach utilized in the STM concept - through sharing information with all actors involved in a clear and effective way. The participants believed that it was easier to monitor the traffic information in SAR scenarios with the help of STM services, and having easy access to SAR operation-related information and traffic information was considered critical for planning their SAR operations. Sharing information using STM services may also result in fewer misunderstandings and bring more clarity to communications. However, it was also noted that all parties involved in a SAR operation need to assume that all other ships are equipped with these advanced systems, use the services correctly and follow their monitored routes, otherwise the services may become a navigation and/or safety risk. Information overflow, distraction from navigation and trust (or rather the lack of it) in the information were mentioned as the main sources of concern.

The other predominant category for expressing concerns was mostly functional limitations that the participants felt during its practical use. While some of the usability issues were due to technical or regulatory limitations (e.g. the way the information may be presented on the ECDIS) others may have been be due to the participant's lack of familiarization with the equipment. Regardless, the introduction of new technologies to already complex systems is one of the most challenging aspects in any work environment and needs to be supported by training.

The future challenge resides in further analysing and assessing the possible impact of introducing STM services on the effectiveness of SAR operations, and how these services may make it necessary to adapt the present regulatory, organizational and management structure of SAR operations.

For the full report refer to STM_ID3.3.9_EMSN SAR Test Report

3.3.3 EMSN Simulations: Ice Scenario

3.3.3.1 Description of the Exercise

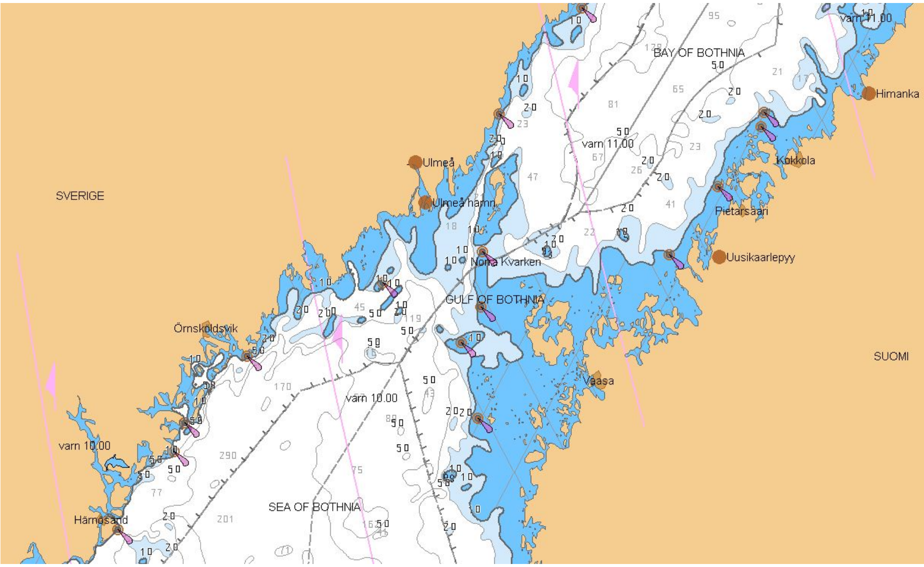

Figure 39 Area: Ice exercises

Sharing routes via STM services (suggested route and S2SREX) reduces workload and frees time for other matters, which is important especially in safety critical and dynamic situations

A two-day exercise amid ice conditions was done to test the benefit and impact of some STM services on the safety and efficiency of ice navigation. Six manned bridges from Aboa Mare and Sikkerhetssenteret Rørvik participated in the exercise. The Finnish Traffic Agency tested their STM Tools (IBNext) during the first day; otherwise, the shore centre was operated by Aboa Mare.

In the scenario, three northbound ships and three southbound ships needed to enter an ice channel made by an icebreaker. Meeting or overtaking was not possible in the ice channel. A meeting point was assigned (open water area), which was located approximately midway in the simulated ice channel. Ships and their bridge teams were required to manage and plan the voyage in terms of how to enter the ice channel and how to meet other ships at the assigned meeting point. During the exercise with STM services the ships received the waypoints (i.e. a suggested route) from the icebreaker (Shore Centre) that appeared automatically on their ECDIS. In the scenario without STM services, the waypoints were given on a paper as a NAVTEX message.

3.3.3.2 Human Factors Analysis and Results

Based on open-ended debriefings of the participants, the results are positive towards the use of several services even though more training is considered needed.

According to the participants, sharing routes via STM services (suggested route and S2SREX) reduces workload and frees-up time for other matters, which is important especially in safety-critical and dynamic situations. However, the Chat message service may divert attention from navigation if the same person is writing a response and steering the ship and there should be some button just to confirm message received. Also, it is suggested that different colours be used to highlight the urgency of the message in the Chat service.

Two days of exercises were insufficient to ascertain whether the deployed STM services had an impact on maritime safety and efficiency in ice conditions. However, the observations and feedback received are consistent with the data from other exercises held in the EMSN within the STM project. There is some indication that especially sending the waypoints as a route suggestion does reduce workload for navigators and therefore can have a positive effect on safety and efficiency.

For the full report refer to STM_ID3.3.5 Evaluation of STM Services_Ice Scenario

3.3.4 Ship to Ship Route Exchange (S2SREX) Simulations

Independent of the EMSN, simulations followed by a qualitative and quantitative assessment were performed at Chalmers and Warsash Maritime Academy to evaluate the S2SREX function and how it may affect the decisions and actions taken by the navigator in various traffic situations including the risk of misusing or relying excessively on its functionality.

The simulation scenarios covered a mix of traffic situations, including longer and shorter-range scales in more confined waters. However, no scenarios were set in any VTS areas, port areas and/or areas with compulsory pilotage. Three ship types of various sizes were used in the traffic scenarios in calm weather conditions and good visibility.

All scenarios were run with and without the use of S2SREX to evaluate the possible effect of S2SREX on the test participants' decisions and behaviour. All runs were automatically recorded in a log file for subsequent automatic reproduction of the exercise.

3.3.4.1 Human Factor Analysis

The total number of test persons recruited was twenty-four, consisting of twelve at Chalmers and twelve at Warsash. Prior to data compilation, each participant filled out an individual digital and paper Consent Form as well as a digital demographics questionnaire. On each day, three participants played the roles of Officer of the Watch (OOW) for their individual ship involved in the scenario. An in-house bridge simulator instructor and a human factor specialist were the observers during the simulations in the control room of the simulation centre. A short briefing was held every morning, complemented with a familiarization session with the S2SREX and Rendezvous (RDV) function for the experimental conditions. The participants were given a chance to explore the features of S2SREX function in a few exercises predefined by the simulator instructor. After each simulation scenario, the participants were required to fill in a brief questionnaire regarding their perceived performance and opinions about the scenario. By the end of each day, there was a common debriefing regarding their overall perceived performance and opinions about the S2SREX and RDV functions.

3.3.4.2 Numerical Analysis

The log files of each simulation run were replayed on an instructor station and the following parameters and values were noted:

- The ships observed in a traffic situation
- The type of situation (crossing, meeting or overtaking)
- Identification as to which ship was the stand-on or give-way ship
- The distance between the ships when one ship took action and the type of action taken (either change of course or speed or both)
- The magnitude of the course change in degrees or the change of speed in percentage terms
- The number of course and/or speed changes
- The indicated CPA and TCPA before taking such action
- The resulting CPA after the action was taken
- If the action consisted of a breach of the COLREGs

Initially, an individual evaluation of each scenario was considered. However, the amount of data was not regarded as being sufficient to permit a scenario-based analysis and it was decided to group the scenarios into two groups:

- Meeting and overtaking scenarios in confined waters (recommended routes, TSS) where planning for meeting/overtaking may be important.
- Crossing scenarios in more open waters.

Means of the distance when taking action and the resulting CPAs were calculated for the runs with and without S2SREX and RDV and subsequently compared.

3.3.4.3 Results and Conclusions

To summarize, the study supports that S2SREX may enhance the officer's situational awareness and shows a tendency to improve navigational safety in traffic situations when used as a tool for supporting decision-making and situational awareness at a longer range, i.e. during strategic navigation.

The study also indicates that there are several risks involved in using S2SREX, notably over-reliance/misinterpretation of the data and potential confusion/uncertainty when the "route" and "intention" are implicitly assumed to be same thing, especially when using S2SREX in tactical navigation.

It is important to note that the study did not cover the evaluation of the possible effect of S2SREX on the test participant's decisions and behaviour in, e.g. adverse weather conditions, restricted visibility or dense traffic conditions. Considering that there are far more factors that possibly affect the decisions and behaviours of navigators in traffic situations, further studies are recommended.

For the full report refer to STM_ID3.3.8_Test Report_Ship to Ship Route Exchange_ver_2

4. Integrating port operations in Sea Traffic Management – the Missing Link in the Maritime Supply Chain

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PortCDM relies on improved data sharing to increase situational awareness thereby enabling more efficient processes and enhanced collaborative decision-making during port calls. This increases the efficiency of port calls for all stakeholders.

The concept itself was validated in four ports in a Mediterranean test-bed and five ports in a Nordic test-bed. More than 80 organizations involved in the port call process participated.

The results of the validation showed that the enhanced situational awareness provided by data sharing following the principles of PortCDM is valuable and beneficial. It was confirmed that the enhanced situational awareness gained provides positive effects on operations, including making better estimates for ETAs and ETDs, improving work procedures, reducing the time spent on information gathering, and a reduction in administrative workloads. A number of the ports involved in the validation intend to continue and build upon the PortCDM concept introduced as part of the validation.

The validation of the PortCDM concept showed that:

- the concept and digital data sharing provide significant positive benefits by enabling port-call actors to plan, coordinate, and synchronize activities more efficiently, thereby giving rise to enhanced and more efficient overall port call performance; and
- the basic doctrine, procedures, and standards for PortCDM have reached a level of maturity that enables them to be used as the foundation for a global implementation.

4.1 The Challenge: the Need for Enhanced Collaboration in the maritime transport chain

4.1.1 Higher Levels of Collaboration Required

Business in general and the maritime sector in particular are considerably different today compared with a hundred, or even fifty years ago. Traditionally, businesses carried out transactions in isolation in order to protect the business from competitors and to create a competitive advantage. Working with competitors or even with those with links in the same market was often seen as detrimental, as this could disclose critical information and reduce competitive advantage.

In our connected world, much greater cooperation within and across markets is necessary for survival. Almost all airlines collaborate in alliances and work closely together when setting up code-share flights, even in a very competitive environment. Without collaborative decision making, well-connected airports would not be able to meet the demands in the aviation transportation chain. Collaboration in the car industry results in vehicle designs being shared between competitors. To remain competitive, the maritime transportation chain must work similarly.

Maritime transport is a highly distributed ecosystem. In some cases, up to 40 different and economically independent actors might be involved in one maritime supply chain. Too often, this results in a level of coordination that often disappoints charterers and other customers, because they experience uncertainty, delays and limited transparency, especially compared with other options such as air transport. The reliability of container ships arriving within one day of the original estimate is below 70%[1], and far too often, multiple days of delay are experienced. In the multi-modal full supply chain, this behaviour of the maritime sector becomes increasingly unacceptable.

4.1.2 Digitalization Enables Collaboration in the Maritime Ecosystem

From a logistics perspective, the shipping industry is largely a self-organizing ecosystem with a huge number of sometimes competing individual actors without one overarching governing authority. No public or commercial entity has complete control over all the resources from exporter to importer. In this ecosystem, it is also extremely difficult to effectively manage the utilization of a wide span of resources – often located in different countries. Accordingly, a distributed ownership of the many elements in the ecosystem has prevailed. If there were a better solution, market forces would likely have fashioned it over time. The most effective way so far seems to have been to base operations on a large number of independent actors, each one responsible for managing its operations.

It is worth noting that each actor is competing both horizontally (one shipping line competes against other shipping lines) and vertically (the shipping line competes with other actors in the vertical value chain; for instance, the freight forwarders) for revenue and profit. This competition forces every actor to be as efficient as possible. Unfortunately, it also means that overall effectiveness, sustainability and safety may not be given appropriate priority. These overall goals for the full vertical value chain are lost as every actor primarily aims at optimizing their own operations. Accordingly, the losers are the shippers, the customer of products, society and in the case of safety also the employees.

A very telling example is that in most ports, the lack of collaboration and synchronization among the actors means that the principle of first come - first served is standard practice. This encourages ships and ship operators to ‘hurry up and wait’, causing unnecessary inefficiencies and consequentially higher levels of pollution and greenhouse gas emissions. Contractual issues, legal constraints, and local practices, which have been established over decades of legacy customs, work arrangements, trade union agreements, and non-optimal business cultures exacerbate this situation in many ports.

Digitalization enables solutions and is now being implemented broadly across many different areas of the maritime field. However, if we look at how the industry has adopted digital technologies and explored new opportunities, these have mainly been oriented towards granting some minimal level of access to data for a small number of stakeholders. There are very few examples where data sharing spans all the way from shipping companies, ports, and operators to diverse (digital) service providers. Unfortunately, mainly for competitive reasons, there is much less emphasis on mutually beneficial data sharing. This results in exchanging only the minimum amount of data, which, in turn, creates ignorance gaps and missed opportunities for system-wide efficiency, sustainability and even safety.

In order for providers in a self-organising ecosystem – such as the maritime transportation chain – to pursue higher efficiency, they need to be informed about related actors’ planned actions and outcomes. Within the transport sector, the spatial and temporal dimensions need to be captured for planned and actual physical movements and service provisioning. By sharing situational awareness of *when*, *where*, and *what* for events related to port call operations, actors are better informed to coordinate their related and often inter-dependent operations.

4.1.3 Initiatives Taken by the Maritime Sector

As the maritime sector recognizes the need for digitalization, improved cooperation and collaboration through information sharing, various projects and programmes have been developed, and some of these are now being successfully implemented. The Single European Sky ATM Research programme (SESAR) for the airline industry and Sea Traffic Management (STM) for the maritime sector are examples of holistic concepts that have been developed over successive phases, with each phase focusing on a specific aspect of the holistic concept.

The IMO e-Navigation strategy is another important initiative, which the IMO defines as *“the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to en-*

1 The industry average reliability for ship arrival on-time which is within +/- 1 day compared to estimated time of arrival promised two weeks’ prior was 67.8% for January 2015 and 69.2% for January 2017.

hance berth-to-berth navigation and related services for safety and security at sea and protection of the marine environment". In addition to STM, the e-navigation concept of digital data sharing has been firmly embedded in projects such as BLAST (Bringing Land And Sea Together), MONALISA (Motorways and Electronic Navigation by Intelligence at Sea project) and the SMART-Navigation project in the Republic of Korea.

4.1.4 Data Sharing among Stakeholders

Maritime transports typically involve a large number of actors, including ships and shipping companies, ship agents, terminal operators, authorities and other port-service providers. Higher predictability of when and where future events will occur requires awareness in the transport chain of the status of events and the intentions of the various actors. This includes knowing the needs of the different actors for co-utilizing infrastructure. Digitalization of all key assets across the common infrastructure creates the foundation for higher predictability.

Until recently, a core problem for shipping has been a lack of means to share and communicate details and accurate timing of events, primarily due to problems in information exchange during the sea voyage. A large proportion of communication throughout the transportation chain is either manual or based on non-integrated, non-automated and non-documented digital systems like VHF, e-mail, phone and SMS. These diverse and incompatible communication capabilities severely limit efficiency and predictability.

With today's technology, it is becoming possible to oversee the full transportation system both during a sea voyage and at the endpoints in port operations. This means that it is possible to increase efficiency by enabling the near real-time digital sharing of critical data among stakeholders, and as well as increasing safety and security.

However, it must be remembered that some actors are competing and may be reluctant to share information, especially detailed information. Accordingly, to facilitate an acceptable level of information sharing, a balance needs to be found between sharing a sufficient amount of decision-relevant information such as status information for the transport unit to facilitate the flow in the supply chain without the need to share detailed information, such as packing lists at the source.

4.1.5 The Introduction of Port Collaborative Decision Making as an Enabler of STM

The overall scope of STM is berth-to-berth. This means that actors in the entire chain of activities from the berth at the point of origin, through the sea voyage, and to the berth at the point of destination are parts of an information chain. For a port to plan its operations with high precision, it needs to be informed about the plans and progress of a ship from its previous port and during the sea passage. Furthermore, the port needs to know the plans and progress of the hinterland transport arrangements that will serve the ship in port. Different elements of STM define service domain concepts to promote (digital) service distribution in the berth-to-berth sea transportation chain. These concepts are Voyage Management, Flow Management, and Port Collaborative Decision Making (PortCDM). These are all supported by Sea System Wide Information Management (SeaSWIM) as the digital infrastructure providing inter-operability within and between the service domains.

The concept relies on a data-sharing environment that supports the port call process with no one actor being superior to another (see figure 40). Under this concept all actors in the port-call process can share real-time or near real-time data on the planning, timing and progress of key events using a standardized, internationally recognized data exchange format.

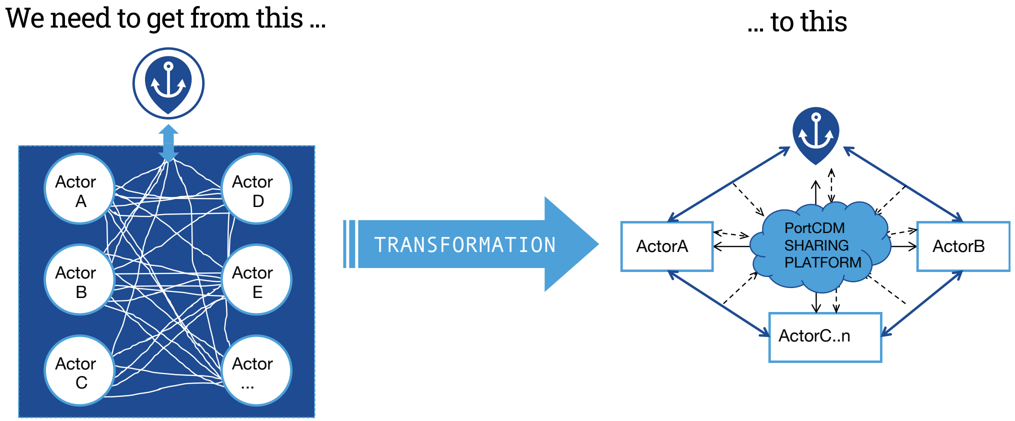

Figure 40. The required transformation for information sharing related to port call operations

The concept takes advantage of digitalization of the maritime sector, e-navigation efforts, and integration of sea transport to establish a holistic transport system, where actions are synchronized and can provide significant improvements in the effectiveness of a port call. It focuses on facilitating communication and information exchange among all actors in a port call, thereby enabling the appropriate services to be made available in order to support just-in-time arrivals and just-in-time operations in general.

The concept can provide significant benefits by enabling and encouraging a collaborative culture and collaborative processes within the maritime ecosystem. The concept encompasses all port-call operations as well as providing technical guidelines for harmonized digital collaboration. Expressed differently, it integrates the practices of enavigation at sea with e-logistics in ports to improve the overall global supply chain by adopting a port-centric point of view.

4.2 Responding to the Challenge

4.2.1 Scope

The purpose or scope of the concept is to support the port-call optimization process by promoting:

- The extension of the planning horizons through intra and inter-port collaboration, ship-to-port collaboration, and port-to-hinterland collaboration
- The sharing of the timing of future events for the coordination of the port call process
- The combination of multiple sources of data for enhanced predictability
- Shared situational awareness by sharing data on the progress of a port call among the internal and external actors involved

4.2.2 Objectives

There are three principal objectives:

1) efficient resource utilization,
2) green steaming (sustainability), and
3) fast turnaround of ships.

The upper part of figure 41, below, shows the 'means-end hierarchy' of the objectives. The operations flow from port to port is indicated in the lower part of the figure.

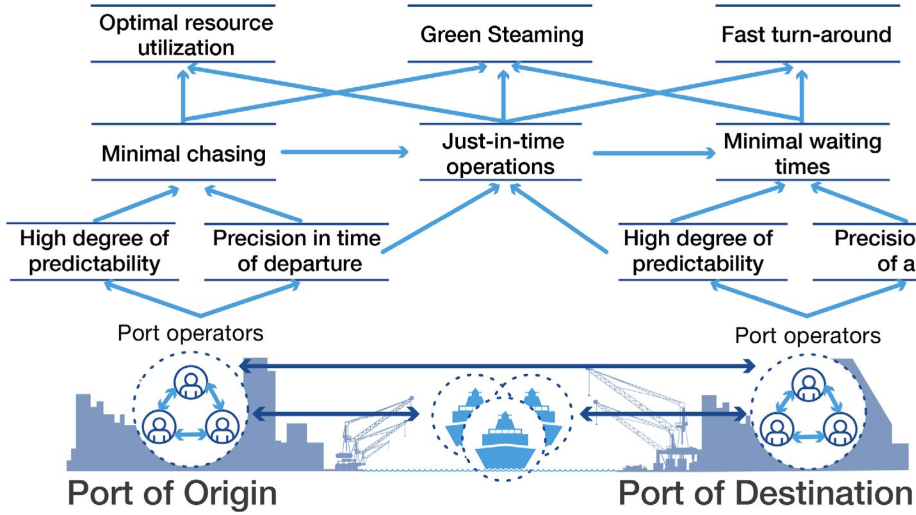

Figure 41. Objectives of PortCDM

As can be seen from the relationships shown in figure 41, precision in time-stamps influences precision in predicted and actual times of departure (ETDs and ATDs) and therefore the degree of predictability of ETA in subsequent ports.

For the port of origin, high predictability and precision in time of departure leads to minimising the need to catch-up or chase an existing schedule in order to make the next port of destination. This has two important implications: superior just-in-time-operations and efficient resource utilization (ships and port facilities). For the port of arrival, high predictability and precision in the time of arrival leads to minimal waiting times, which influences a faster turnaround.

4.2.3 Standardized Data Exchange

Underpinning PortCDM is the exchange and sharing of relevant key information using a standardized digital format. This is the S-211 - *Port Call Message Format*

Figure 42: Participant ports in STM test-bed

(PCMF), based on the S-100 data exchange format. S-100 is created in conformance with the ISO 19000 series of data standards and adopted by the International Maritime Organization as its baseline data exchange format for enavigation. The PCMF enables the sharing of port call information, mainly time-stamps and related metadata between all the actors with authorised access.

The PCMF enables the various actors to gain better situational awareness emerging from shared time-stamps, and improve their operations to increase the efficiency of a port call. It also allows the optimization of the sea voyage, as ships get information on when the port can best serve them and, with this information, allow them to sail just-In-time to reduce fuel consumption and improve their environmental footprint.

4.3 Identified Benefits in Port Collaborative Decision Making

During the STM Validation Project, PortCDM was validated in four ports in a Mediterranean test-bed (Limassol, Sagunto, Valencia, Barcelona) and five ports in a Nordic test-bed (Gothenburg, Brofjorden, Vaasa, Umeå, Stavanger). More than 80 organizations involved in the port call process participated. The results of this validation effort are reported comprehensively in the validation report of PortCDM test-beds.

During the PortCDM validation activity, port call actors interacted in a number of workshops that followed the *living lab*[2] process see figure 43 below.

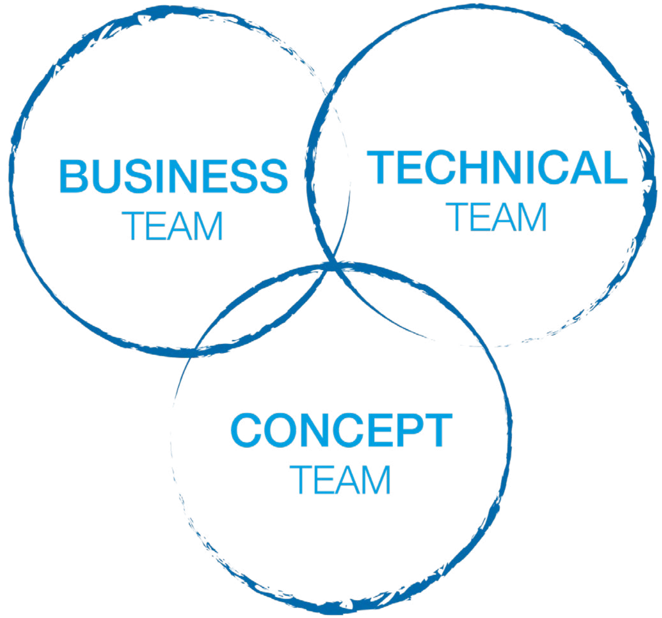

Figure 43. Actors collaborating in the living lab approach

2 A **living lab** is a concept to change users from being traditionally considered as observed subjects for testing modules against requirements, into value creators by contributing to the co-creation and exploration of emerging ideas, breakthrough scenarios, innovative concepts and related processes.

During these workshops they developed, among other activities, an organizational *metro map* (see figure 44 below) for each port that identified the actors, their functions, their interdependencies, and the pinch points in their port-call process. They then carried out live operations during several *focus months* using specially developed software applications and a dedicated platform for PortCDM data sharing. This software, working as a PortCDM demonstrator, comprised back-end as well as front-end services.

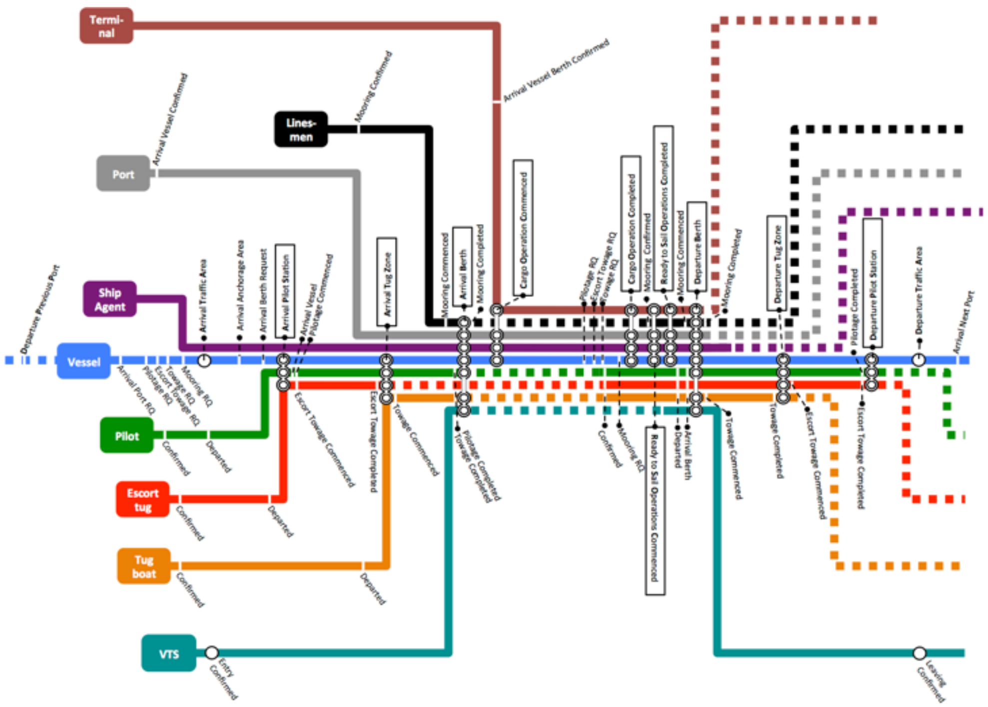

Figure 44. Generic metro map showing status and coordination points in a port-call process (Lind et al, 2016)

4.3.1 Validation Methodology

The validation process involved a number of benefit hypotheses and design principles. During the STM Validation Project, various enabling components, shown in figure 52, were identified in close collaboration with the participating ports. These different components then became the focus in the development of the benefit hypotheses and the design principles.

The lack of comparable historical data and the difficulty in getting access to paper files in diverse locations complicated the validation of the concept. Furthermore, the project was mindful that when attempting to validate an inherently disruptive procedural innovation such as PortCDM[3], within an existing operational scenario, it is not easy to quantify the effects of a new methodology. This is because some operations and activities must continue as before so that those actors not taking part in the validation are able to continue to operate “business as usual”.

Because of the difficulties just described, the chosen validation process took the benefit hypotheses and the design principles and concentrated on qualitative results to examine how the identified enabling components were received in a practical operational test-bed scenario. Furthermore, respondents were then asked about their expectations in the event of PortCDM being implemented on a large scale in the future.

Qualitative analysis was achieved through interviews, questionnaires and collaborative reflections. Quantitative analysis was undertaken by examining the data shared during operations over the focus months. Across the nine participating ports, nearly 100 actors were involved, and feedback was received subsequently from 70 of these, either through responses to questionnaires or through interviews.

The identified enabling components resulted in the following benefit hypotheses and design principles that formed the basis of the analyses:

3 The principles of data sharing and collaboration for enhanced port call operations challenges the existing port practices in two aspects; that port call operations become more harmonized as a global concern, and that patterns of behaviour resulting in sub-optimization is aimed to become avoided

Benefit hypotheses

H1: Standardized data sharing improves the capital productivity of a port and the shipping companies using it by facilitating efficient resource utilization.

H2: Standardized reporting by key port actors of intended and completed actions improves coordination of the port-call process.

H3: Establishing among key actors that the self-interest benefits of data sharing will improve collaboration.

H4: Success is dependent on each actor sending and receiving relevant and timely data to enable all actors to coordinate their actions.

H5: A well-coordinated port call increases resource utilization and reduces ship turnaround time by requiring timely and accurate standardized data sharing by key stakeholders of their intended and completed actions.

H6: The application of mechanisms for trust building among key actors within a port and across ports will increase the range of data shared and the speed at which it is shared.

Design principles

P1: Errors in predicting the timing of intended actions disrupt the planning of subsequent events of current port visits or future visits to other ports.

P2: PortCDM must be configurable to fit the local circumstances and resources of each adopting port.

P3: Port performance can be continuously improved by collecting and analysing operational data for each port visit and acting upon such analyses.

P4: Sustained success is dependent on a governance infrastructure that maintains the standard for data sharing within a port and identifies improved processes for enhancing port-call productivity.

4.3.2 Results of the Validation of the Benefit Hypotheses

Improvement potential from enhanced data sharing and collaboration (benefit hypothesis H1)

The validation results clearly indicated an improvement potential for port-call operations by adopting digital data sharing complying with the design principles of the PortCDM concept, see figure 45.

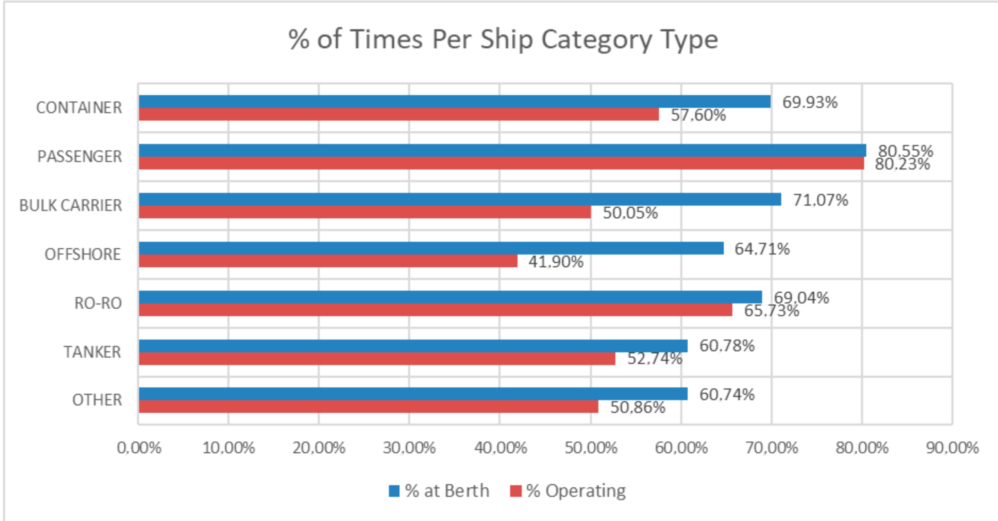

Figure 45. Average time per ship category in port activities as reported in test-beds

As part of the STM Validation Project in the Mediterranean and Nordic test-beds, 43,976 port calls generated 1,696, 115 records (on average 38 records per port call) all based on the standardized port call message format. As shown in figure 45, turnaround times for passenger ships and Ro-ro ships were the most effective, with larger inefficiencies observed for bulk, off-shore, tanker, container and other ship types. For the ports used in the test-bed, it was noted that cargo ships of various types spent only 60% to 70% of their port time at a berth. Only 40% to 65% of time at berth was used for operations. For example, on average container ships in a harbour spent only about 70% of their time at berth, while only 58% of their time was spent conducting operations; so the remaining time can be considered as idle time.

After the introduction of PortCDM, our analysis indicated that the predictability regarding ship arrival at each of the four critical states (Arrival Traffic Area, Departure Traffic Area, Arrival Berth and Departure Berth) had a huge improvement potential for a large number of port calls. In some cases, the improvement potential could approach 90%. For example, for Arrival Traffic Area predictability, the results indicated that predictability could be improved by at least 25% for 2,683 of the port calls, 50% for 678 of the calls and 75% for 229 calls. Similar improvement potential was also observed for the other three critical states.

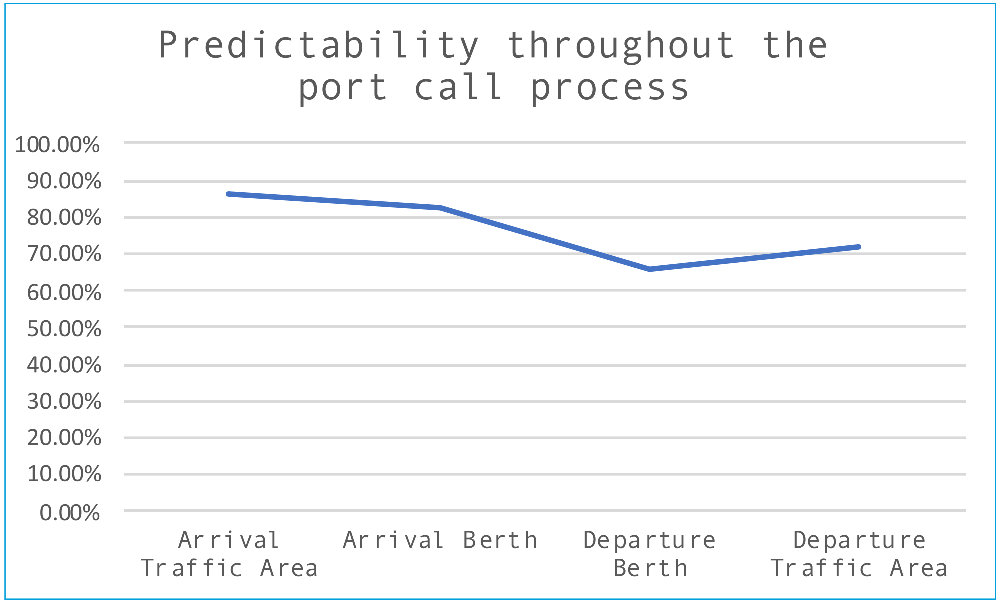

Figure 46. Predictability throughout the port call process based on the analysis of 43,976 port calls

From figure 46, it is also evident that the overall average predictability decreases as a ship progresses through a port call up to the actual time of departure from its berth. This is not surprising, since delays in earlier stages of a port call will always have a potential, and sometimes unavoidable, knock-on effect.

There was clear agreement among the participants (either by fully agreeing or agreeing to some extent) that standardized data sharing improves the capital productivity of a port and the shipping companies using it by facilitating efficient resource utilization. There were no respondents that did not agree. PortCDM was considered to respond to many of the challenges in a port call as shown in the figure 47.

Figure 47. Biggest challenges to planning and realizing a port call.

Contribution to shared situational awareness and access to reliable information (benefit hypotheses H2, H4)

The overwhelming majority of participants agreed that standardized reporting of intended and completed actions by key port actors improves coordination of the port call process. It was highlighted that PortCDM will improve the current situation of missing real-time information and the resulting lack of situational awareness.

92% of respondents from all the ports agreed (either fully or to a great extent) with the statement the usage contributed to a shared situational awareness of port calls as shown in figure 48. None disagreed. This indicates particularly strong support for PortCDM.

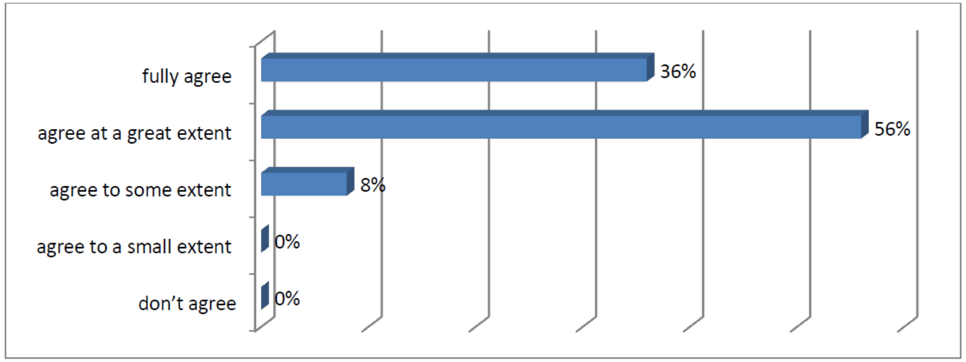

Figure 48. Contribution of PortCDM demonstrator to shared situational awareness

The results showed that most participants agreed that adopting the concept will improve collaboration because it highlights the benefits of data sharing as shown in figure 49 below. However, from the feedback, it was also seen that overcoming the culture of data protectionism may be a challenge for some actors.

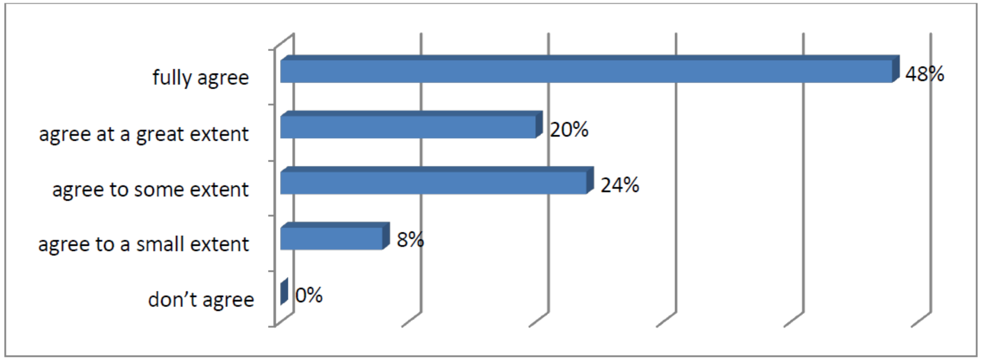

Figure 49. PortCDM validation trial enabled better access to reliable information

There was significant agreement among participants that the success of PortCDM depends upon each actor sending and receiving relevant and timely data to enable all actors to coordinate their actions. As already indicated, and notwithstanding the majority of supporters, feedback from the validation trials showed that certain actors were reluctant to share data.

The qualitative analysis showed strong support for the hypothesis that a well-coordinated port call improves resource utilization and reduces ship turnaround time because of the sharing of timely and accurate standardized data among key stakeholders regarding their intended and completed actions. Analysis of the data collected during the focus months indicated positive improvement trends that would also indicate that adopting the principles of collaboration and data sharing brought forward would be beneficial.

The verbal comments in the qualitative analysis indicated that the application of mechanisms for trust building among key actors within a port and across ports will increase the range of data shared and the timeliness in which it is shared.

During the test-bed activities, it was challenging to achieve a continuous flow of data between ships and ports under operational conditions. Synchronizing a port call by sharing data among ships and ports will require significant cultural change. It will be assisted by encouraging closer understanding and collaboration among actors and perhaps identifying and establishing appropriate incentives for data sharing.

Port call synchronization improvement potential (benefit hypotheses H1, H2, H5)

The validation results showed an improvement potential for port call synchronization through the use of the principles of PortCDM and digital data sharing between a ship and its intended port of arrival.

Several use cases were reported that illustrated the benefits of sending a Recommended Time of Arrival (RTA) to a ship that has previously shared its planned time of arrival with the port. The identified challenges in successfully completing the process involve:

- a reluctance to send an RTA because of the competitive nature of ports, (by following a first come, first served principle);
- inability to commit to an RTA because of congestion at berth and uncertainty in planning;
- late sharing of the planned time of arrival by the ship making the sending of an RTA obsolete; and
- non-acceptance of the RTA by the ship.

Since this port call synchronization procedure was only implemented for a few port calls, so far more testing is needed to clearly demonstrate the benefits and any remaining challenges. It would seem, however, that the development of a collaborative culture among the various actors at a port for mutually agreeing on important points like a ship's RTA, is currently the most important prerequisite for making this happen.

Collaboration improvement potential – the Living Labs approach (benefit hypotheses H3, H6)

The validation results indicated the benefits of the creation of a collaborative culture through the living labs process. All the actors that participated in the living labs were satisfied with the meetings, 70% of them stated that through the living labs meetings they started talking to some other port actors for the first time. 40% went on to collaborate with these newly connected actors, of which 67% found that this collaboration enhanced their operations.

Developing a collaborative culture within the port is at the very heart of the PortCDM concept, and through the living labs process this project demonstrated how to create and maintain such a culture.

Conclusion from the validation of the benefit hypotheses

Based on the overall results obtained, there was solid support that the benefit hypotheses are correct and that the concept will fulfil its intended purpose.

4.3.3 Results of the validation of the design principles

A summary of the results obtained in assessing the design principles is as follows:

Poor prediction leads to poor planning (design principle P1)

Positive feedback was reported by participants confirming that errors in predicting the timing of intended actions disrupts the planning of subsequent events of current port visits or future visits to other ports.

Concept is configurable for local conditions (design principle P2)

The design principle that PortCDM must be configurable to fit the local circumstances and resources of each adopting port was supported both by remarks from those in the ports involved as well as by the qualitative data from the different ports.

Continuous improvement and governance (design principles P3, P4)

Because of insufficient pre-project baseline data available in the quantitative analyses, it was not feasible to assess the design principle that port performance can be continuously improved by collecting and analysing operational data for each port visit and acting upon such analyses. The same was also true for the principle that the success is dependent on a governance infrastructure that maintains the standard for data sharing within a port and identifies improved processes for enhancing port-call productivity.

Conclusion from the validation of the design principles

While there was a good indication that the selected design principles are rational, two (P3 and P4) of the selected design principles require more data and study in order to provide a conclusive result.

4.3.4 Overall Impact of PortCDM

The feedback from those involved in the validation of PortCDM as part of the STM Validation Project indicated that, together with its revolutionary effects (see figure 50), it is viewed as a beneficial concept for improving the performance of the port-call process.

The use of the living lab approach in bringing the various port call actors together was acknowledged by the participants as a successful mechanism for bringing the actors together and fostering the open, information-sharing environment upon which the concept depends.

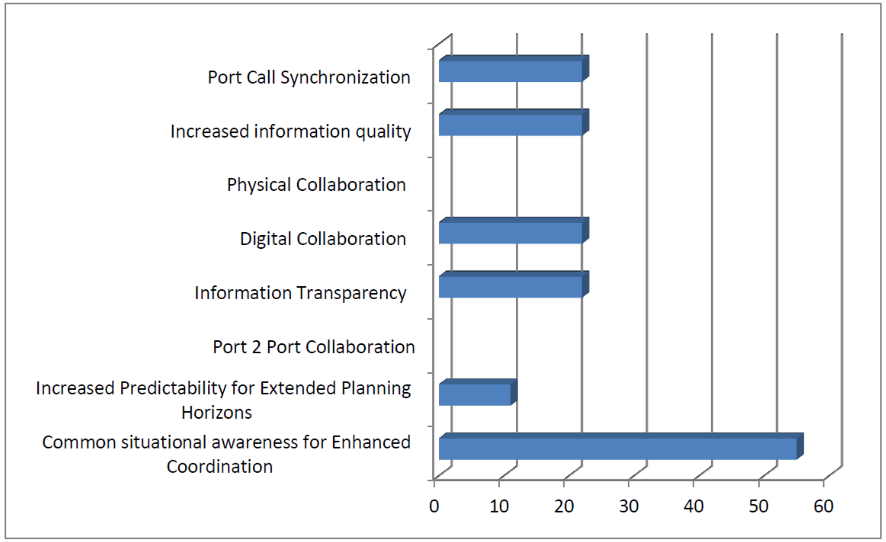

Figure 50. Actors' opinions on the most revolutionary effect of PortCDM

The validation process confirmed that the following benefits were obtained:

- Better coordination among port-call actors.
- Improvement of port-to-port collaboration and communication provided better updates and a more holistic view of the ships and the port calls.
- Reduction of demurrage costs.
- Better communication basis for all actors involved in a port call, since everyone involved has the same information as the basis for their planning.
- More efficient distribution and sharing of resources.
- Higher data transparency providing fair play among all port actors.
- Better visibility of other operators' plans.
- Better understanding of the daily situation in a port.
- Common understanding and situational awareness regarding port-call operations.

A number of participants were sceptical as to whether it was possible to share what was considered commercial or security-sensitive data. However, once the PortCDM process was implemented, there was a general agreement that sharing time-stamps covering ships' movements was not contentious. On the other hand, the sharing of data regarding cargo operations was in some situations considered commercially confidential, and it may require further consideration as to whether these data can be freely shared.

Port-call stakeholders also strongly agreed that PortCDM provides more accurate, reliable, and real-time ETAs and ETDs for those ships arriving from all the nearby ports.

Many of the participants in the test-beds provided suggestions on how the system used in the validation could be improved. However, it is worth stressing that there was no notable adverse criticism of any aspects of the STM Validation Project. On the contrary, the majority of participants were enthusiastic and looked forward to a full implementation of PortCDM in the future.

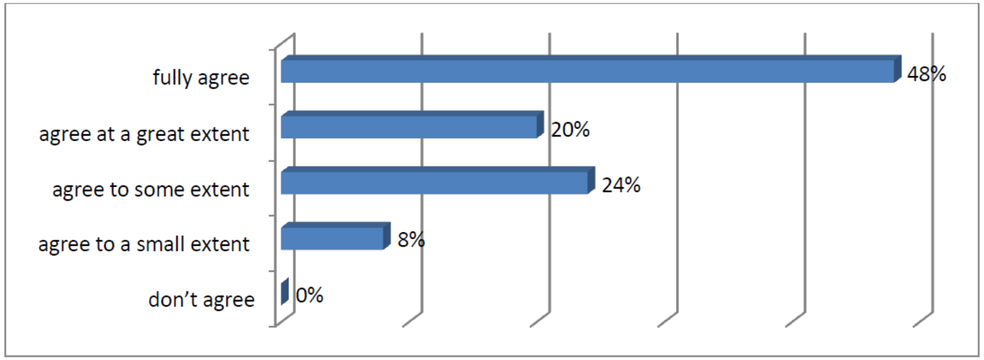

Figure 51. Full-scale PortCDM implementation will enable better access to reliable information

4.3.5 Summary Conclusion

Overall, the validation results clearly showed that:

- ***the PortCDM concept and digital data sharing provide significant positive benefits by enabling port-call actors to plan, coordinate and synchronize activities more efficiently giving rise to enhanced and more efficient overall port-call performance; and***
- ***the basic doctrine, procedures and standards have reached such a level of maturity that they can be used as the foundation for a global implementation of PortCDM.***

4.4 Achievements and Roadmap for Bringing PortCDM to the Maritime Sector

The enabling components required for a sustainable transformation of existing port operations to a PortCDM operational environment are shown in figure 52. These components can be seen as the means for reaching the vision of appropriate data sharing and collaboration associated with port call operations.

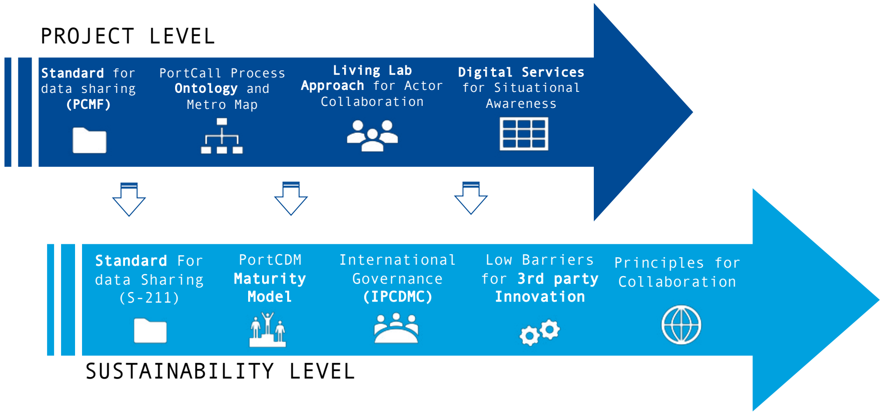

Figure 52. The enabling components validated in the test-beds that will bring PortCDM forward as a sustainable innovation

4.4.1 Collaboration Arenas

During the course of the project, it became evident that PortCDM could improve collaboration in four different arenas: the intra-port, port-to-port, ship-to-port, and port-to-hinterland collaboration arenas.

The validation efforts have hitherto focused on the intra-port collaboration arena, the port-to-port collaboration arena, and the ship-to-port collaboration arena, where the focus was on qualitative analysis, backed up by quantitative statistics wherever possible.

However, even though the port-to-hinterland arena was not identified for consideration in the original project application, the challenges in this arena became evident and it was therefore considered. This was especially the case in the discussions regarding the finalizing of S-211, the Port Call Message Standard. The existing logistical standard, EPCIS, maintained by GS1 was collaboratively discussed especially in the working sessions of the International PortCDM Council (IPCDMC) and when reaching out to other initiatives, such as the Port Call Optimization Task Force, chaired by the Port of Rotterdam. These discussions highlighted that the inclusion of the port-to-hinterland collaboration arena surrounding EPCIS could generate a substantial benefit for the actors implementing PortCDM. Accordingly, S211 was enhanced to allow data integration with data sets delivered in EPCIS.

It was evident that PortCDM could improve collaboration in four different arenas: the intra port, port-to-port, ship-to-port, and port-to-hinterland collaboration arenas.

4.4.2 Foundations for the Global Implementation of PortCDM

Several important foundations for the global implementation of PortCDM were laid during the validation process:

4.4.2.1 Internationally Recognized Message Format for Sharing Time-tamps Related to Port-call Operations

As described earlier in this report, the S-211 PCMF was developed, enhanced and eventually submitted for international recognition as a data-exchange format.

4.4.2.2 Establishment of an International PortCDM Council

In order to ensure that, once validated, it would become a sustainable concept, the International PortCDM Council (IPCDMC) was established.

The IPCDMC develops and agrees common procedures, standards, data formats, guidelines and guiding principles for the successful implementation of collaboration and data-sharing principles at the regional and local level.

The constitution of the IPCDMC ensures that its members are representative of all those actors involved in PortCDM across the world. By early 2019 the IPCDMC had members and observers from international organizations, flag states, maritime authorities, major ports, large shipping companies and terminal operators from around the world. A complete list of current members is available at www.ipcdmc.org.

4.4.2.3 Refinement of the Concept

The concept was progressively refined and improved as a result of the continuous feedback and monitoring that took place throughout the STM Validation Project. The living lab approach was particularly useful in engaging the various stakeholders in port calls, which, in turn enabled their practical experience and insight to be considered in the fine-tuning of the concept as it was being validated.

4.4.2.4 Incremental Implementation and Maturity Model

Feedback and experience during the STM Validation Project indicated that PortCDM must be implemented locally in such a way as to provide optimal information related to port specifics, such as the designation of locations and relevant services. Every port has to consider its specific conditions and circumstances and how data sharing and enhanced procedures of collaboration can best be implemented. Depending upon a port's characteristics and the attitudes and capabilities of each of its actors, implementation strategies may vary. There is a great difference in operations and scale depending on whether a port is managing 40,000 port calls per year or only three per week. For this reason, seven levels of maturity have been defined that characterize both the range and the maturity of a PortCDM implementation.

The seven maturity levels (see figure 53) have specific requirements related to the achievement of each level. Not all ports, particularly smaller ones, will need or wish to rise to the highest maturity level, but most should be aiming towards the higher levels, which brings with it increasing levels of coordination, synchronization and efficiency. Progression moves through the levels from the foundational capabilities (level 1 and 2) to the use of digital instant message-sharing among all port-call actors (level 3-5), to the continuous improvement enhancing effectiveness and also competitiveness of a port (level 6 and 7).

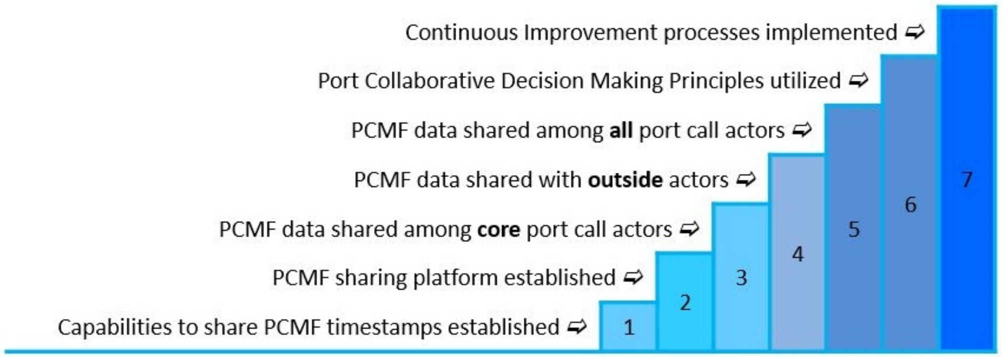

Figure 53. The seven-step maturity framework

At entry level 1, S-211 - the PCMF, is being used as the mechanism for the submission and consumption of time-stamps for port call coordination using standardized interfaces. This level provides the basic capability for exchanging data with external actors, such as ships, shipping companies, and fleet-operation centres that are fundamental to the coordination of a port call. At level 7, all aspects of the concept are being embraced, all activities in the port are synchronized, and PortCDM KPIs as well as locally defined KPIs are being used to measure and continually improve port-call operations through innovation.

4.4.2.5 Data-exchange Infrastructure for Lowering the Barriers for Third-party Innovation

A number of mobile and desktop applications were developed as demonstrators to enable project participants to successfully input, access and share data during the focus months (See Figure 54). The underlying PortCDM API's and the data-sharing test-bed capability could now be used as the building blocks for low-cost third-party implementation of the concept.

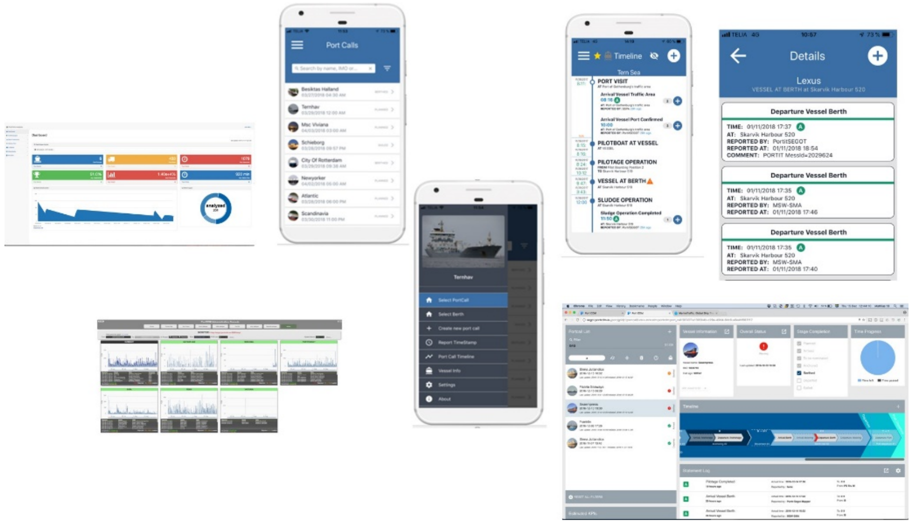

Figure 54. Illustrations of APPs and API's developed during the project in order to lower the barriers for third party innovators

4.4.2.6 The Creation of International Awareness of PortCDM

Maritime stakeholders worldwide have shown substantial interest in PortCDM, awareness of its potential benefits is high, and there is a general interest in adopting the concepts. Accordingly, a large number of service providers are now in a position to provide components to the growing PortCDM community.

A key strategy to increasing visibility and awareness among maritime actors has been the use of the technical press and social media. So far, the authors of this report have been engaged in publishing twenty-two *concept notes* on the STM and Fathom World websites. These notes, each between eight and ten pages in length, explain diverse aspects of PortCDM and STM to different market segments and actors in the maritime sector.

The concept notes were also published and promoted through social media as well as in technical and industry journals and publications - both as printed versions and online. This regularly gathered five-digit readership numbers.

The various postings and publications resulted in regular feedback, new connections and interest from other market sectors, such as logistics.

Other articles on the topic were published in various journals. Examples included the journal of The United Nations Conference on Trade and Development (UNCTAD) and a cover story in *Seaways*, the journal of The Nautical Institute.

4.4.3. Specific Business Benefits and Effects for Different Actors

A major aspect of the Nordic and Mediterranean test-beds was to obtain an evaluation from the different actors and stakeholders. The significant beneficial effects are identified in the table below:

For shipping companies /ships • saved bunker due to just-in-time arrivals • saved bunker due to just-in-time departures avoiding chasing the time window at the next leg • fleet optimization and saved bunker due to shorter turn-around-times	**For shipping agents** • enhanced basis for planning and easier coordination of port call operations • less time spent on chasing different actors, more time for other services to the ships
For terminal operators • enhanced possibilities for berth management • enhanced capacity utilization (resources and infrastructure) • better planning horizons for approaches to be served	**For VTS operators** • possibilities to digitally log entrance and departures. • better coordination of ship movements. • increased capability to synchronize the traffic dependent on the status in the port
For port authorities • safe and efficient port approaches • long and short-term overview of port visits	**For port control / pilot planning, tug operators, mooring companies, and service providers** • enhanced basis for planning • optimised capacity utilization • enhanced capacity utilization (resources and infrastructure)
For hinterland operators • enhanced capacity utilization (resources and infrastructure) • better planning horizons for loading / offloading at ports • enhanced predictability	**For digital service providers** • low entry barriers to provide digital innovations • enhanced capabilities in existing systems by being connected to the "outside"

Maritime stakeholders all over the world have shown substantial interest in PortCDM, awareness of its potential benefits is high, and there is a general interest in adopting the concept.

4.5 Next Steps

The full benefits of PortCDM will only become available when all parts of the maritime transport chain become inter-connected and collaborates in the four collaboration arenas – intra-port, port-to-port, ship-to-port, and port-to-hinterland. This is an absolute necessity in order to obtain the benefits of the Sea Traffic Management concept as a whole - of which PortCDM is one enabling element.

The PortCDM concept has now been validated. At the core is the sharing of time-stamps enabling each actor to optimize their planning. The key elements for implementation are now proven and available:

- The standardized data-exchange message format, S-211.
- The maturity model providing for incremental implementation.
- Low barriers for third-party developers of digitization technology, and
- the principles for collaboration, including the use of living labs and *metro maps.*
- The international governance structure (IPCDMC).

The full, operational implementation of PortCDM for all stakeholders can now begin. In fact, some ports are already doing so, based on their positive experiences during the validation efforts.

For example, within the EfficientFlow project, involving the Swedish port of Gävle and the Finnish port of Rauma, the implementation of STM in the daily operations of the ports is initiated. Also within the STEAM project on Cyprus and the port of Limassol, STM is taken from theory into practice.

As implementation proceeds, there will be a need to capture any concerns as they are raised during the industrial and governmental uptake. However, given that the test-beds centred on real operations and scenarios, it is anticipated that many, if not most, of the potential concerns have already been raised and considered.

The sharing of best practices, the emergence of a PortCDM community, as well as the accreditation of ports reaching different levels of maturity and certification of digital services that could be claimed as PortCDM compliant will all be important aspects of implementation.

The validation effort pursued within the STM Validation Project has provided insights on the need for richer empirical data for gaining an even better understanding of the value of PortCDM. This is something that should now be done in parallel with the implementation by different stakeholders throughout the world as well as the ongoing work of the International PortCDM Council.

For those actors that now wish to adopt PortCDM, the next practical steps are:

- ensure that the digital data-reporting mechanisms being used in their business are interoperable with the S-211 data exchange format.
- discuss the mutual benefits of PortCDM with their direct collaboration partners and other actors in their locality.
- discuss the mutual benefits of PortCDM with the other actors in their profession and business.
- help to establish a local "PortCDM community" to bring all the interested actors together.
- participate in the IPCDMC either as a participant or an observer.

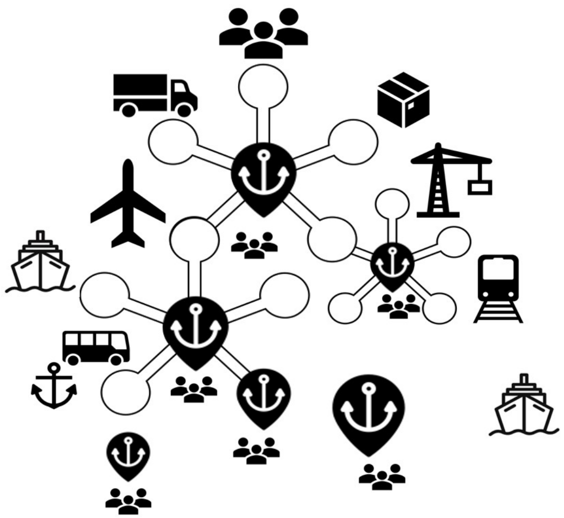

Figure 55. The data sharing, collaborative, synchronized vision for PortCDM

5. A Common Digital Infrastructure as Enabler for Digitization of the Maritime Industry

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Within the STM Validation Project, a vendor independent maritime digital service infrastructure has been created, enabling seamless interoperability between different systems (ship systems, VTS systems and other). The architecture allows for an ecosystem of systems and services to communicate seamlessly machine-to-machine without human intervention, where this is not desirable.

The agreed solutions in the eco-system, in the project denoted Maritime Digital Infrastructure, include cyber security measures and enable episodic tight-coupling between maritime actors for example ship-shore communication between systems from different manufacturers. Given that a ship, VTS center or a port system supports the same standardized artefacts, Application Programming Interfaces (APIs), data formats and common authentication mechanism, they can exchange information seamlessly.

STM is built on a service-based-architecture that is based on a common digital infrastructure, which in turn is based on international standards. The operational services in STM are developed and delivered by different service providers and will be presented in this section. All services in STM need to be registered in the Maritime Service Registry and all users need to be registered in the Maritime Identity Registry for secure and trustworthy authentication. These registers are part of the Maritime Connectivity Platform

A standard for the transfer of S-100 products, based on the Voyage Information Service (VIS) is being proposed as a new work item for IEC. The VIS is the generic information service/standard Application Programming Interface (API) that provides a standard interface for exchange of routes/voyage plans. The VIS service interface is used by all actors in the testbed with positive effects on interoperability and the lowering of thresholds thereof.

Some of the leading manufacturers of systems (SAAB, Wärtsilä/Transas/SAM, Airbus, Kongsberg, Furuno and others) have within the STM Validation Project updated their systems to allow interoperability in the information exchange ship-to-ship and ship-to-shore.

The information exchanged in the testbed includes voyage plans, navigational warnings, port call messages and text messages. In addition, route messages – a segment of a ship's monitored route – which are sent on AIS as Binary Broadcast Messages (BBM) to other ships within AIS range. This information exchange has been used to digitalize and distribute already existing maritime services by new means in order to facilitate service discoverability, consumption and visualization for concerned stakeholders.

Sharing a ships' voyage plans has proven to be useful in many different operational services e.g. Pilot Route Service, Winter Navigation Service and Baltic Navigational Warning Service. In their turn these operational services support several of the identified maritime services, which are by IMO as the means of providing electronic information in a harmonized way.

IALA's Service Guideline G1128 for maritime services has been implemented in the service ecosystem within STM and has proved to create vendor independent interoperable information exchange of voyage plans, navigational warnings, port call messages and text messages. The service interface documentation can serve as an input for standardizing APIs to facilitate implementation of services based on standardized payloads as defined by IHO/IEC product specifications. Furthermore, it could act as a best practice for the future development of maritime services within e-navigation.

Further standardization, updates of relevant international regulations and industry buy-in are important aspects to pave the way for even broader market adoption and reach large-scale implementation.

In the STM Validation Project, leading system suppliers of on board navigation systems such as ECDIS, Ship Traffic Service (VTS) systems, maritime service providers and authorities have joined forces to achieve interoperability in the exchange of ships' voyage plans, time-stamps such as estimated times of arrival to ports and navigational warnings, – based on core services such as the common digital infrastructure SeaSWIM.

It provides solutions such as a global digital identity of users, ships or systems, which is a serious bottleneck in starting a digital maritime revolution across different companies and individuals. Just as human-to-human communication on a global scale would be impossible without global, unique telephone numbers or email addresses.

As one of the strategic enablers of STM, SeaSWIM was tested and evaluated in the STM Validation Project during 2015-2019 as core infrastructure to demonstrate the STM concept in large-scale test-beds in both the Baltic and Mediterranean Sea. Based on this, we make recommendations on how to mature the common digital infrastructure, by e.g. strengthening governance, commercializing SeaSWIM, further investments in security-related issues as well as the further development of SeaSWIM components.

5.1 SeaSWIM as Enabler for Digitization of the Maritime Industry

Sea Traffic Management connects and updates the maritime world in real time with efficient information exchange – based on the maritime digital infrastructure SeaSWIM (Figure 10). Through data exchange among selected parties such as ships, service providers and shipping companies, STM is creating

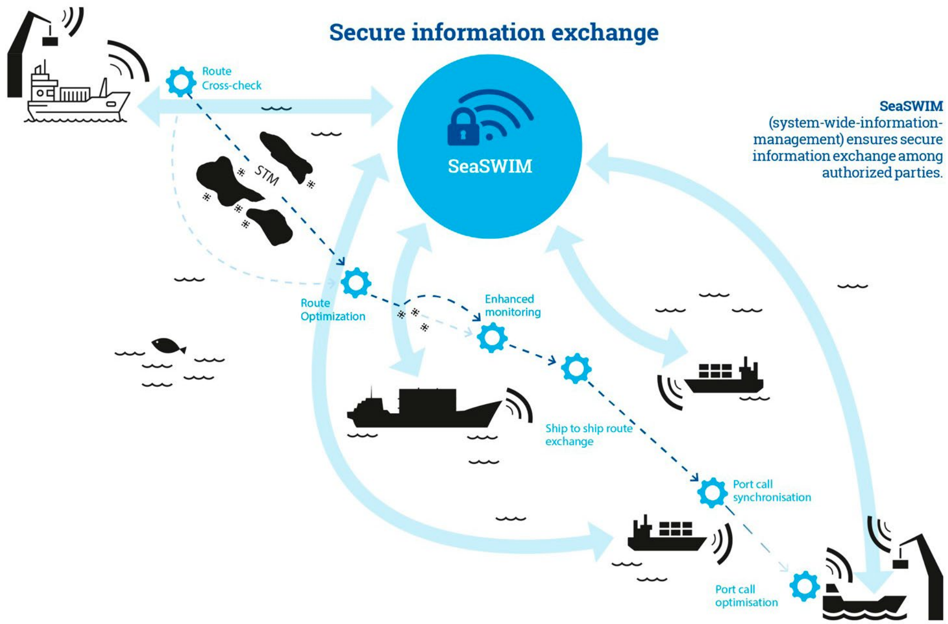

Figure 10. Services on a ship's voyage

a new paradigm for maritime information sharing, offering tomorrow´s digital infrastructure for shipping. Maritime information can be shared in a unified way across organizational boundaries. To allow interoperability and enable communication in STM, we ensured that the entry barriers to developing, producing and consuming data and information in the SeaSWIM environment should be as low as possible, but yet secure. The SeaSWIM services were implemented for this purpose – either to assist developers by instantiating generic functionality that is needed by most services in the SeaSWIM/MCP environment, or by providing standardized interfaces or reference services according to the SeaSWIM specification.

The scope of the solution is to allow for machine-to-machine interoperability. This means that information exchanges are strictly defined and enable a previously unknown system to receive and use information. Just like two strangers who are able to understand one another through a shared language.

5.2 Procedures and Principles of the Common Digital Infrastructure, SeaSWIM

The underlying procedures and principles of SeaSWIM were established in order to enable interoperability, communication and information exchange between, e.g. system suppliers of on board navigation systems, VTS systems and maritime service providers as well as authorities. The maritime service infrastructure is composed of various components, summarized under the abbreviation SeaSWIM. All STM users should know the procedures and principles of the SeaSWIM components. These components are as follows:

Maritime Connectivity Platform (MCP)

- Common identities are handled by the **Maritime Identity Registry as part of the Maritime Connectivity Platform (MCP)**, which provides tokens for human interaction and certificates for machine-to-machine exchange. The Identity Registry can be compared to a Central Person Registry or a Central Business Registry for STM service providers and users.

- The **Maritime Service Registry as part of the Maritime Connectivity Platform (MCP)** provides guidance on how to specify and register services and supports the discovery of services. It can be described as a sophisticated yellow pages phone book that includes all STM services.

SeaSWIM Connector (SSC)

- In order to comply with STM, you can download the **SeaSWIM Connector – a SeaSWIM service,** use this as reference to start communicating.

Technical Compliance Checker (TCC)

- If you are still unsure regarding STM compliance, use the **Technical Compliance Checker – a SeaSWIM service**, to ensure you are on the right track.

STM identifiers

- The elaboration of identifiers in STM as basis for SeaSWIM compliant information exchange fulfils the need for a unified and unambiguous reference to a specific voyage and to a port call.

5.2.1 Registering Identities and Services in the Maritime Connectivity Platform

The MCP, or Maritime Connectivity Platform, has been defined as "a communication framework enabling efficient, secure, reliable and seamless electronic information exchange among all authorized maritime stakeholders across available communication systems", matching the goals of the EU e-maritime initiative and the IMO e-navigation strategy. STM uses two core MCP components: Identity Registry and Service Registry (https://maritimeconnectivity.net/).

The main purpose of the Identity Registry is to securely provide reliable identity information. It provides a single login mechanism to all services. It can be compared to a Central Person Registry or a Central Business Registry. The Identity Registry contains relevant information to authorize stakeholders and enable confidentiality in information-transfer processes. The aim is that all services depend on unique identifiers that, for example, define specific users, services and transferred data objects to avoid misunderstandings.

The Service Registry contains information about the services and is the main source of service information for developers, providers and consumers of services. The Service Registry can be viewed as a sophisticated yellow pages phone book or the equivalent of an App Store that can be run on different platforms. The aim is to make it convenient for service providers to register a service and for service users to readily discover and use a maritime service. Thus, the Service Registry provides functionality to publish and find services, in addition to their functionality and endpoints.

Access to the MCP includes gaining access to the Identity Registry (IR) and Service Registry (SR) and enables the issuance of certificates. In addition, another component called Almanac serves as an offline version of parts of the Service and Identity Registry, to be used – if no radio coverage is available – to establish a stable internet connection for accessing the online versions of SR and IR and thus to always have access to the most relevant information during a journey. The offline copy will be synchronized if an internet connection with sufficient bandwidth is available.

5.2.2 Access to MCP

From a service provider perspective, the MCP can be seen as the basis for an eco-system of maritime services that are deployed at several platforms and on board-equipment. As a service consumer, once registered you have access to a wide range of maritime services, currently including route optimization, route crosscheck, port call synchronization/optimization, winter navigation, etc.

Service Registry and Identity Registry provide their own interfaces, i.e. REST and SOAP APIs, and data formats to communicate with any kind of MCP services or with a ship-side Maritime Connectivity Platform component. The interfaces enable publishing and searching for services, as well as publishing and retrieving related service documentation. Its primary function is to offer a curated, geo-searchable list of services, particularly their endpoints as well as their documentation.

Services have to be defined in a structured way.

1) Starting with the service specification, where the services are described from an operational point of view. Then,

2) the technical design details the implementation of such a specification, without including the actual service endpoint address. And finally,

3) the actual running service instance(s) are described separately, with a reference to the technical design they are implementing, which itself points to the service specification.

5.2.3 Registering Identities

To allow all users to use the MCP, their organizations need to be registered in the Identity Registry first. An organization is an entity, such as an institution, company or an association, that has a collective goal and is linked to an external environment. Examples include international organizations such as IMO, IALA, or IHO, national authorities such as US Coastguard, Swedish Maritime Administration, local authorities such as Sound VTS, Port of Rotterdam, Hong Kong SAR, or commercial companies such as Wärtsilä or Maris.

For registration with the Identity Registry as a STM test-bed user, the MCP governing body validates the organization. This ensures that only validated and trusted organizations get access to the MCP. The process is currently manual, although it is planned to change this by 2019. However, one possible solution would be for the maritime authorities with whom a particular organization is registered to put the stamp of approval on the signup application. Please refer to the Online Documentation for the procedure to register an organization, its users and/or any ships of the organization.

A Maritime Resource Name (mrn) is generated for each organization. IALA is hosting the mrn Registry: "Maritime Resource Names (mrn) is a naming scheme that can uniquely identify any maritime resource on a global scale. This makes it possible to identify organizations on a global scale, which can be compared to global, unique telephone numbers or email addresses for organizations. Assignment of Organization IDs are mainly reserved for maritime standards development organizations, research projects, scientific societies, and similar bodies. However, anyone can apply, and each application is evaluated on a case-by-case basis by the IALA secretary. For more details, and on how to manage namespaces within organizations, see IALA Maritime Resource Name.

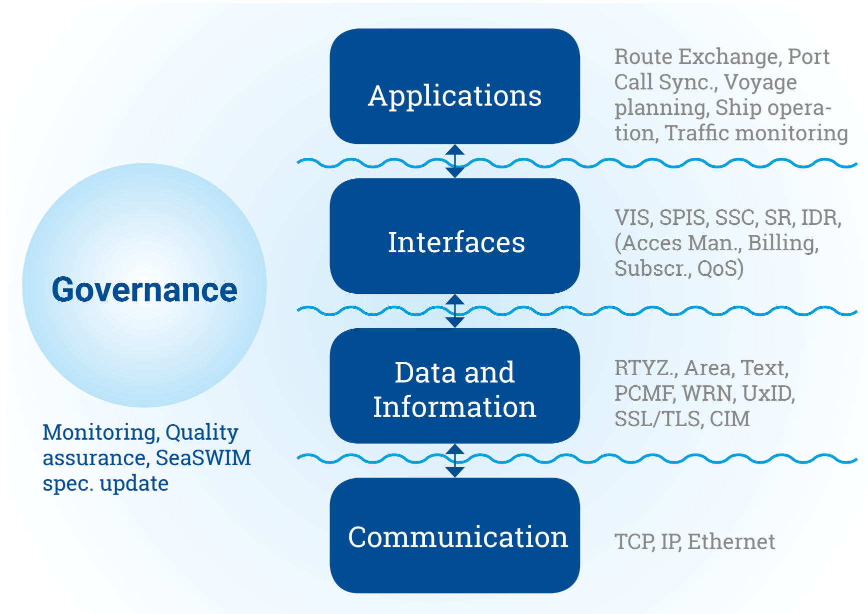

Figure 56. To enable interoperability standards were set for data and information exchange as well as for interfaces

The STM Validation Project applies mrn methodology also to validate the concepts of Unique Voyage ID and Unique Port Call ID in the maritime context. In the testbeds, it is applied to identification of ships voyages with the Unique Voyage Identifier (UVID) and Port Calls by the Unique Port Call Identifier (UPCID). It uses mrn syntax as described in IALA MRN Registry.

5.2.4 Certificates

Certificates are required for STM service providers and STM service consumers. A certificate can be obtained.to use MCP identities in machine-to-machine communication. Certificates can be issued for 5 different entities that may be registered in the MCP: User, Device, Ship, Organization, and Service.

> Please **refer to the** Online Documentation regarding which attributes are provided in the certificate for each entity type.

5.2.5 Registering and Consuming Services

A service can be published in MCP by using the MCP Management Portal. This is done essentially by uploading the service documentation file and service XML file. As previously described, a service features three levels; Specification, Technical Design and Instance. The IALA guideline on specification of e-navigation technical services specifies a structured way of defining services. The foundation is the service specification, which describes what a service is about in an operational context. The technical design on the other hand details the implementation of such a specification, without including the actual service endpoint address. Running service instance(s) are described separately, with a reference to the technical design they are implementing, which itself points to the service specification.

Considering that the Service Registry may be used either by humans or machines, the Service Registry offers two approaches to discovering services, a manual discovery for human users and a machine-to-machine discovery process. The main difference between the manual and the automatic service discovery process is the need to receive unique answers from the service registry in case of automatic discovery. This is achieved through a "spatial exclusive" flag. For this service specification there is only one combination of service specification and technical design, valid within a defined area/location.

The Maritime Service Registry is not involved in the actual service usage itself, i.e. it does not store services but connects you further to the favoured service. It provides endpoint URI information to services based on a variety of search attributes.

5.3 Services for Communication and Compliance

Both, SeaSWIM Connector (SSC) and Technical Compliance Checker (TCC) are software components/reference services providing generic functionality that is needed by most services in STM using the SeaSWIM environment.

The SeaSWIM Connector/SSC is a software component that enables the use of the Identity and Service Registry of the Maritime Connectivity Platform. The SSC acts as an intermediary to facilitate communication between services. To achieve the inclusive scope of the SeaSWIM environment, entry barriers to developing, producing and consuming data and information in the environment should be as low as possible. The SeaSWIM Connector is implemented for this purpose – to assist developers by instantiating the generic functionality required in the SeaSWIM environment. It is provided as a reference service in STM according to the SeaSWIM specification.

To simplify the run time connection with the SeaSWIM environment, SSC handles the interaction with the core infrastructure services IR and SR. It can be described as a standardized interface to the more generic MCP registers. The SSC is described in further detail in the technical design/service specification document (SSC specification).

To achieve the inclusive scope of the SeaSWIM environment, entry barriers to develop, produce and consume data and information in the environment should be as low as possible. The SeaSWIM Connector is implemented for this purpose - to assist developers by instantiating generic functionality needed in the SeaSWIM environment.

The use of the SSC technical specification and core functionality is mandatory, which ensures all partners have a compliant procedure to communicate via the digital infrastructure and to achieve interoperability. Any stakeholder is free to develop its own equivalent version/implementation if it follows the SeaSWIM technical specification (SSC specification).

As the SSC is designed to facilitate communication between services, it calls a generic web service part of the STM infrastructure, checking the certificate authentications. The SSC also enables communication with the Identity Registry to discover that the organization is part of the STM infrastructure.

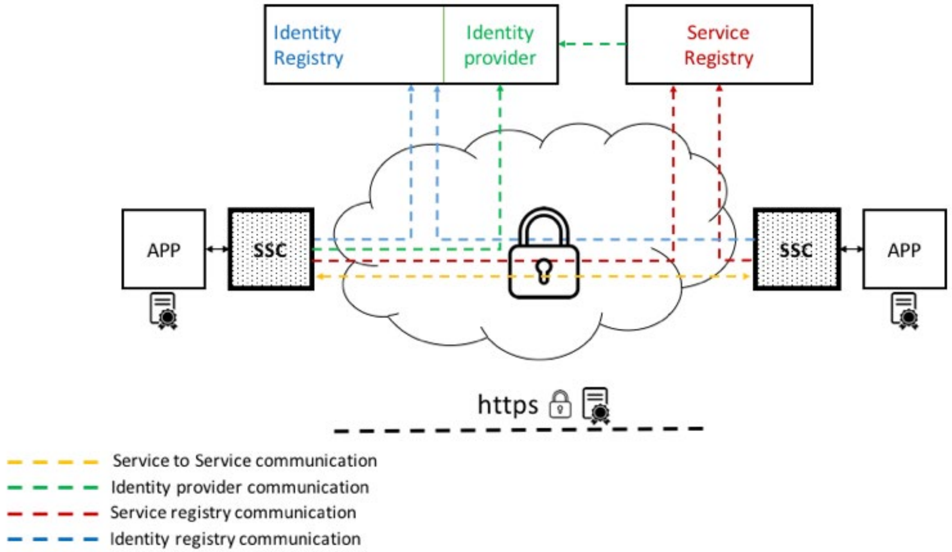

Figure 57. SeaSWIM Connector functionalities

Finally, the SSC handles communication with the Service Registry service in order to discover services within the STM infrastructure. This means, that the SSC support service intercepts the incoming service request, handles authentication and – if the source is authenticated – forwards the service call to the "master" service endpoint. Authentication and encryption (SSL/TLS) are added to all outgoing messages and checked on all incoming messages.

SSC reference implementation is a software service component that works like a proxy web server, i.e. listens on a configurable port and intercepts the incoming calls. The SSC proxy is hosted both by the providing and consuming application service (Figure 57). This way the SSC or its equivalent supports communication in line with the STM principles, with minimal development and implementation efforts.

The SeaSwim Connector can also be integrated as a function library that manages the functions implemented in the reference implementation as a proxy. By this means, a parent service that works over the SSC, such as a Voyage Information Service, can be implemented in an integrated and simpler way.

Standards have been defined for STM and the EfficienSea2 partner project (c.f.), for example how a service must be documented and implemented in order to be part of the SeaSWIM environment. To support service providers in complying with these standards while developing, providing or refining services, the Technical Compliance Checker, TCC, has been developed as a reference implementation. The TCC can help in answering questions regarding compliance such as: Does the service description document follow the right template in a correct way? Are all relevant description documents for one concrete service available? By way of analogy, the TCC checks that you have written your cooking recipe correctly and completely to permit you to join the STM kitchen.

The TCC is implemented as a service within the Service Registry itself. It checks the services within the SR according to the defined guidelines and assists developers with the registration and creation of compliant/legal documents.

In brief, the following checks were realized in the TCC:

1. Check existence of all necessary files, such as service specification, technical design and service instance as XML and PDF documents as well as additional documentation.

2. Check XML schema when uploaded to the Service Registry, validate against the latest schema in the SR.

3. Check status (provisional, released, simulated, deprecated or deleted).

4. Check if PDF documentation includes the corresponding XML file content.

5. Check if identification table matches the PDF and XML file, i.e. information for identification, mrn, name of service, version number, contact information.

6. Check if OpenAPI definition/description in the technical Design conforms with the standard.

7. ContactInfo contains email address.

The TCC is hosted by OFFIS e.V. and available for test purposes via (TCC):

- Web-App: http://tcc.offis.de:8080/

5.4 STM Identifiers

As noted earlier, we lack global digital identities for maritime organizations, ships and systems, which is a serious bottleneck in starting a digital maritime revolution across numerous companies and individuals. The need for a unified and unambiguous reference to a specific voyage and to a port call was recognized during the requirements analysis of the digital infrastructure for STM and the SeaSWIM compliance information exchange. Unique identifiers based on standards are needed to ensure effective and STM-compliant information sharing as well as a seamless information exchange among different actors, thereby ensuring interoperability and security,. Existing standards and actual achievements in the maritime domain have been elaborated, further developed and considered during the conception of the STM identifiers. The STM identifiers are called Unique Voyage Identifier (UVID) and Unique Port Call Identifier (UPCID).

The unique voyage identifier (UVID) should:

- compile all information related to a voyage without explicit reference to other systems
- do so during its entire lifecycle
- enable efficient and SeaSWIM-compliant information exchange among various actors at different stages of a voyage

The unique port call identifier (UPCID) should:

- sort and uniquely identify the relevant data for a port call
- identify uniquely each visit of a ship
- guarantee interoperability
- enable efficient information exchange among many port actors

Uniform Resource Names (URNs) as defined by the IETF (Internet Engineering Task Force) are intended to serve as persistent, location-independent, resource identifiers, and are designed to make it easy to map other namespaces (which share the properties of URNs) into URN space. Therefore, the URN syntax provides a means to encode character data in a form that can be sent in existing protocols (like ASCII), transcribed on most keyboards, etc. The URN syntax provides a mechanism to ensure the uniqueness of the name of a resource, which is already widely used in different domains such as supply chain management and unique identification of books or laws.

The working group on identifiers has contributed to the introduction of the Maritime Resource Name (mrn) approach based on the Uniform Resource Name (urn) approach (Klensin 2017). Among others, this approach is used for the syntax of the UVID and UPCID. Various possibilities for the syntax and structure have been elaborated in order to come up with an identifier syntax and semantic that can be used by the entire maritime transportation chain, and complies with the main principles of STM and its technical infrastructure.

The primary function of the namespace hierarchy is to distribute management of namespaces. An organization managing a particular namespace (such as an STM governance body for the namespace urn:mrn:stm) may thereby issue sub-namespaces and delegate management of such to other organizations, for example urn:mrn:stm:org:sma as a namespace to be managed by the Swedish Maritime Administration.

Based on these design principles, the following syntax has been designed and is used for the UVID in the STM Validation Project: ***urn:mrn:stm:voyage:id:<org>:<id>***
Example: ***urn:mrn:stm:voyage:id:sma:34678901234***

The organization ID is organized as follows: *urn:mrn:stm:org:<short org name>*
Example: ***urn:mrn:stm:org:sma***

The format of the UPCID follows the proposed mrn standard and is described in more detail in STM Validation Act1: PCMF: urn:x-mrn:stm:portcdm:port_call

During the conception phase and analysis of existing standard, the precision of UN/LOCODE for UPCID for the unambiguous identification of a port was discussed. Maybe GLN (Global Location Number) with 13 numerical digits could be an alternative. GLN can, for example, identify a port, an organization, a berth, a waterway, or a computer that sends/receives transmissions, etc.

For the test-bed, the voyage was defined as the scheduled route between a given start and a destination point. A route itself does not have a time component. It consists only of waypoints. The direct geographical distance between two waypoints is called route segment. Therefore, the difference between, route segment, route and voyage are given.

Figure 58. Screenshot of procedure for registering a new service in the MCP Management Portal

One of the open issues to be taken into consideration for the future is the official registration of the namespace urn:mrn:stm in the mrn registry. This step is considered a crucial one for the establishment of STM in the future, and creates a reference point for further technical and nontechnical (government and management of STM) developments.

In the future, it should be possible to create a UVID in the strategic phase of a voyage, that is, without knowing the first port and the next ones. Preferably other information regarding crew and cargo could be matched and recognized with the UVID. The UPCID should be automatically connected to the UVID. There exists no data source for the creation of a port call. Looking ahead, the UVID from a ship approaching a port should be used as a trigger for generating a port call and beginning with the port operations. A clearer and more precise definition for a voyage should enable these connections. Furthermore, during the STM concept validation, a number of challenges emerged that may be solved by answering the question: Who is the owner of the UVID?

5.5 Recommendations Regarding Infrastructure Enlargement

In joint workshops and talks with project partners, including service providers, the most important functionalities of the common digital infrastructure SeaSWIM were defined. Yet, throughout the integration and validation phases, the original list of functionalities was continuously discussed and recommendations as well as open issues regarding SeaSWIM functionalities were defined.

The functionalities directly involved with the operational test-bed were implemented and are described in the report STMVal_D4.19 Procedures & Principles SeaSWIM

So far, the digital service infrastructure provides standardized interfaces or reference services according to the SeaSWIM specification. However, standardization is a constantly ongoing and iterative process in which new input needs to be managed in a collaborative manner, gaining and re-gaining support from system suppliers and other stakeholders. When looking at the principles and procedures of MCP, SSC and TCC as well as STM identifiers, we also see a need for a continuous process of adopting, maintaining and further developing these principles and procedures of SeaSWIM in order to achieve a *common* digital maritime infrastructure. Basically, the STM Validation Project laid the foundations for this and needs to be further developed through the joint efforts of interest groups and industry initiatives. The following list of most important recommendations and open issues serves as an input for future work on the digital maritime infrastructure.

5.5.1 Establishment of Governance Structure for Future Development and Business

The current alignment efforts are an important start for future development and business for STM and the digital maritime infrastructure. On the one hand, there is the formation/establishment of an MCP governance structure, currently called MCC. On the other hand, the ongoing creation of an industry cluster offers major potential to integrate the common maritime digital infrastructure in current operations and take it into production with agreed Service Level Agreements. Already, the distinct interest from such a broad industry group indicates that SeaSWIM and the STM services have identified a significant need. However, it is important that this initiative is supported in parallel by new projects that continue the development of STM in new directions. This will ensure that the common infrastructure remains relevant and continues to challenge the maritime industry.

5.5.2 Transform SeaSWIM to Business Ecosystem

Commercializing SeaSWIM is regarded as one of the key success factors. However, much is still unknown of users' real needs of the SeaSWIM framework. Since users are paid to use the project artefacts, it is difficult to derive their incentives and intentions for using SeaSWIM after the STM project as it is currently implemented. Actively promoting and understanding the needs of potential users outside the STM Validation Project will be critical in ensuring that SeaSWIM provides commercial value. In STMVal_D4.19, we reflect on the future business strategies for the digital infrastructure of STM on a higher level and identify two potential business models for STM; namely, the matchmaking and the multi-sided models.

5.5.3 Focus on Vulnerabilities and Security-related Issues

During integration testing and discussions with commercial end-users of the STM infrastructure, a number of security concerns were raised, in addition to the currently implemented security mechanisms of the SeaSWIM/MCP prototype. STMVal_D4.19 gives an overlook of the security issues, such as encryption, authentication, access management, accounting and auditing, support, certificates and governance.

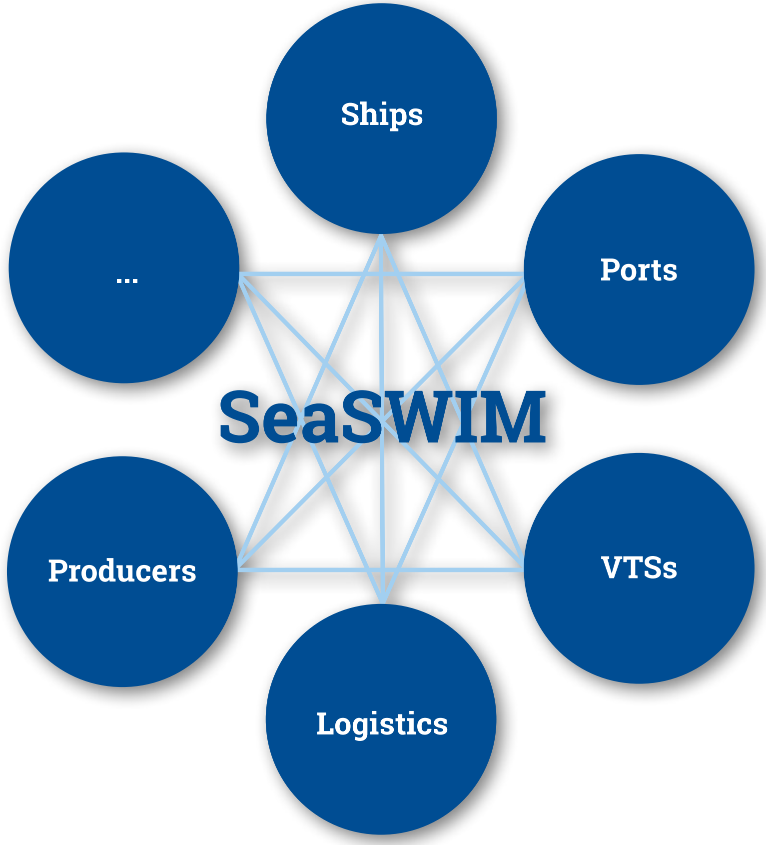

Figure 59. SeaSWIM as a common digital infrastructure enabling interoperability, secure communication and information exchange between various maritime actors

5.5.4 Define SLA for Monitoring, Reporting and Optimization of Performance

The Service Level Agreement (SLA), where the level of quality is defined/documented in, e.g. standard Key Performance Indicators (KPIs), could improve monitoring, reporting and optimization of performance. Quality of Service (QoS) could be realized as a service to monitor the quality of the other services, for example of the Service Registry in terms of average response time, availability, etc.

5.5.5 Iterative Refinement of SSC/TCC Requirements

Both reference services, SSC and TCC, proved useful in lowering entry barriers for users of SeaSWIM/MCP and STM in general to enable compliant implementation of services. Yet, a constantly ongoing and iterative process is needed for iterative refinement of requirements, concerning SSC, for example towards the following:

- How SSC should support access management/access list handling.
- How SSC should support encryption and signing of data (based on S-100).
- How SSC should perform authentication.

The TCC increases the quality of the Service Registry, which leads to increased trust throughout the infrastructure. The collaborative work on how to define compliance for STM/SeaSWIM/MCP was truly essential and should be continued. During the work on the second version of the TCC, the following input on further requirements was gathered, such as checks for security, for payload of a service, checks against naming conventions or automated API checking.

5.5.6 Refinement of STM Identifiers after Validation in Test-beds

During the test-bed operation, efforts were made to explore how to use the STM identifiers with some essential recommendations for further work:

- Official registration of the namespace urn:mrn:stm in the mrn registry for management and governance reasons.
- Make it possible to create a UVID in the strategic phase of a voyage, e.g. without knowing the first port and the subsequent ones.
- UPCID should be automatically connected to the UVID – e.g. use the UVID from a ship approaching a port as a trigger for generating a port call.
- More clear and precise definition of a voyage, e.g. further specification and division of a voyage into smaller and modular units.
- Clarify UVID creation and ownership.

6. STM Overall Impact Evaluation and European Added Value

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The mission of the Analysis and Evaluation (A&E) Activity within the framework of the STM Validation project has been to facilitate the validation of the STM concept, through the quantification of the benefits associated with STM implementation.

As described in the previous chapters of this report, the large-scale test-beds developed for the project have provided an abundance of valuable results. However, during the definition of the STM Validation Hypotheses, the berth-to-berth approach was pinpointed as the most interesting outlook in terms of efficiency and environmental sustainability. Thus, an ad-hoc study has been performed, with the aim of forecasting the potential benefits for the shipping industry, including ports, on the assumption that STM was implemented globally and just-in-time arrivals and departures were a reality.

As a main output for STM validation in academic terms, an ad-hoc study has been developed in order to obtain the potential benefits of port-call synchronization for the shipping industry. This was achieved by selecting some of the ships involved in the STM test-beds and analysing their AIS data during one year, in an effort to gain a representative view of their current behaviour and some of the apparent inefficiencies that could be mitigated by the use of STM tools. Hence, a simulation of the future impact of STM implementation was developed and a number of results obtained. The data sources and methodology for the AIS data-processing procedure are described below.

Finally, the results will be presented at a macro-level, using the results from the test-beds and inserting them in a database created for this purpose, which is represented by the world map screen and the Fundación Valenciaport Short Sea Shipping (VESSL) Database Logo, and the methodology is described in section 6.7.

6.1 Hypotheses Validation Model

The report describing the information environment created during the project is available in the information environment report, in which the range of methodologies used for the organization of the information expected to be collected during the course of the test-beds was defined. The report enumerated and described these hypotheses and outlined the expected benefits jointly with the different STM services to be developed within the project framework. The steps observed in constructing the Information Environment are depicted in Figure 60.

The first layer represents the review of the **STM Concept** and the basis of the need for building up such a system by defining the different STM concepts: Strategic Voyage Management, Dynamic Voyage Management, Flow Management, Port Collaborative Decision Making and Sea System-Wide-Information-Management.

In the second layer, the different **STM services** were defined with proper specifications for service providers/manufacturers. During this process, A&E was indirectly involved in order to gain understanding of the services and to determine which were the most relevant objectives in defining the hypotheses that could counteract the inadequacies in the maritime sector. These results complete the third layer of the Information Environment Structure: STM Validation Hypotheses Model.

In the framework of the project, several working groups were created and conformed by experts in the different areas upon which STM is expected to have positive impacts for the maritime industry: efficiency, safety and environmental sustainability. These working groups gathered participants with in-depth knowledge both of the services that the project would develop and of the maritime transport sector. The goal of these working groups was defining a series of key performance objectives and how they could be reached through the STM development. This joint effort resulted in a series of hypotheses describing potential changes that STM could generate in the maritime industry.

According to the deduced hypotheses and considering the data that could be extracted from the test-beds, the simulations, and the transversal issues such as legal, business, operational, safety and training aspects, the fourth layer of the information environment was defined as **Information Environment Sources**.

The fifth layer of the Information Environment Structure is entitled **Collection, Processing and Analysis of Data,** which explains the methodology for collecting the data from different sources to conduct analyses using various tools and show the results that can fulfil STM validation.

Figure 60. Information Environment Architecture

6.2 Use Case Selection

The "use-case" approach takes the hypotheses as the point of departure to validate from a quantitative point of view the assumptions stated in STM Validation Hypotheses. Performing a berth-to-berth analysis of the navigation of ships, as well as of their stay in port was selected by the project as one of the main aspects in the validation of STM benefits. This type of holistic analysis would best permit quantifying the potential benefits associated with the stated STM hypotheses by estimating the impact on fuel consumption, the primary operational cost in navigation and the related GHG emissions.

Regarding the methodology to select the ships for the analysis of the STM fleet, the criteria were as follows:

1. The analysis should be conducted using ships with STM bridge modules that allow real-time information sharing: ship-to-port, ship-to-ship, ship-to-shore and requesting assistance and information from service providers to make decisions en-route.

2. The ships should be selected from those historically calling at different PortCDM ports during a representative period of time, In particular, the analysis focused on the period June 2017 to May 2018. For this reason, those ships with a higher number of different PortCDM ports called or with a higher number of calls in those ports were prioritized.

3. Finally, the selected ships should frequently cross the areas of those shore centres included in the project, namely, Tarifa, Gothenburg, Kvitsoy and Horten, to maximize the number of interactions when navigating in their area of influence in order to evaluate the ship-to-shore services.

According to the extension of STM ships and the types of ships included in the STM fleet regular services category, ten use-cases have been selected with the aim of providing sufficient evidence about the quantitative effects that STM can introduce in these particular use-cases, through a detailed evaluation of the results obtained through the simulated models. The reasons for discarding the other types is related to one of the assumption made in the project that "Port call synchronization will lead to the use of optimal steaming according to prevailing circumstances". This synchronization implies the ability to, on the one hand, use real-time information and of, on the other hand, being able to offer or consume certain information, like accurate estimated times of arrival or departure (ETA/ETD), with a substantial anticipation.

Expected outcomes of this synchronization are that cruising speed are lower and have less variation, for instance, leading to a lower fuel consumption and emissions. In order to simulating these scenarios and being able to estimate the inefficiencies present in nowadays shipping, data that captures multiple repetition of the same route or leg, performed by the same or similar ships, is needed. This repetition allows capturing many aspects that Tramp services, which are usually organized according to market demand would not. This particularity makes them less valuable for this analysis, given that a ship may not be following any route in a regular basis and, hence, will not allow enough information the type of analysis pursued. Moreover, it may happen that we had repetitions but some changes in speed or other parameters were due to the commercial agreement, which is unknown in a general basis

Thus, the ten use cases showed in Table 4 have been selected with the aim of, through a detailed evaluation of the results obtained by the simulated models, providing sufficient evidence about the quantitative effects that STM can introduce in these particular use cases.

USE CASE No.	SHIP NAME	USE CASE No.	SHIP NAME
CS1	NJORD	PAX1	BIRKA STOCKHOLM
	PIRITA	RPX1	STENA GERMANICA
	ATLANTIC COAST		STENA SCANDINAVICA
CS2	E.R. PUSAN	RPX2	STAVANGERFJORD
	DIMITRIS Y		
	MSC GENEVA		BERGENSFJORD
	MSC CAROUGE	RPX3	VIKING AMORELLA
	MSC LAUSANNE		VIKING GABRIELLA
CS3	MSC ANTALYA	RO1	BALTIC BRIGHT
	MSC ARBATAX		POLARIS VG
	MSC CATERINA		LINK STAR
	MSC CHANNE	RO2	SCA OBBOLA
	MSC CLEA		SCA OSTRAND
	MSC JULIE		SCA ORTVIKEN
	MSC LETIZIA	RO3	BORE BANK
	MSC MICHELA		
	MSC SILVIA		

Table 4. List of ships in the Use Cases

6.3 Data Collection, Processing and Analysis

The goal of the current analysis relies on quantifying the potential benefits of introducing STM in the shipping industry. To do so, AIS data for 50 ships were purchased from Marine Traffic. These data refer to the period 1 June 2017 to 31 May 2018 and consist of more than 5.3 million registers. Note that these data did not include satellite AIS data.

Additionally, data from the PortCDM test-beds were consumed. The data from the PortCDM test-beds are very extensive and include many different types of information related to the different events occurring during a port call. These data span nine European ports and more than 43,000 port calls, mainly from 2018. From these data, in particular, we measured the efficiency as the time the ships spend at berth compared with the time used for (un)loading operations, for different types of ship and ports.

In order to perform the analysis, there is an initial processing of the AIS data, jointly with the addition of some extra data for each ship of interest. This extra data is inputted through **configuration files** to our algorithms. The entire process is described in the report "STM Validation Use-cases" and it is summarized in Figure 61.

Furthermore, a European Added Value evaluation will be carried out through an additional evaluation methodology that uses a specific database of European maritime routes and ports specifically built into the project framework. VESSL (Valenciaport European Short Sea Shipping Database - VESSL) is an ad-hoc tool where thousands of data metrics have been 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. VESSL features information about all the regular lines calling at any core and/or comprehensive port of the Trans-European Transport Network in the European Union, including the Norwegian ports incorporated in the STM validation project that has also been used to complete the analysis.

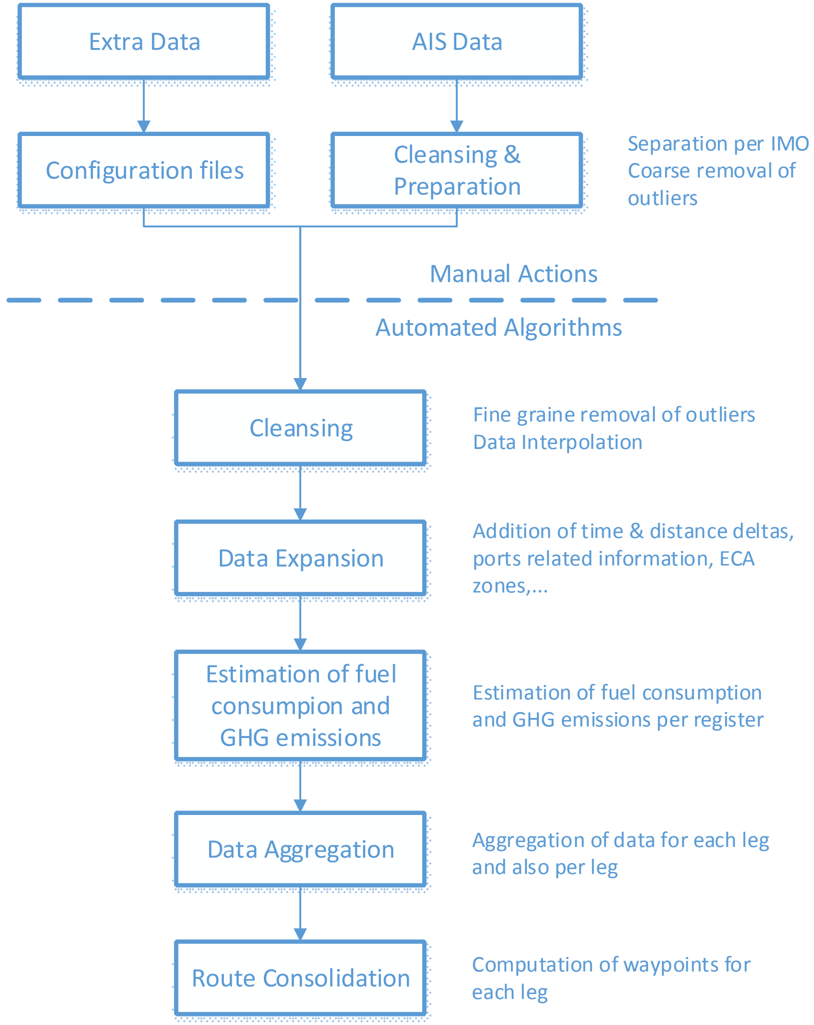


Figure 61. Overview of the processing applied to the data used in the analysis

The database will enable a wide-scale extrapolation of the results obtained through the use-cases analyses, thus offering a quantification of the potential effects of STM in terms of time savings, fuel consumption and emissions reduction at a European level, with all these aspects translated into financial figures (expressed in €).

6.4 Scenarios Simulation Methodology

Taking into account the varying levels of maturity of the systems included in STM, 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:

Current Situation: in the current situation we calculate the fuel consumption, GHG emissions and time in service as per the AIS data available, using ICCT (Olmer et al, 2017) formulas.

Scenario 1: the first scenario it is assumed that ports, thanks to STM in Ports, can provide more accurate recommended times of arrival; that ships, thanks to the consumption 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. As a consequence, anchoring times are minimized or eliminated.

Scenario 2: In scenario 2 we assume 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.

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 has been analysed. In particular, we used three different speeds,

- Lower Speed.
- Median Speed.
- Maximum Speed.

Note that this will have an impact not only on fuel consumption and GHG emissions, but also on the time used to cover a particular route. We assume that the calls are completely synchronized and that the ships are allowed into port upon arrival. Basically, we are assuming just-in-time arrivals and departures, adapted to the selection of the aforementioned speeds.

6.5 Impact Evaluation of Efficiency

A series of hypotheses were defined at the beginning of the project. These hypotheses targeted different current problems in the shipping industry, but could not quantify their effects. This section presents some of these problems, explains why they are relevant and describes how they were quantified. In particular, we focus on the variability of the speed while navigating, the deviation between reported ETAs and ATAs and the time ships spend at anchor.

6.5.1 ETA / ATA Deviation

The following item of study is how accurate is the ETA provided by the ship at the beginning of a leg. This aims again at the need for synchronization, improved communications between ship and port based on real-time data, if possible, improved coordination between actors in the port or facilitating just-in-time arrivals and departures.

The analysis of the Estimated Time of Arrival (ETA) versus Actual Time of Arrival (ATA) allows a study of how severely shortcomings in these factors affect current planning and synchronization of port calls.

Whenever possible[1], the analysis of each use-case will include figures like Figure 62 and Figure 63. These figures show the ratio of calls that arrived late or early, including Cumulative Distribution Functions (CDF) of the ETA deviation for each ship (port) for the cases where the ships were late or early. Additionally, another line is displayed showing the aggregated CDF for all port calls. These figures provide valuable information about, first, whether the behaviour is consistent among ports and ships, or are some performing better or worse. It is possible that there are ships arriving later than others in their itinerary on a regular basis, or ports for which deviations are larger, maybe because of more unexpected changes in the berth availability windows. Similarly, in these figures it is easy to see how strong these deviations are, and in percentage terms.

1 These figures depend on whether the ships are reporting the ETA adequately. We found that some ships were not updating the ETA after arriving at a port and leave it obsolete for the following legs.

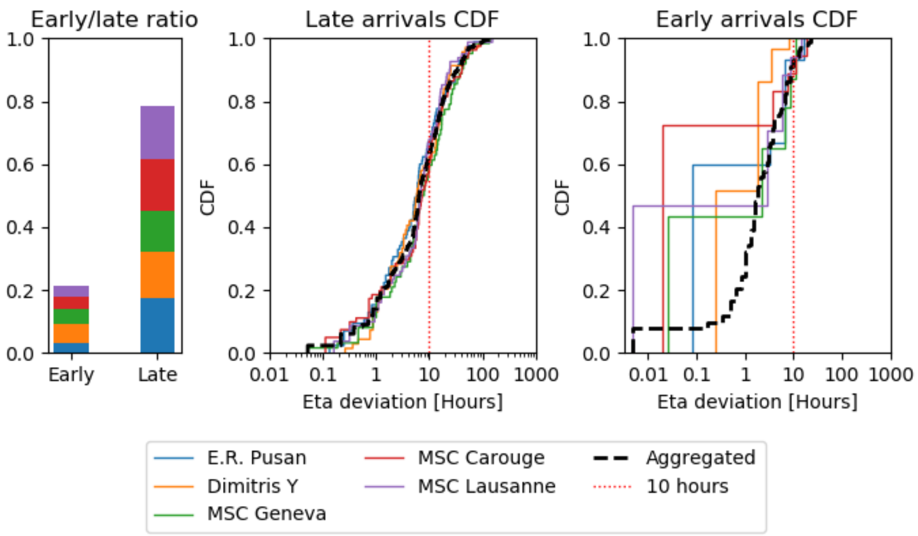


Figure 62. Example of the ETA deviation analysis per ship for CS2.

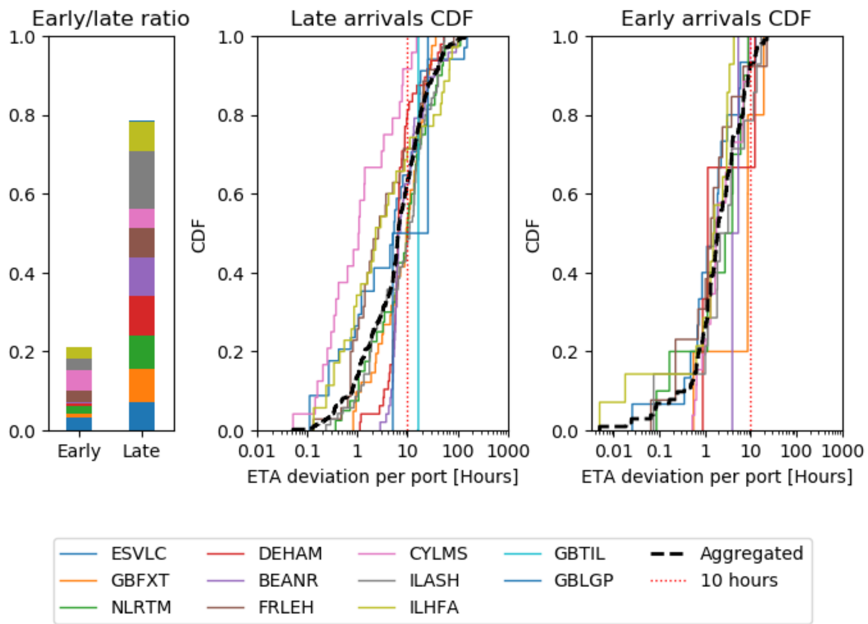


Figure 63. ETA Deviation per Port in CS2

6.5.2 Anchoring Results

Figure 64 shows the CDFs of anchoring times for the different use-cases. It is worth noting that we also regard possible waiting times during the entry to port as anchoring times.

There are three differentiated groups, Containerships, Ro-Ro traffic, and Ro-Pax/Pax. Containerships go to anchoring between 20-40% of the time, as can be seen in the different Containership use-cases. This is reflected in the smoothness of the curves, showing much more occurrences than for other traffic. Similarly, their stays at anchor are substantially longer. In fact, CS2 ships stay at anchor more than 10 hours more than 40% of the time, while CS1 and CS3 ships go beyond the 10 hours approximately 10% of the time.

Interestingly, Ro-Ro ships spend substantially less time at anchor. This may be because Ro-Ro traffic is lower than containers and easier to allocate in the dedicated terminals. We can observe how the number of times they remain at anchor is not only low, but most of the time is short or, as in the case of RO3, merely stopping by before mooring at berth as the longest wait was in the order of 30 minutes.

Finally, with very few exceptions, Ro-Pax and Pax do not anchor, unless there are exceptional reasons. These ships carry passengers, which grants them very high priority when entering any port. RPX2 was the only Ro-Pax case showing some waiting time. However, for both RPX2 and Pax these waiting times were very few and in the order of minutes.

In contrast to Ro-Pax, and Pax, Ro-Ro and Containership traffic have low priority when entering port, having to wait outside the port if any passenger traffic is arriving at the same time. Hence, the mix of higher traffic, lower priority, and more complicated and elevated number of operations at berth adds a certain degree of unpredictability that complicates synchronization. STM will help solve these issues primarily by improving the real time communication between actors in ports and between ports and ships. Additionally, the digitization of this communication and the analysis of the resulting data will help improve resource management in ports and, hence, avoid congestion through better management of incoming and outgoing traffic.

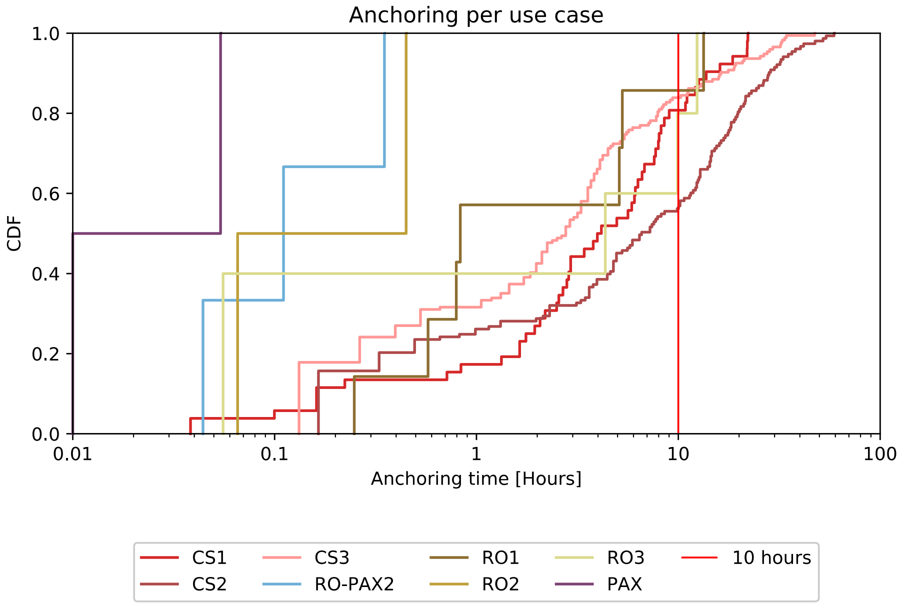


Figure 64. CDFs of the anchoring times per Use Case

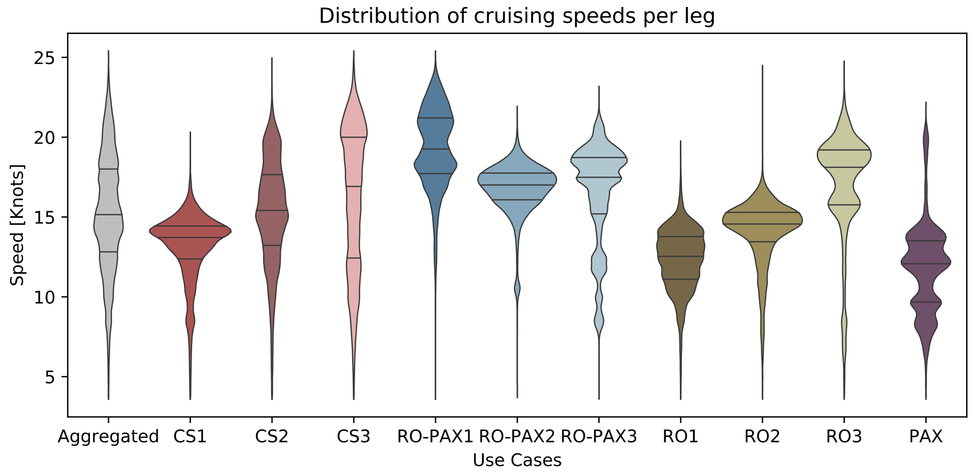


Figure 65: Distribution of cruising speeds per use case plus the aggregated distribution.

6.5.3 Speed Variation

From our point of view, variations in ship cruising speed represent one of the clearest symptoms of inefficiency in shipping. Figure 65 shows the speed variation in each one of the use-cases. The behaviour exhibited by RPX2 and RO2, and even by CS1, is close to what we would expect to see from rational or uneventful navigation. There is a narrow tail due to the approximation and departure from port but, most of the time, speeds are concentrated around its median value. Ideally, the upper tail should be narrow and short as well. The ships in RPX1 individually meet this pattern as well, but due to differences in the types of ship, this is not reflected in the aggregated pattern of Figure 65.

The remainder of the use-cases exhibit very wide distributions, like CS2 or CS3, or bimodal or multimodal ones, like RO3 or PAX1. These distributions of speed lead to an immediate conclusion; it is impossible that these ships are navigating at their most efficient speed most of their time. While we do not know this for certain for CS1, RPX1, RPX2 or RO2, there is a chance it is the case and, at least, the lack of high variations is more efficient than using a wide range.

The reasons underlying these speed distributions vary. These include aspects that are inherent to the routes covered by the ships, e.g., more or less calm waters or complicated geography, to unexpected changes in berth availability in the destination ports, circumvention of congestion or meteorological difficulties/events during navigation. Most of these issues could potentially be solved using STM. Better synchronization with ports, between ships, or by the use of weather forecasting services and route optimization made available to ships, would largely reduce speed variations.

6.6 Impact Evaluation on Environmental Sustainability

The main goal of the evaluation of environmental sustainability is to estimate the quantity of fuel and emissions (GHG and pollutants) that could be saved if STM were to gain broad-based implementation (Pan-European scale). The document "STM Use Cases Evaluation" shows the results of the estimates of annual fuel consumption for the selected ships and the simulation of the new figures if the inefficiencies (waiting times during navigation and at ports) were eliminated by the use of STM. In this document, we summarize and analyse the overall results.

6.6.1 Fuel Consumption and GHG Emissions Analysis

Two figures are presented per use case. The first figure presents the fuel consumption of one of the ships in the use case for the real AIS data and for each one of the proposed scenarios, disaggregated per navigation phase. Figure 66 shows an example of these figures. The results and savings are expected to be similar for the different ships of a use case, as the ships on the itinerary are usually similar. Moreover, the shape of the figures for the different GHG emissions is similar to that of the fuel consumption, as they are relatively proportional.

The second figure aims at offering a broader view of the savings for the use-case. An example of this figure is seen in Figure 67. Here, the average percentage of savings in each scenario for fuel consumption and emissions are shown jointly with error bars, giving a perception of the deviation across the various ships in the use-case. This figure offers a clear overview of the benefits of each scenario in terms of fuel consumption and emissions. It is interesting to note that in some cases, especially in Scenario 3 with high speed, there may be no savings in terms of fuel consumption or GHG emissions, as the increment associated with speed is larger than the reduction due to other improvements associated with STM.

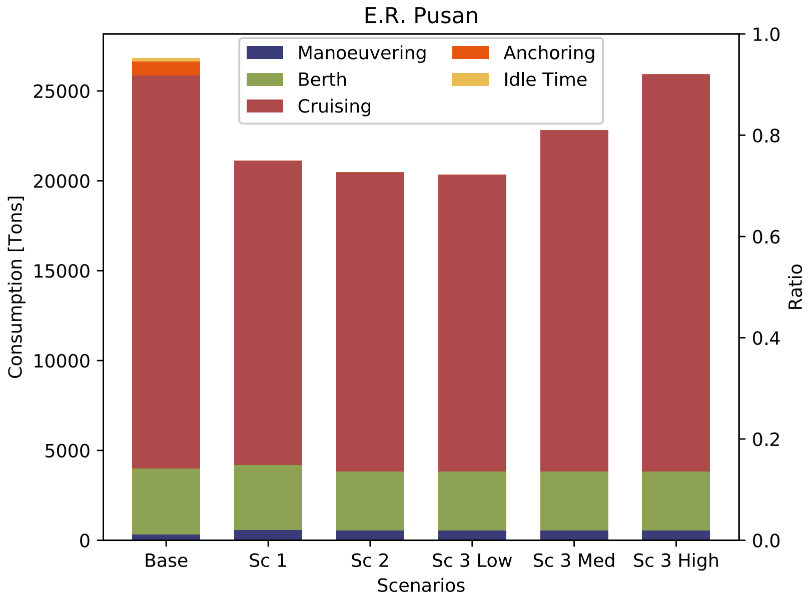


Figure 66. Estimate of the fuel consumption disaggregated per phase for one of the ships in CS2, the E.R. Pusan

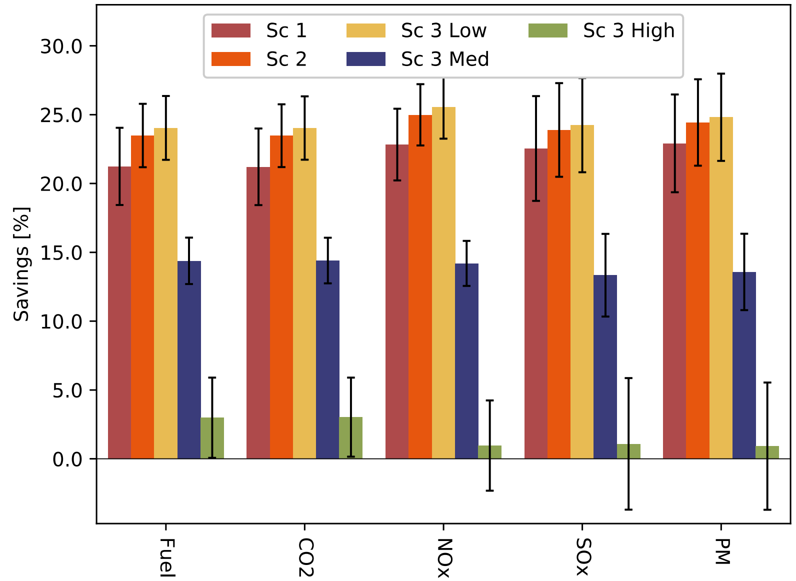


Figure 67. Overview of the savings in fuel consumption and emissions in each scenario for CS2

Jointly with these figures, each of the use-cases includes different tables with the real consumption and GHG emissions per ship, and joint savings in fuel consumption and GHG emissions. In Table 5 the use cases aggregated savings for each scenario are showed.

Results for Scenario 3 at low speed, which uses the speed corresponding to the 1st quartile of the distribution of cruising speeds, show that large savings can be achieved if itineraries are re-studied to allow ships to reduce their speed and STM is fully operational.

USE CASES		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%

Table 5: Use Cases Aggregated Fuel Savings for each Scenario

6.6.2 Impact on Navigation Time

Finally, the analysis is completed by presenting the impact that each of the scenarios would have on the navigation time. The reader must bear in mind that, besides the impact on fuel consumption and GHG emissions, shipping lines must take into account how this is reflected in the time a ship needs to cover its route. Figure 68 shows an example of this factor for CS2.

As noted earlier, lower speeds generally result in lower fuel consumption and emissions, but also longer navigation times. The improvements associated with the deployment of STM will also help compensate for the use of lower speeds, but each use-case has its own reality. Hence, it will be possible to observe that there are cases where the savings achieved by applying Scenario 3 do not compensate the impact on navigation time, or cases where it does. The goal of this analysis is to provide shipping lines with more information to help the decision-making process.

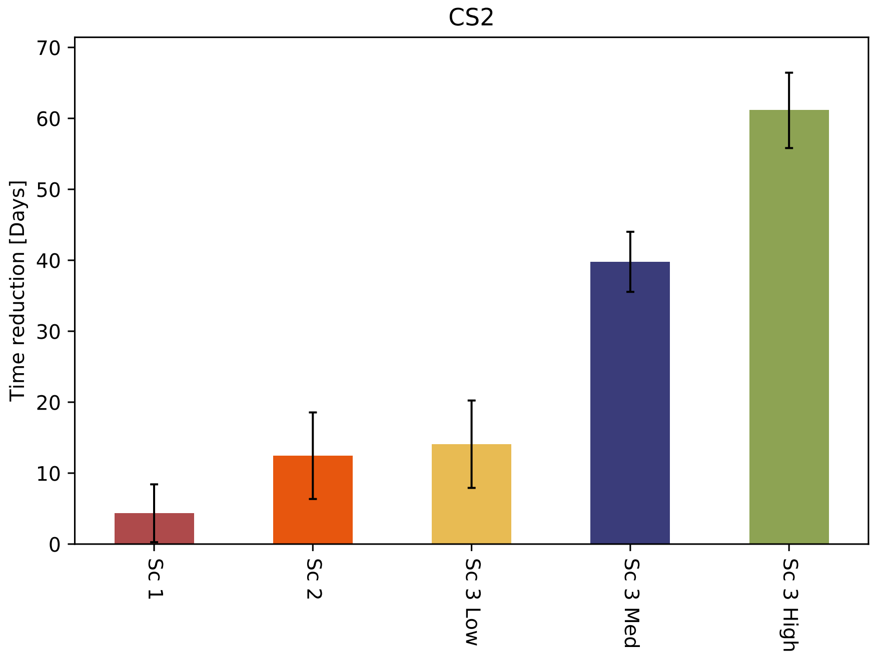


Figure 68. Variation in navigation time for each scenario in CS2

6.6.3 Use-cases Scenarios, Overall Evaluation

The figures following present the results for Scenario 3, low and median speed fuel consumption and for each one of the GHG pollutants. Each figure has two plots: the first shows the total savings versus the total consumption/emissions for each use-case. The second relates these savings to the reduction in navigation days for each use-case. Note that a negative variation implies that more navigation days are required at that speed. Each circle is a ship and the use-case is indicated by its colour.

In general, ships of the same use-case have similar total current consumption or emissions. However, there are substantial differences in some cases. For instance, in RPX3, the Amorella and Gabriella cover the same route, but spend different amounts of time at berth, one in the order of 1 hour in big ports such as Stockholm or Helsinki, while the other spends about 6-8 hours. Another example could be the ships in CS3, that cover very long distances, and have some small variations in the ports covered, which also contributes to the apparent dispersion of its ships in the figures.

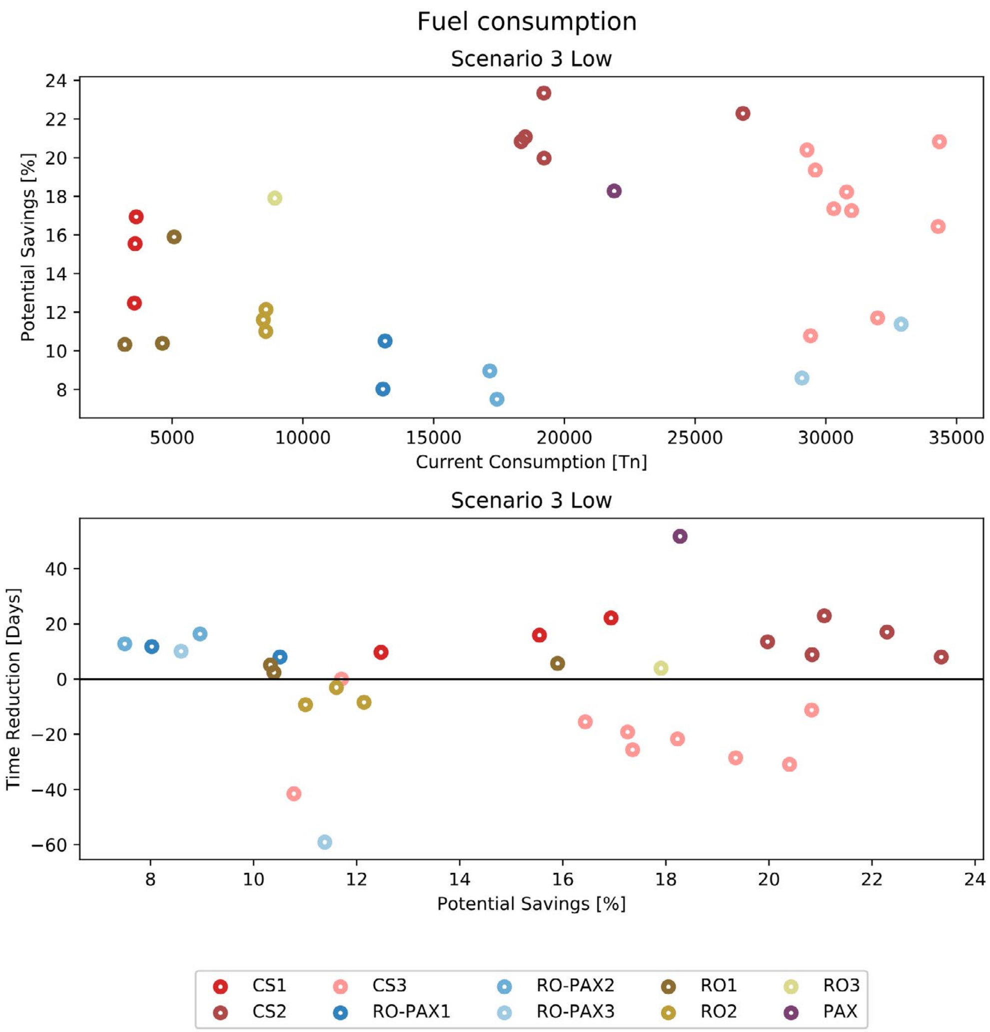


Figure 69. Fuel consumption savings for all use cases in scenario 3 low scenarios

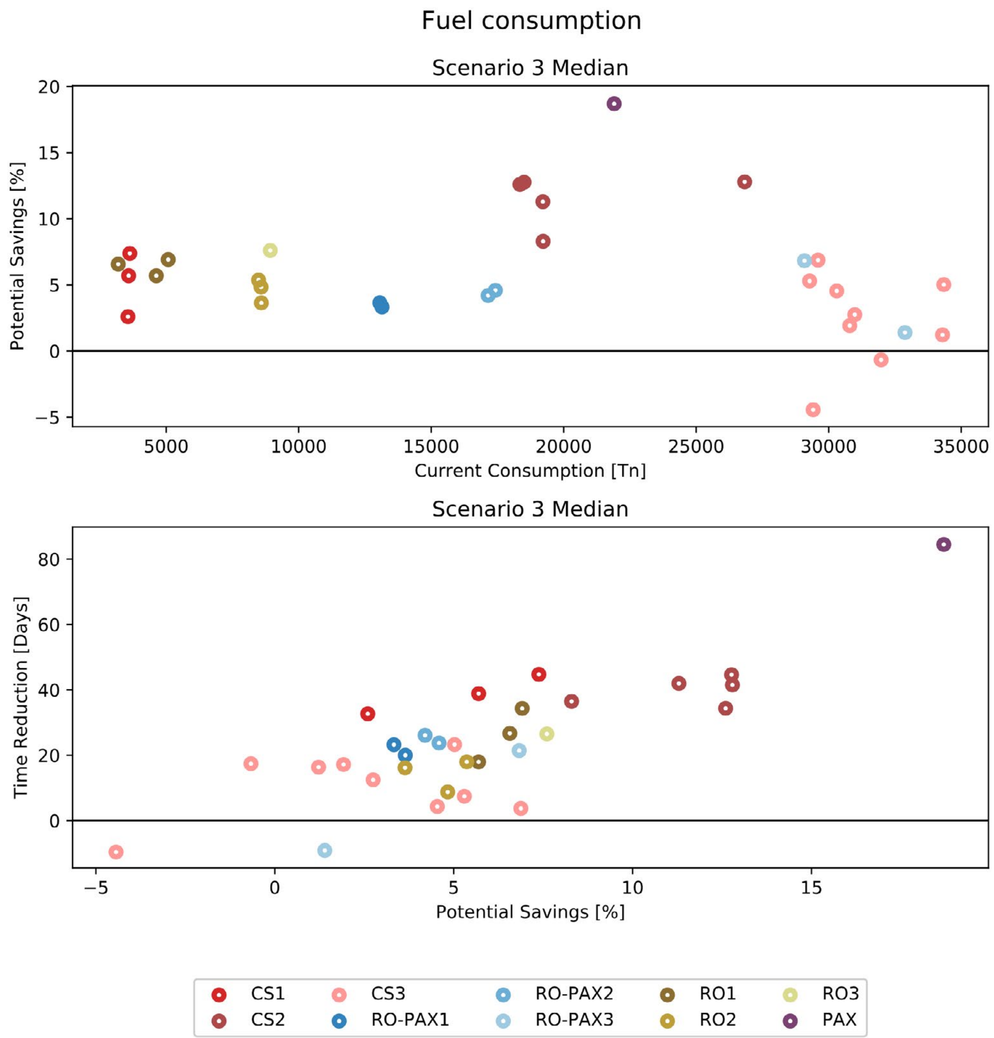


Figure 70. Fuel consumption savings for all use cases in scenario 3 median scenarios

Figure 69 and Figure 70 show the fuel consumption results for the Scenario 3 low and median speeds. The upper part of the figures represents the total consumption versus the potential fuel savings for each use-case; the lower part shows the potential savings versus the estimated reduction in days of navigation. Note that a negative reduction implies more navigation days.

Results for Scenario 3 at low speed, which uses the speed corresponding to the 1st quartile of the distribution of cruising speeds, show that large savings can be achieved if itineraries are re-studied to allow ships to reduce their speed and STM is fully operational. Completely synchronized port calls help increase the time the ship can maintain constant speeds during cruising. Although there are upper limits to these potential savings, the thresholds range from 7% to 23%.

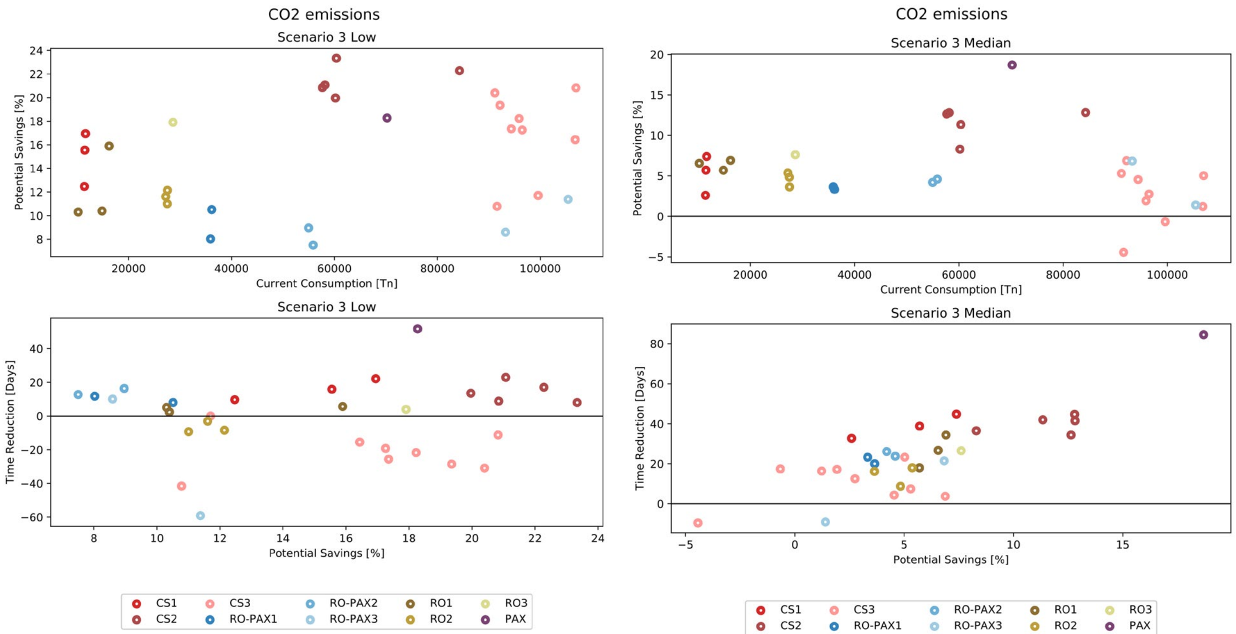


Figure 71. CO_2 savings for all use cases in scenario 3 low (left) and median (right) scenarios

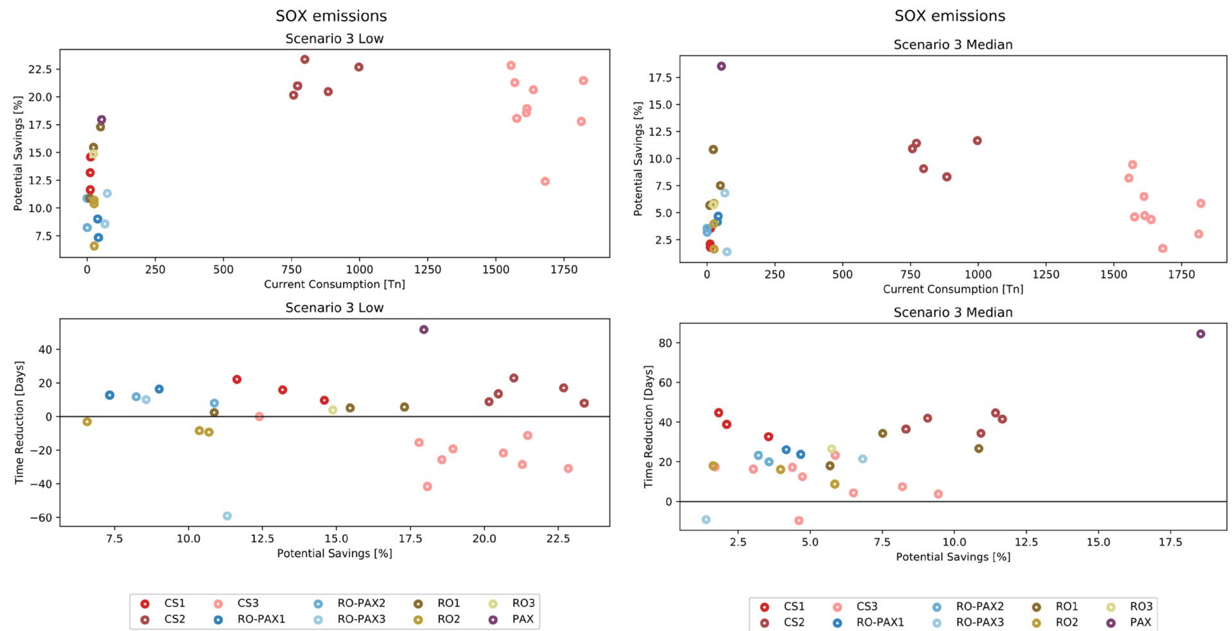


Figure 72. SOx savings for all use cases in scenario 3 low (left) and median (right) scenarios

Even a 5% reduction in fuel consumption is considered a more than desirable reduction; here we indicate that the potential benefits could be greater than this 5%. Of course, adopting the low speed scheme implies a re-scheduling of the itineraries, given that, as the lower figure shows, transoceanic containerships like those in CS3 may need between 10-30 more navigation days to cover the same number of port calls at present.

However, short sea shipping and medium distance containerships (CS1 and CS2 respectively), and some of the Ro-Ro examples could still reduce their navigation time despite using a slow or relatively slow steaming speed only at the expense of reducing current inefficiencies.

The Ro-Pax and Pax cases, however, are subject to strict schedules and varying their frequency has an impact on commuters. Nevertheless, the feasibility of a speed reduction could be worth studying.

Scenario 3 median speed uses the median speed of the ship during navigation, thus, giving a better impression of the impact of current inefficiencies. In this scenario, most ships are still able to reduce the fuel consumption, beyond 5% in many cases, while the navigation time is also reduced in all but two cases. Most of these savings can be directly associated with the lack of synchronization between ports and ships or an excessive variation of the cruising speed.

Figures 71 to 74 show the impact of both scenarios on different types of GHG emissions, namely, CO_2, NOx, SOx, and PM. The results for CO2 are comparatively similar to those shown for fuel consumption. However, for NOx, SOx and PM, the ships shift in the figure due to the influence of navigating in ECA and non-ECA zones.

Consequently, CS2 and CS3, which have the most powerful engines and, additionally, do not, or hardly cross ECA zones, appear on the left-hand side of the figures. Whilst RPX2, RPX3 and Pax still show an order of magnitude similar to that of CS2

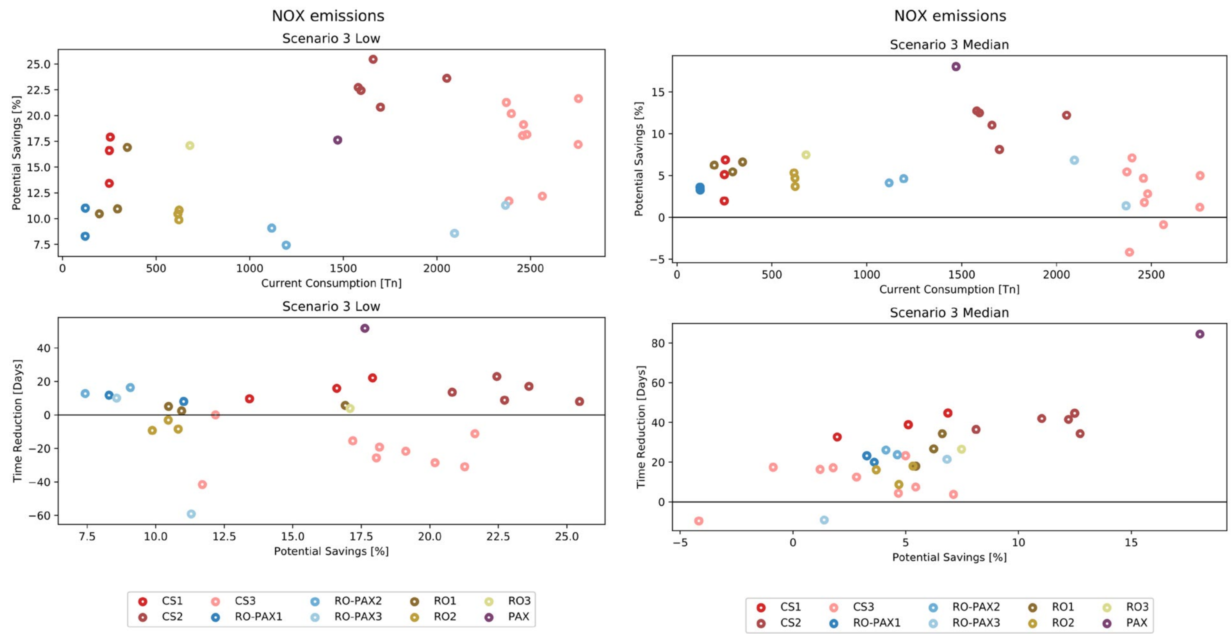


Figure 73. NOx savings for all use cases in scenario 3 low (left) and median (right) scenarios

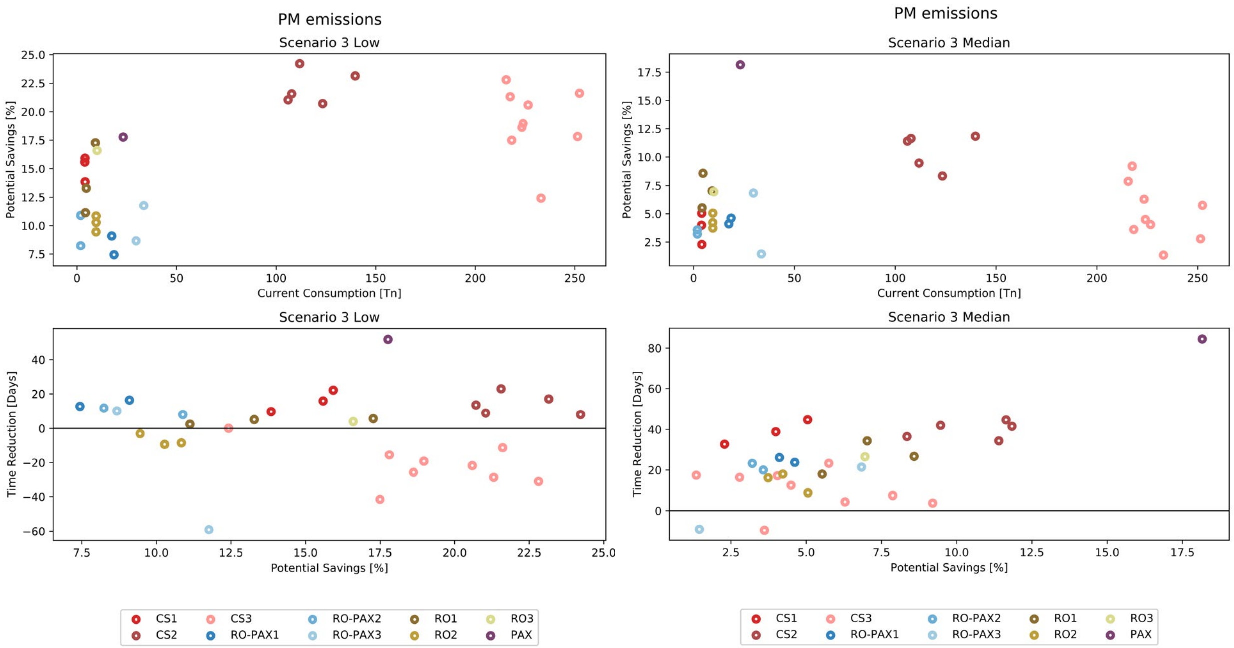


Figure 74. PM savings for all use cases in scenario 3 low (left) and median (right) scenarios

and CS3 for NOx emissions. For SOx and PM, the reduction due to ECA zones is more substantial and shifts to the left-hand side of the figure.

In general, all figures exhibit similar patterns. Most ships have upper limits in their potential emission savings of some 10-25% for Scenario 3 Low, with the aforementioned implications in terms of navigation days. For Scenario 3 Median, the upper limits on the potential savings are lower but still in the order of 5-15% for most ships.

The upper part of the figures represents the total consumption versus the potential NOx emission savings for each use case. The lower part, the potential savings versus the estimated reduction in days of navigation. Note that a negative reduction implies more days of navigation.

6.7 STM European Potential Added Value

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 of STM at the European level.

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.

More than 2 million data have been collected, compiled and validated from the various sources of the different actors involved in the maritime business. The types of services have been categorized based on the cargo transported and the characteristics of the ships used. According to these criteria, regular services have been classified as car carrier, container, passenger, cruise ships, Ro-ro and Ro-pax services.

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 **main objective** of using VESSL is to have a comprehensive and reliable tool that enables the extrapolation of the impact of STM benefits at macro-level in terms of time, fuel consumption and GHG emission savings on all Short Sea Shipping and cabotage services in 23 Member States of 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 Figure 75 (2017 basis).

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.

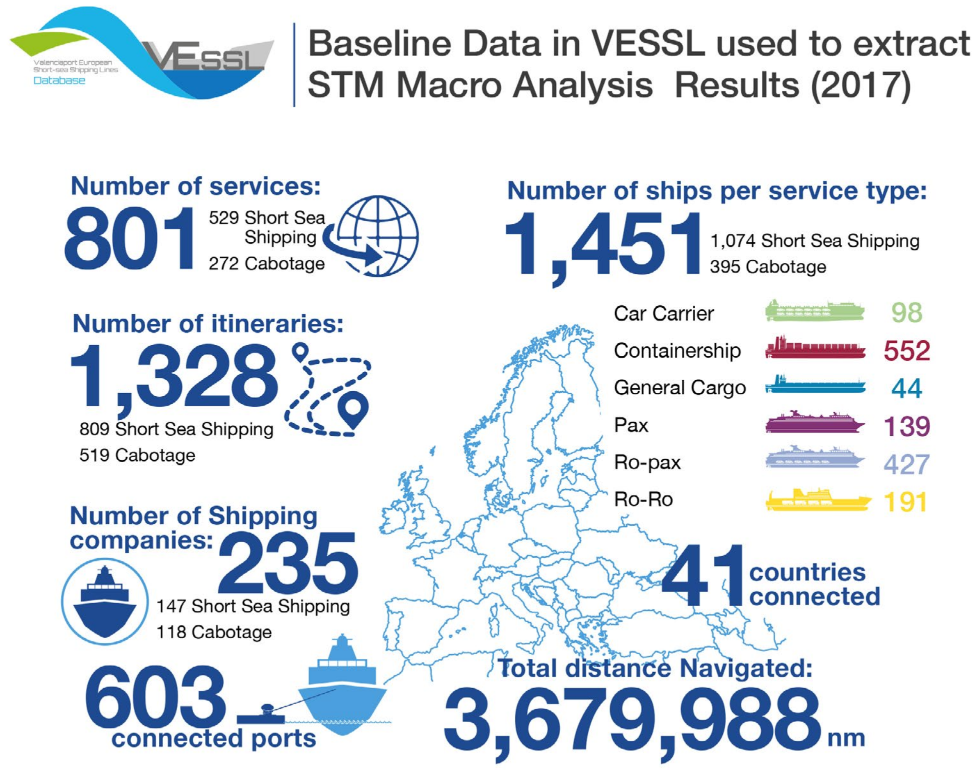


Figure 75. Baseline data in VESSL used to extract STM Macro Analysis Results (2017)

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.

6.7.1 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 the percentages mentioned above.

6.7.1.1 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 6 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 in Table 6:

Time Saving for 1,097,544 port calls (2017)	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 (mins)	3,123,360	8,251,200	14,663,520

Table 6. Time saving in port estimation

6.7.1.1 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 NOx; 2,500 tons of SOx and 1,637 tons of PMx at ports.

As observed in Table 7 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.

Savings in 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

Table 7. Saving tons at ports

Table 8 rates the GHG emissions on the basis of the following reference values:

- 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 (reference according to the estimated costs included in the Cost Benefit Analysis of Investments Projects Guide (Sartori, Davide, et al., 2015).
- NOx emissions - €3,790/ton (average damage cost per ton for maritime transport included in the Update of the Handbook on External Costs of Transport (Gibson G., et al, 2014).
- SOx emissions - €17,240/ton (Gibson G., et al., 2014).
- Emissions PMx - €6,080/ton (Gibson G., et al., 2014).

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 mentioned above.

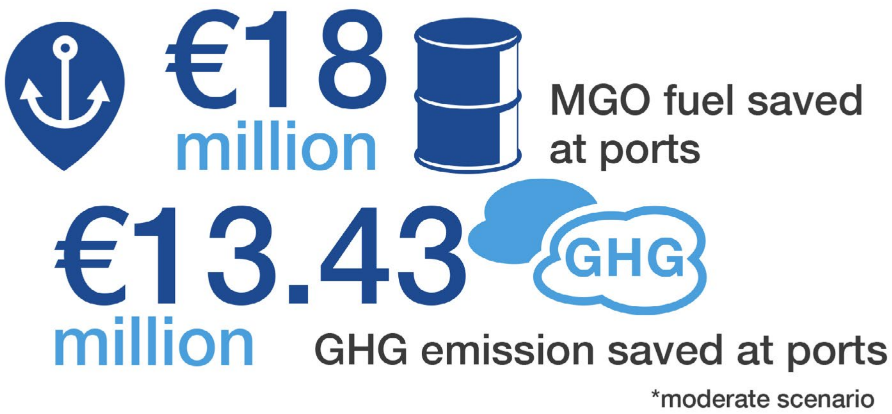
Monetary Savings in ports	Pessimistic scenario	Moderate Scenario	Optimistic Scenario
Amount of Fuel saving in Ports	7,081,873 €	18,038,119 €	31,733,425 €
Amount of CO_2 saving in Ports	1,034,171 €	2,634,120 €	4,634,056 €
Amount of NO_X saving in Ports	3,699,138 €	9,422,013 €	16,575,605 €
Amount of SO_X 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 GHG saving in Ports	5,275,346 €	13,436,745 €	23,638,492 €

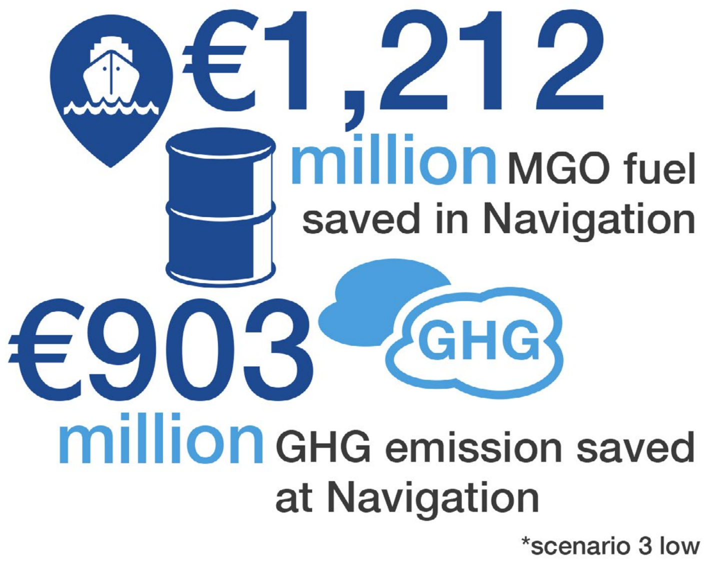
Table 8. Monetary savings in ports estimation

6.7.2 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. For this purpose, we have used the time and fuel savings estimations for the five given scenarios.

Once the potential savings percentages from the Table 9 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, 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.

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 9. 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€

Table 10. Monetary savings in Navigation estimation

Table 10 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.

In conclusion, 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.

6.8 STM Overall Cost-Benefit Analysis

This section contains the results of the Financial Analysis and Economic Analysis (CBA) of the STM Validation Project. The CBA has been carried out in line with the methodology included in the Guide to Cost-Benefit Analysis of Investments Projects (Sartori, Davide, et al., 2015) drawn up in December 2014 by DG Regio.

The project's overall performance has been measured by the appropriate financial and economic performance indicators: Financial and Economic Net Present Value (FNPV and ENPV) and the Financial and Economic Rate of Return (FRR and ERR) expressed in monetary values. These indicators have been calculated in order to measure the welfare effects of the action.

The specific objectives of the STM Validation project is to push the maritime industry towards more collaborative and digitalized operational environments, enabling the transition of the sector to the "Industry 4.0" paradigm, where digital and real time connectivity is the driver for increasing efficiency, safety and environmental sustainability.

Several services have been developed and implemented during the project for both the port perspective and maritime navigation dimension. The implemented services have been analysed in depth in large-scale test-beds during the project, thereby facilitating the basis of calculation of the CBA. In addition, some of them have been analysed with simulations to check their functionality, applicability and to receive feedback from stakeholders.

Regarding the financial analysis, four scenarios have been designed in order to facilitate accurate calculations. The four scenarios have been defined according to the actors involved, the functionalities of the services included and the potential savings calculation hypotheses.

The four scenarios are described as follows:

- Port-Call Coordination – In this case, the calculation hypotheses are related to an operational optimization of the ship port-call management, where the actors involved have been port authorities, port terminals and nautical services (mooring, towage and pilotage).

- Port-Call Synchronization – This has been calculated taking into account the potential improvement related to the information exchange between the actors, which should enable the application of the just-in-time arrivals and departures concept. The updating of the ETA from ships will lead to better resource management in the port and to a reduction in fuel consumption during navigation due to the speed adjustment. Thus, the reduction of GHG emissions is an impact that has been treated as an externality in the economic analysis. The actors involved in this scenario are the shipping companies, port authorities and port terminals.

- Ship-to-Ship Route Exchange - This service improves the on board operations of the OOW (Officer of the Watch), facilitating strategic route planning and preventing ships to arrive in close quarter situations. The digital communication and exchange of data among ships will avoid misunderstandings and will enhance safety and security from an economic point of view. The actors involved in this service are the shipping companies, specifically ship crews.

- Ship-to-Shore/Service Provider: the services included in this scenario are described below, as well as the specific agents involved. The financial analysis regarding this scenario is the total of all of them.

  - Enhanced Monitoring Service - This functionality provides accurate information to make navigation safer in complex situations. The information exchanged with the shore centres is crosschecked and this aspect adds to efficiency in calculating the safest route in certain difficult navigational areas. It has a strong economic dimension, as it encourages the reduction of accidents such as groundings and collisions. The actors involved in this service are shore centres (including VTS) and shipping companies (ship crews).

  - Nordic Pilot Route service - This service deals with validated information on safe routes before arrival at ports and during navigation through inland waters by pilots in the Baltic area. The focus is on saving time in calculating the safest route during port approach. The actors involved are maritime administrations and shipping companies.

  - Baltic Navigational Warning Service - Information regarding unexpected events or situations in coastal navigation in jurisdictional waters is the responsibility of the national maritime administrations. The fact that the information is automatically sent to the ships' bridges saves time in drawing up the voyage plan, and in proposing an alternative for reliable navigation using the most updated information. It has a strong economic impact by helping to avoid potential collisions and all types of accidents at sea. The actors involved are the national maritime administrations and shipping companies.

  - SSPA Route Optimization Service – In this service, the potential savings are restricted to bunker consumption and, hence, bunker costs for the route sailed. Optimizing the route has a strong impact on the operational costs for fuel and it is translated into GHG emission savings. The main actors and beneficiaries are shipping companies and the service provider, in this case, SSPA Sweden AB.

  - SMHI Route ETA Forecasts – The service provides a more probable time of arrival for each waypoint on the route as well as a calculated time-window for the estimated time of arrival. This information reduces workload on board in terms of managing the weather routing information from NAVTEX and provides a tool to enhance the mandatory operational procedures on the bridge. The main actors and beneficiaries involved are shipping companies (ship crews) and the service provider, in this case, SMHI (Sveriges Meteorologiska och Hydrologiska Institut).

  - Winter Navigation Service - This service enables accurate information on available navigable routes through ice-bound waters. It provides simpler and more reliable on board operational calculation models as well as real time information for calculating the voyage plan. The actors involved are the national maritime administrations and shipping companies.

  - STM Search and Rescue - The functionality of this service aims at simplifying and improving the information shared from the MRCC (Maritime Rescue Coordination Centre) with the SAR units collaborating in rescue operations. The shared information is more efficient and reliable. From a safety point of view, the time saved when searching for people and saving human lives in danger at sea could represent a significant economic impact. The actors involved are the national maritime administrations and public bodies in charge of Search and Rescue at sea.

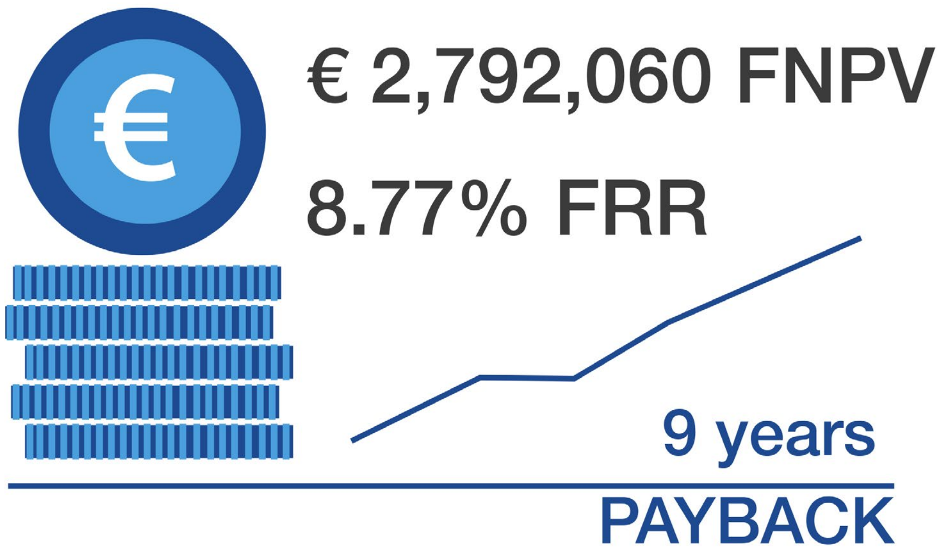
Following the indications of the Guide, the assumptions taken into account in the Cost-Benefit Analysis are described below:

- Inflation rate – 2%.
- Financial Discount rate – 6.08%.
- Social Discount rate – 3%.
- Sector reference period lifespan – 10 years (other sectors).
- Average annual traffic growth rate – 1%.
- 8 ports, 268 ships and 52 terminals considered.
- 3,679 port calls by STM ships studied from a total of 5,291 calls (five types of ships, namely, Containerships, Ro-Pax, Car Carriers, Pax and Ro-Ro).
- The monetary value for fuel and emissions and the average EU social accident costs, at market prices (PPP) have been selected according to the agreed EU references in the updated handbook on external costs of transport indicated by the CBA Guide (Gibson et al, 2014).

For the set-up of the investments for each scenario, the STM Validation Project budget in the grant agreement has been taken into account for those activities directly related to the services developed. It should be note, however, that although certain activities have contributed to the completion of the STM Validation Project, nonetheless their budget could not be directly imputed in the CBA, according to the cost-benefit guide. Consequently, the total investments considered are shown in the following table:

TOTAL INVESTMENTS	
PORT-CALL COORDINATION	6,820,449 €
PORT-CALL SYNCHRONISATION	5,450,521 €
STS ROUTE EXCHANGE	1,763,612 €
SHIP-TO-SHORE/SERVICE PROVIDER	9,656,902 €
TOTAL INVESTMENTS	**23,691,484 €**

Table 11. STM Total investments



The Financial Net Present Value (FNPV) of an investment is defined as the sum that results when the expected investment and operating costs of the project (discounted) are deducted from the discounted value of the expected revenues. It indicates how much the invested wealth has increased after the recovery of the initial investment. The minimum required return on the investment is implicit in the discount rate, which represents the cost of capital, or opportunity cost of relinquishing the return on alternatives involving the same level of risk. The second indicator used is the FRR, which is defined as the discount rate that produces a zero FNPV.

The Financial Net Present Value result of the STM Validation project has a positive figure of €2,792,060 with a FRR of 8.77% and a payback of 9 years. This means that the STM Validation project is profitable and the investment is retrieved within the project timespan, that is, 10 years.

The following figure 76 shows the financial results, in percentage terms, per actor involved according to the total calculation of the FNPV:

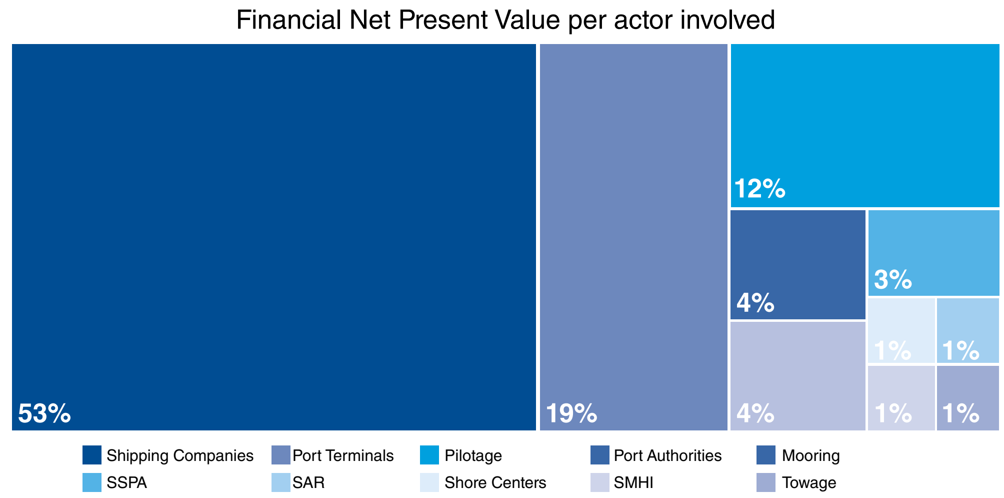
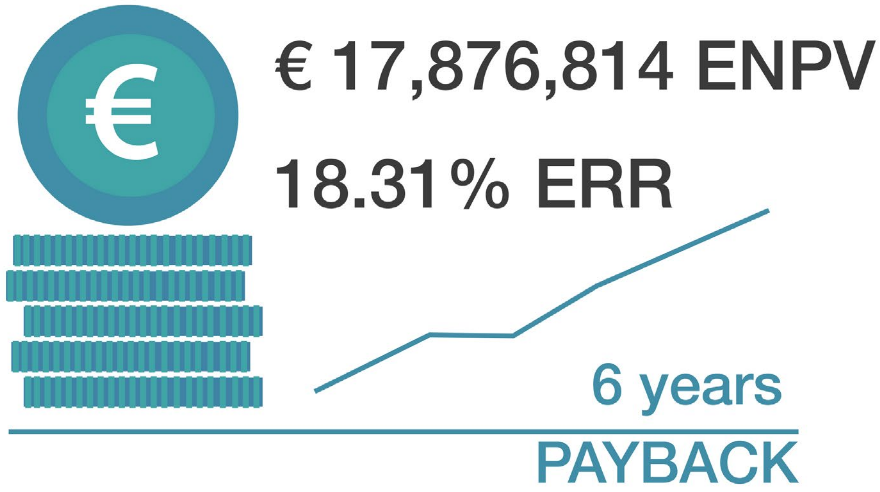


Figure 76. Financial NPV per actor



As can be seen from the results, the positive financial result of is 73% for shipping companies and port terminals, while 21% derives from port authorities and port services. This represents an impact of 94% on the shipping sector compared with only 6% for service providers and other actors.

This is a clear example of the tangible benefit favouring the competitiveness of the European Union's port-maritime sector, which has an impact on external and intra-European trade and, therefore, on the consumers. Without these funds, it would not be possible to achieve these benefits and the potential future benefits if the introduction of STM became a reality for the European Union.

The Economic Net Present Value has been calculated as well. In this context, the social discount rate has been applied according to Annex III of the Implementing Regulation on application form and CBA methodology. The European Commission recommends that the social discount rate of 3 % be used for major projects in member states. The main variables analysed have been mainly the externalities, the consumer´s surplus and the gross producer´s surplus, adjusted investments, and operating and maintenance costs.

As mentioned throughout this report, the objectives of STM are safety, efficiency and environmental sustainability. These goals have been thoroughly analysed in the economic analysis through externalities as well as through the increase in port calls and the potential growth of freight traffic associated with port terminals and port authorities thanks to the efficiency gains.

The results of the externalities can be divided into two main group of elements:

1. Savings in GHG emissions (CO_2, NOx, SOx and PMx) calculated from the fuel savings deducted in the financial analysis for 10 years and valued in monetary terms as suggested in the EU CBA Guide, see figure 77:

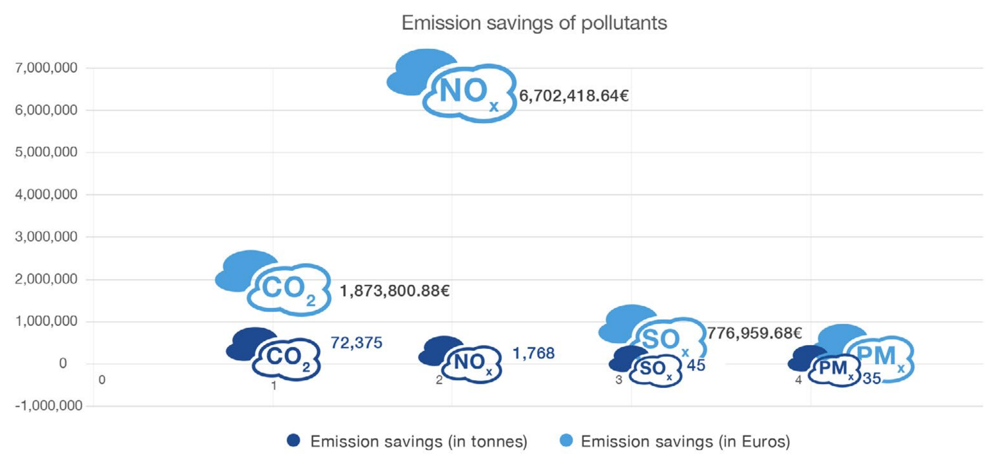


Figure 77. Potential reductions in GHG emissions in a 10 year STM scenario

2. Savings in potential accidents and incidents at sea, mainly due to collisions and groundings, expressed in the next figure according to the EMSA statistics for 2016-2018, which are valued in monetary terms according to the recommendations of the EU CBA Guide, see figure 78:

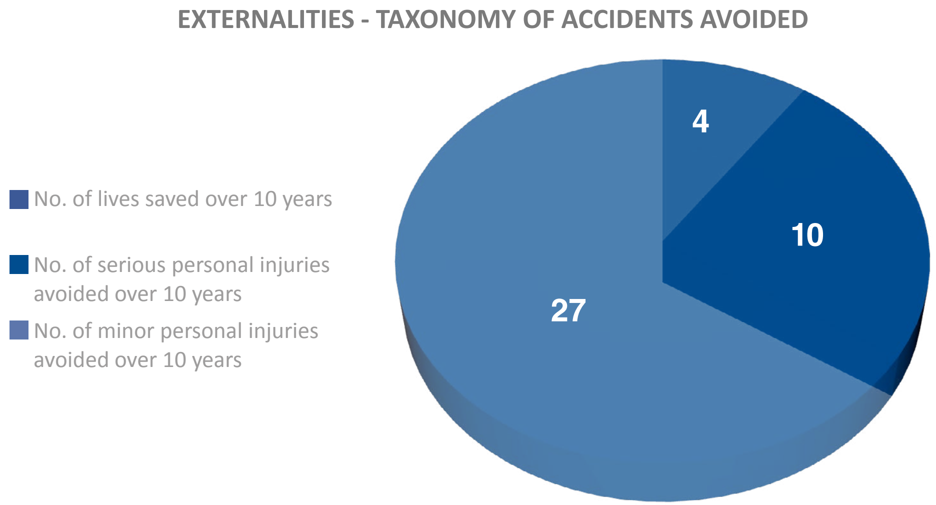


Figure 78. Externalities used in STM CB

The socio-economic analysis shows that the project generates a positive welfare change and, therefore, the funds received by the EU for its implementation provide a profit. The ENPV is the most important and reliable social CBA indicator. The present amount of the net benefits is calculated as the difference between the total discounted social benefits and costs.

The results of the economic analysis show the significance of the project in terms of its societal benefits, which show an ENPV of €17,876,814 and an ERR of 18.31%, with a payback period of 6 years for the entire STM Validation Project.

Finally, it is vital to highlight that applying the real market costs of the required investments to the total ports, the ships operating in the European Union and port terminals for SSS and cabotage traffic would represent a huge financial and economic impact. The adoption of STM services by the sector would have a very substantial impact on cost savings and a remarkable reduction of externalities. These assumptions are in line with the macro results shown in the previous section and the main objectives of the STM project relating to efficiency, safety and environmental sustainability.

6.9 Impact Evaluation on Operational Aspects

The overall operational idea of the STM concept is to support the ship's voyage through all navigation phases with interoperable services. These services are built on an enhanced information exchange between ships and shore and offer new potential for assistance of ships en-route. The strategic concepts of STM (PortCDM, Strategic Voyage Management, Dynamic Voyage Management, Flow Management and SeaSWIM) are defined to meet the user's information needs, collaborative needs, and by that increase the situational awareness. The effective implementation of these strategic concepts is carried out through a number of operational services. Some of the services proposed already exist but have been enhanced with an increased exchange of information, whilst others are completely new. These services need to be considered in their real operational environment and therefore some operational procedures on board or ashore might need to be updated, i.e. Bridge Standard Operation Procedures and VTS Operator procedures, based on the operational recommendations resulting from this project.

The methodology used to perform such impact evaluation consisted of data collection and discussions coming from those project activities dealing with test-beds (PortCDM test-beds, Voyage Management test-beds and European Maritime Simulator Network test-beds). This approach includes both quantitative data (test-bed results) and qualitative information (interviews, questionnaires, actors' reflections and evidence), and the discussions of those results in the test-bed activities. However, these data do not offer a sufficiently robust statistical base for any firm conclusions but nonetheless provide indications. Based on those results, operational aspects are discussed and recommendations given.

> **The outcome of this analysis** and its operational implications together with recommendations for successful future deployment are presented in depth in Milestone 24 of the project (M24 STM Report on Operational Aspects).

In this final report, the following operational results represent just a brief summary of them.

- The proposed Chat message function could be an efficient means of communication, as written messages may be more easily understood than spoken ones and it would improve the traceability of the information flow. However, in contrast to VHF, Chat messages will not allow the OOW (Officer on Watch) to navigate and communicate at the same time and it may prove distracting for the navigator when misused. Also, information exchange using Chat messages may exclude other stations from receiving possibly important information, which would not be the case if VHF were used. The usage should focus on supporting other STM functions and services, e.g. explaining and providing a rationale for a route suggestion from a shore centre.

- The ship-to-ship route exchange function would enhance situational awareness by anticipating potential traffic situations at long distance. However, it may be difficult to use this function in tactical situations, e.g. in dense traffic. It may generate misinterpretation of the monitored vs. followed route. Hence, it is important that its deployment is regulated under bridge/safety/company procedures.

- The new route suggestion function may reduce misunderstandings and the fact that it is based on local knowledge/expertise is highly appreciated by the OOW. Nevertheless, it may be time consuming to receive, control and approve or reject a suggested route.

- Regarding the STM navigational warning service, it may allow faster access to the information than NAVTEX and reduce workload, although it was noted that some usability issues should be improved.

- There were generally positive comments about the STM pilot route service, and its capacity to create a common operational picture between pilot and bridge team was highlighted; whilst in the case of the route crosscheck service, there is still room for improvement in terms of the understanding of some specific ship characteristics.

- The enhanced monitoring service, performed by a VTS or other shore centres, enables the prediction of future critical navigation situations. It could increase the workload for the shore centre's operator based on the number of alarms received. The STM winter navigation service was well received by the users, with the potential of reducing the workload and enhancing situational awareness in the context of ice navigation.

- The positive aspects of the STM SAR (Search and Rescue) service is the provision of a holistic approach, resulting in a clear picture for ships/units involved, the improvement of cooperation between the RCC (Rescue Coordination Centre) and the VTS. However, additional information is required at the RCC for sending search patterns to ships of opportunity (e.g. ship characteristics, ship data, etc.). This enhanced SAR service would require updates of SAR procedures and working praxis. It should be noted that all ships involved in a rescue operation might not have STM-compliant equipment.

Regarding PortCDM related services, a basis for information exchange among the stakeholders – including ships – has been developed using the S-211 data format. A new mindset within ports is required to get ports to issue recommendations internally and externally.

- The port call synchronization service, interconnecting the ship with the port domain, may contribute to reducing the total turnaround time through collaboration and data sharing as a driver for the ideal port call process. STM ships could share the voyage plan with the various STM-compliant ports in the same way and through the same functionality.

- The port-call coordination and port-call monitoring services have shown their potential to provide better estimates for gaining access to multiple data sources, using indicators and warnings to ensure coordinated actions and achieving common situational awareness. However, ports should make efforts in the medium-long term to increase their PortCDM maturity, e.g. by adapting the PortCDM maturity model, to achieve these promising results.

Finally, it is important to stress that each service or function implementation as operational procedure implies a need for additional training, as indicated in the previous sub-section.

6.10 Impact Evaluation on Regulation and Charter Parties

Sea Traffic Management introduces an entirely new paradigm for information exchange in shipping, optimizing voyages and port calls and providing real-time data to navigators.

The analysis from the legal and regulation perspectives focused on four primary aspects:

- **The legal feasibility of STM, relating to the compliance of STM with the International maritime legal framework;**
- **The business model and STM, relating to the commercial aspect of STM;**
- **New and additional risks linked with cyber-security, depicting the legal framework surrounding the relevant security obligations at the EU and UK level; and**
- **EU and global policies for STM support, outlining some aspects of EU legislation and International activities that could support the use of STM.**

The legal and regulatory evaluation examines the various jurisdictional zones in which STM will be implemented, and the potential issues arising between the Flag State and the Coastal State in regulating the use of STM. The use of information exchange in navigation is also discussed, especially in relation to collision avoidance. Another major issue analysed relates to the installation and carriage of an additional device assisting navigation, both from the aspect of installation and usage requirements, including manning and training, and from the apportionment of liability perspective. The analysis of the legal feasibility has four main pillars: the first three (Safety of Navigation, Manning and Training, Protection of the Marine Environment) deal with issues mainly concerning Flag States and their obligations, while the fourth part deals with the liability issues, which involves Coastal States as well.

The analysis of the business model recognizes the effect that STM will have on the commercial obligations of the ship, but mainly focuses on those under Voyage Charter Parties. It also includes the STM Clause for Voyage Charter Parties, an innovative clause adopted by BIMCO on 13th November 2018, drafted in collaboration with project stakeholders, which addresses some of the issues arising from the optimization introduced by STM.

Concerning cyber-security issues, the nature of the data exchanged by the STM services is studied to check whether certain actors ought to abide by the stricter laws regulating the processing of personal data, while a framework is provided containing parameters that need to be taken into account when assessing the security measures to be implemented.

Table 12 shows the main legal and liability constraints found from the regulatory study developed during the project, addressing each of the services tested in the STM Validation project.

Service	Legal and Liability Constraints
Route optimisation services	No problem - Speed suggestions must respect safe speed and any speed limitation in the area.
Ship to ship route exchange	Some potential for perception problems conveyed by shipowners acting collectively to create a self-fulfilling prophecy with indirect legal consequences affecting the right to limit liability under the LLMC.
Enhanced Monitoring	No Problem
Port Call Synchronization	No Problem - Port Calls predominantly governed by national law
Winter Navigation	No Problem
Importing Pilot Routes	No Problem
Navigational Warnings	No Problem
SAR – Search and Rescue	No Problem - STM Positively Endorsed

Table 12: STM services and constraints

6.11 Impact Evaluation on Business Models

As it stands, the shipping industry's current business model does not embrace optimization. Many aspects of shipping cannot encompass the changes introduced, as the industry is currently focused on generating profit through rigidity and inefficiency, with the examples of the shipment window and the laytime and demurrage both under the carriage and the sale contract being indicative of the commercial status quo.

Figure 79 presents a classification of the different regulations, conventions and international agreements studied in the project and their degree of impact over the potential implementation of STM principles in the shipping industry.

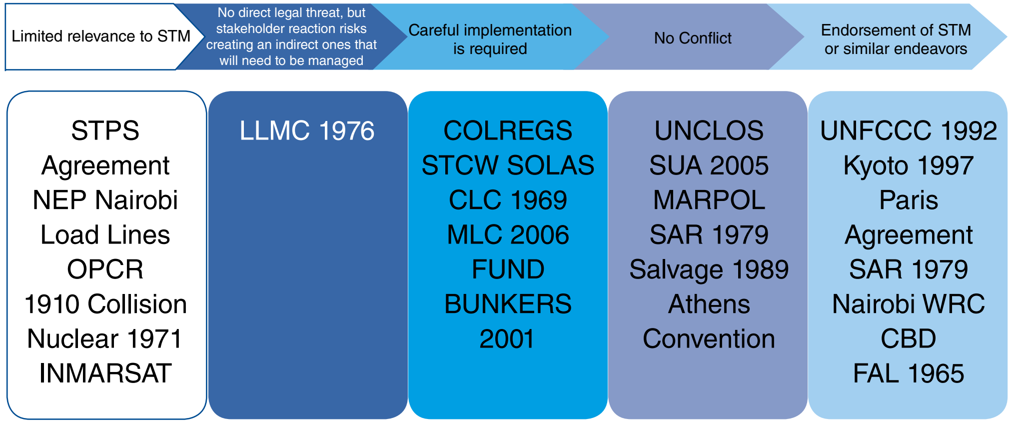
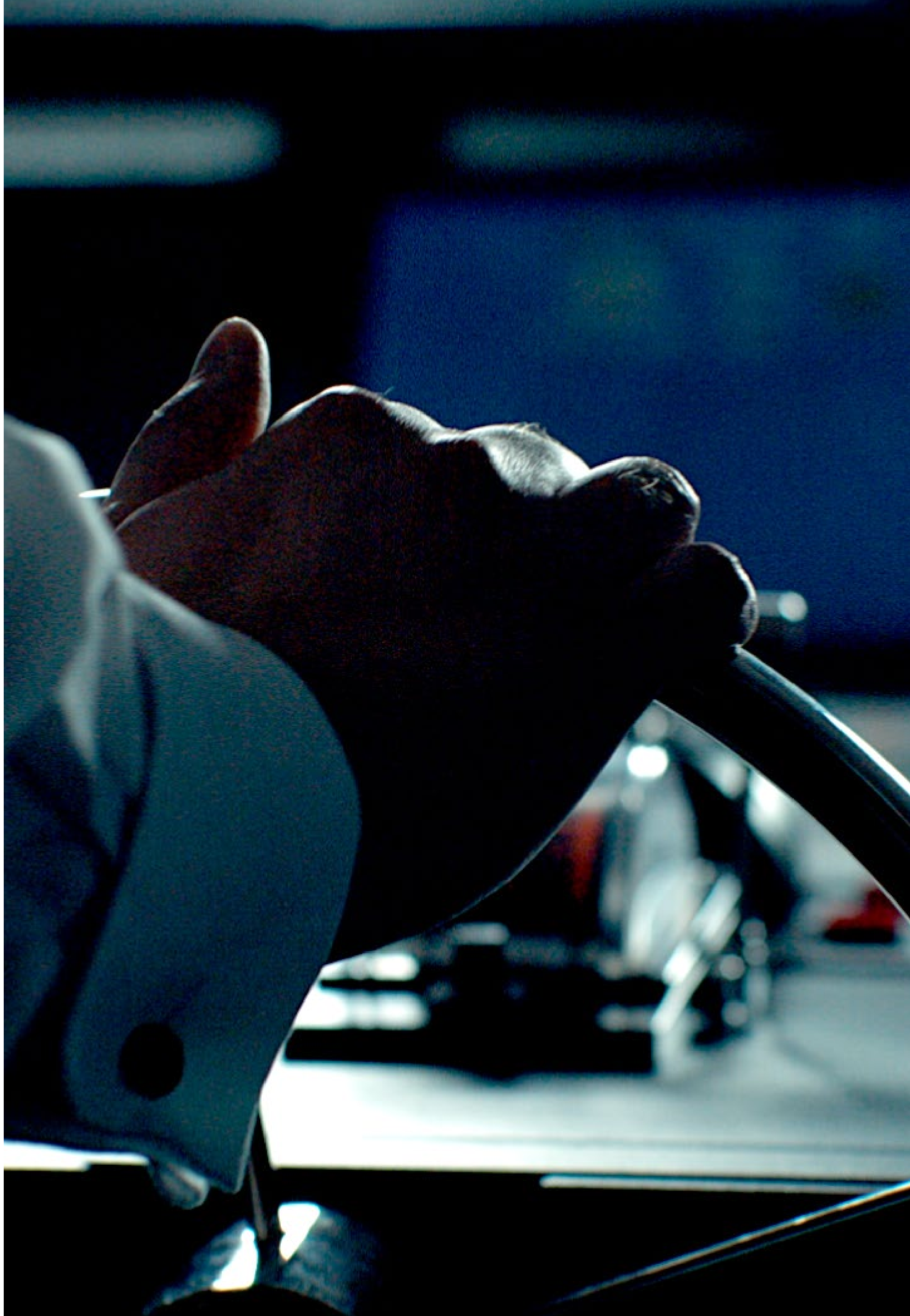


Figure 79. STM Concept and the international maritime legal framework graph

Voyage optimization relies on the availability and sharing of information. This is central to the workability of the provision, with parties required to use "best endeavours" to obtain and exchange information about a vessel's arrival time. The clause is binding only between the contracting owners and charterers. However, the obligation means that information that either party may have under STM arrangements or other relevant facts that might affect the ship's arrival should be exchanged. This might, for example, include owners' knowledge of weather conditions en-route, pilotage delays or a tug strike and matters known to charterers including local cargo handling delays and labour shortages, as well as matters beyond the port confines such as known problems with road transport.

In order to make progress in this field, BIMCO was invited to develop a functional contractual clause for use with voyage charter party forms. BIMCO provisions are normally drafted to allocate obligations, liabilities, risks, costs and expenses in relation to defined commercial needs or regulatory requirements. However, in order



to encourage parties to partake in the STM validation project, the clause has been developed to provide interested parties with a balanced contractual regime for use with STM arrangements. Current transport arrangements and procedures mean that waiting time cannot be eliminated. However, slowing a ship down or speeding it up to arrive at a given time can enhance voyage efficiency, leading to improved logistics management. Shorter waiting periods may also lead to lower emissions.

The content departs from the traditional BIMCO approach as it identifies STM as a named system rather than setting out procedures in conceptual terms. This was a policy decision due to the increasing use and understanding of STM as a shipping industry term and the possible future use of the clause with other similar systems.

The clause addresses only issues of speed. Requests from charterers for re-routing or a change of port rotation must be dealt with under the appropriate provisions of the underlying Charter Party. In the absence of covering Charter Party provisions, requests should be dealt with on a case-by-case basis taking P&I Club or other legal advice as necessary.

6.11.1 BIMCO Sea Traffic Management (STM) Clause for Voyage Charter Parties

(a) The Owners and Charterers shall use their best endeavours to obtain and share information regarding the Ship's Arrival Time, this shall include, but not be limited to, information from, or required by, an applicable STM system. For the purpose of this Clause, "Arrival Time" means the time of arrival at the place advised by the STM system.

(b) Notwithstanding any other clause in this Charter Party, the Charterers shall be entitled to request the Owners in writing to adjust the Ship's speed to meet the Arrival Time, always subject to the Owners' consent which shall not be unreasonably withheld and, in the case of an approach voyage, subject to agreeing an amended cancelling date. The Charterers shall not be entitled to request an adjustment of speed that exceeds the Ship's speed as set out in the Charter Party.

(c) Any extra time used on a sea voyage as a direct consequence of the Ship adjusting speed pursuant to the Charterers' request shall be compensated by the Charterers to the Owners at a rate equal to ___ % of the demurrage rate (if left blank then fifty per cent (50%) shall apply).

(d) The amount of extra time used shall be agreed by the parties, and compensation under Subclause (c) above shall be payable by the Charterers to the Owners, prior to completion of final discharge. Failing such agreement, the amount of extra time used shall be determined by ____________ ("the Expert"), who shall act as an expert and not as an arbitrator and whose decision shall be final and binding upon the parties. Such Expert shall reach a determination, using such data and evidence as deemed appropriate, and which the parties are required to provide, within 30 days of completion of discharge. Payment shall be made by the Charterers immediately on receipt of the Expert's determination. The costs of such Expert shall be shared equally by the parties.

(e) Where the Ship proceeds at a speed adjusted in accordance with Sub-clause (b), this shall constitute compliance with, and there shall be no breach of, any obligation as to despatch and shall not constitute a deviation.

(f) The Charterers shall ensure that the terms of the bills of lading, waybills or other documents evidencing contracts of carriage issued by or on behalf of the Owners provide that compliance by Owners with this Clause does not constitute a breach of the contract of carriage. The Charterers shall indemnify the Owners against all consequences and liabilities that may arise from bills of lading, waybills or other documents evidencing contracts of carriage being issued as presented to the extent that the terms of such bills of lading, waybills or other documents evidencing contracts of carriage impose or result in the imposition of more onerous liabilities upon the Owners than those assumed by the Owners under this Clause.

(g) The Owners and Charterers shall give due consideration to environmental factors, including emission reductions, when determining the reasonableness of any orders given under this Clause.

Purpose of the clause

The STM clause is distinct from, and does not supersede or replace, the BIMCO Virtual Arrival Clause. It has been developed with its own features to meet the needs of STM arrangements.

It sets out a self-standing regime for voyage optimization. The content is without prejudice to other provisions in the underlying charter party, which must be read in accordance with the contractual terms. In particular, the STM clause does not affect, or eliminate, the requirement for a notice of readiness to be tendered in accordance with laytime provisions applicable under the charter party.

Voyage optimization relies on the availability and sharing of information. This is central to the workability of the provision with parties required to use "best endeavours" to obtain and exchange information about a ship's arrival time. The clause is binding only between the contracting owners and charterers. However, the obligation means that information which either party may have under STM arrangements or other relevant facts that might impact on the ship's arrival should be exchanged. This might, for example, include owners' knowledge of weather conditions en route, pilotage delays or a tug strike and matters known to charterers including local cargo handling delays and labour shortages as well as matters beyond the port confines such as problems with road transport.

The clause addresses only issues of speed. Requests from charterers for re-routing or a change of port rotation must be dealt with under the appropriate provisions of the underlying charter party. In the absence of covering charter party provisions, requests should be dealt with on a case-by-case basis taking P&I Club or other legal advice as necessary.

6.12 Impact Evaluation on Competence and Training

In the digital era, the human element plays the most important role as never before. Digitization of international trade and transport requires a new generation of staff and the updating of the former generation of currently active professionals, covering different job positions where decision-making processes and the management of large amounts of information are key tools for optimizing procedures, reducing time and costs, and guaranteeing standards of quality, safety and security.

Within the STM Validation project, some interesting and valuable results have been gathered by using a survey methodology concerning the existing international education and training rules provided by IMO, ILO, IHO and IALA. A multidisciplinary team, covering all of the aspects of the STM project has provided a wide spectrum of opinions and recommendations to meet the competences and training that maritime transport will require in the mid and long terms based on the next generation of navigation and port strategies, where STM-demonstrated services are crucial. The stakeholders, the clusters and the international forums have also been consulted in order to provide suitable solutions that promote the recruitment of qualified professionals and staff to the maritime and port industries in the coming years.

The survey employed was divided into five thematic blocks covering the main pillars of the STM Validation project:

- New technologies and connectivity.
- Ship navigation.
- Communications.
- European Maritime Simulator Network.
- PortCDM.

STM has investigated the industry's training needs for navigating and non-navigating staff for the future implementation and deployment of the concepts contained in the STM Validation project. A summary of the most relevant study results are listed below:

New technologies and connectivity: One of the most intricate debates when analysing the behaviour of bridge officers in collision avoidance is VHF communications. In this respect, the research identified two standpoints after analysing the results:

- Those who consider that the ships must govern according to COLREGs and not to the VHF, in the sense that they understand that the rules are precise and therefore any radio-communication between people of different cultures and languages can be ambiguous.

- Those who consider that knowing the intentions of the other ship in advance is very positive in collision avoidance.

While it is true that on many occasions the courts have criticized the excessive time that bridge officers lose contacting the other ship instead of taking effective measures, there is a general perception supporting the opinion that if radio communication is made in due time, it can be considered a good practice. It is worth mentioning that COLREGs, in its Rule 7, obliges the officer on duty to use all available means on the navigating bridge to assess the risk of collision.

Ship navigation: new integrated information systems (ECDIS/AIS/RADAR) should always be understood as “Aids to Navigation” and/or “extra - information provided by technologies in the decision-making at risk situations” by the Duty Officer, along with his/her knowledge of traditional navigation skills. If not, new techs can be an additional stress factor. All navigational aids are good, but the new generation of mariners should complement their safety skills with common sense and not just base them on new systems.

The use of AIS, VHF and other aids to navigation are increasing by poorly trained ‘white paper’ officers who should not have a white paper certificate.

Communications: small craft can carry a VHF (walkie-talkie or radio system installed) on board and when DSC fails in larger ships it’s good to know that somebody is watching in VHF Ch.16. AIS signals displayed on screens are not very reliable in terms of the real situation, especially in congested areas. They provide more info to OOWs and give them a decision-making advantage, but could prove a bit confusing if they are regarded as the real situation instead of being a mere aid to navigation. On the other hand, satellite communications are useful on the open sea where VHF is out of range. Internet access must be cheaper in order to maintain good communication service throughout the entire voyage or route.

European Maritime Simulator Network: Around 40% of respondents gave a high score, expressing a high acceptance rate for the professionals from the different simulator centres who are highly qualified and experienced. After participation on some EMSN simulation sessions, it can be concluded that this is one of the main successful tools of the STM project.

PortCDM: A concurrent situational awareness and the means of getting information from all stakeholders in a port-call heighten the possibility of attaining Just-in-Time operations. In order to be a professional actor, port stakeholders need to know the “window of opportunity” from the ship {The “latest possible time” and the physical “earliest time” (of ETA and ETD) that the ship can accept from the port and its service providers/actors}.

The analysis performed within the framework of the STM Validation project was based on the assumption that proposed solutions and services will be technically integrated into existing systems. Operational integration will take place in a way that the existing services provided today like Information Services (INS), Navigation Assistance Services (NAS) or Traffic Organization Services (TOS) will continue to exist but extended in their specific content.

In the present state of technological development and operational validation of the suggested STM Validation Project and PortCDM Services, the study concludes that no additional training in terms of independent separate courses is needed.

The ambitions and aims of the development of the proposed services include easy and simple handling and integration of new or advanced functions/services under new applications development to build human-to-machine interfaces user friendly and adapted to the next generation usability requirements.

Training and integration of STM functionalities and STM services requires training of personnel onboard and operators in ports, shore centres and at service providers.

The analysis within the STM Validation Project concludes that training should provide a good understanding of the concept and – in line with the development of the STM Validation Project’s proposed solutions, functionalities and enhancements – training should be designed to include a variety of these new developments once they have been completed and demonstrated.

For further information, see the report: STMVal_D5.26 - Catalogue of New Competences related to the Stakeholders involved in STM in Shore, on board and for Operational Safety

7. Conclusions

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Over the past decade, total losses in shipping have declined by more than a third (38%), according to the Allianz 2018 Safety & Shipping Review (AGCS), driven by improved ship design, technology and advances in risk management and safety. However, the review points out that despite huge improvements in maritime safety, fatal accidents at sea persist. Human error continues to be a major driver of incidents and captains and crews are under increasing commercial pressure as supply chains are streamlined.

Moreover, the AGCS analysis shows bad weather directly contributed to at least 21 total losses in 2017, a figure that could further increase. Fuel markets, cargo, cruise ship and port operations were also disrupted, leading to natural catastrophes being ranked the primary risk by shipping experts in the Allianz Risk Barometer 2018. Again, the real-time information provided by the STM tools could help cut these kinds of risks.

What's more, the new "Paris Agreement for the Shipping Industry", and the IMO regulation for the reduction in sulphur emissions by 2020 engages a call to action in terms of environmental sustainability to the extent that the shipping industry has an impact on climate change, both from the sea side and port side.

As regards port side outcomes, an in-depth analysis of shipping movements in nine European ports noted that cargo ships of various types spent only 60% to 70% of their port time at berth. Only 40% to 65% of time at berth was used for operations. Obtaining a much higher degree of predictability for arrivals, cargo operations and departures would enable higher fleet and capacity utilization, thus impacting on both sides.

Considering the number of regular port calls made by ships, one might expect every port call to be primarily repetitive and routine. It should be easy to forecast the different time and spatial dimensions associated with the events of the call. However, analysis of ship movement data shows that, irrespective of type of transport and type of port, the time spent in port is not similar and does not seem to follow any predictable pattern.

Unreliable forecasting of ship departure times and when other ships can enter a port, find a vacant berth and start cargo operation is a further consequence of these poor levels of predictability and has an impact on GHG emissions, as confirmed in this report.

To overcome this, actors in shipping need to collaborate and share data about plans and progress, enabling each port call to be managed and coordinated to minimize delays or conflicts for resources, as is currently the case.

These challenges drove the need to define and validate the STM concept.

Enabling Data-sharing Improves Operations

Instant exchange of information between actors involved in the port call process is an important mean to address the climate and environmental challenge of maritime transport, as well as it contributes to increased maritime safety and to integrate maritime transport in the overall logistic chain.

The results of the STM Validation Project shows that Sea Traffic Management can save up to 20% of CO_2 and air pollution from shipping, improve the quality of port calls, contribute to the integration of maritime transport into the intermodal logistic chain as well as it contributes to improved safety by improving the situational awareness in VTS centres and onboard ships.

By providing ships with the ability to see each other's planned routes, navigators get a more complete picture of how ships in the vicinity will influence their onward voyage. The same functionality also provides opportunities for shore-based actors to enhance planning capabilities. Using this data, other services are able to produce information and offer advice to ships on their routes, such as recommendations to avoid congestion in areas with high traffic density, avoidance of Particularly Sensitive Sea Areas (PSSAs), and Maritime Safety Information (MSI). The information exchange between ships and port actors is anticipated to improve planning and performance for arrivals, departures and turnaround times for ships. By exchange of this kind of information, the hinterland transports to and from ports can also be optimised.

Findings from the navigational part of the STM Validation Project end-user feedback, indicate that digital information sharing between shore-ship, ship-shore and ship-ship can improve situational awareness and improve operations on board, in shore centres, maritime rescue and coordination centres, and VTS centres. According to the findings at the simulators, the utilized services have the potential to improve communication, decrease bridge crew workload, while perhaps simultaneously increasing the time to respond, plan and act accordingly in challenging navigational and traffic conditions.

The findings as to whether STM has reduced workload vary. Some services are considered to reduce workload while others are not, since not all services aim to reduce workload but, instead, the benefits of these services are related to, for example, safety aspects or enhanced operations on shore-side.

Numerical analyses indicate that the STM services are valuable in areas where strategic navigation is applicable, i.e. where there are fewer temporal and spatial constraints. In areas with dense and regulated traffic (for example traffic separation schemes) and less room for strategic navigation, the value of the available STM services inproving traffic safety on a global scale at this moment could not, however, be directly demonstrated.

From the VTS Operator perspective, although the communication between ship and shore will increase, the STM Services will promote navigational safety and efficiency through the availability of additional navigational information, monitoring services and communications. Although it is important to study further the communication patterns between ship and shore to understand how workload, training, and procedures in the VTS station will be affected by STM, the innovative possibility to review ships' intentions well in advance before entering the VTS surveillance area would allow the VTS to work more proactively than is currently the case.

Additional testing is also required to understand if there is a shift of workload to other aspects of the maritime decision chain and how these services may make it necessary to adapt the present regulatory, organizational and management structure to the shipping domain.

However, it can be assumed that better use of data will help to address some of the safety issues in shipping, while over-reliance on technology on board must be taken into account. As a result, continuous training is imperative to ensure the optimum balance between technology and human intervention.

Furthermore, STM in Ports/PortCDM, as a port-centric concept, enables all stakeholders in the port-call process to share data for significant events by the use of a common port-call message format (S-211). Actors obtain a common situational awareness for enhanced and synchronized planning. Actors are informed about upstream disruptions affecting their operations and inform those further downstream. Just-in-time arrivals, departures, and shorter turnaround times lead to more efficient use of assets and improved predictability of operating and delivery times. The productive time of operations can be increased through access to up-to-date status information leading to better-informed decision-making, thereby reducing unnecessary waiting times.

Cross-industry Collaboration is Key

One of the main successes of the STM Validation Project has been the cross-industry collaboration, as leading competitors among providers of ECIDS and VTS-systems have developed the services during the project and, as a result, are currently planning to establish an open non-profit consortium to operate and develop the maritime digital infrastructure established in the STM Validation project. The consortium includes project partners, associate partners, as well as other actors who see the potential of a common basis for delivering services and growing their software.

During the simulations, there were some negative comments about the usability difficulties of the ECDIS/STM client interface. This is to be expected because of the limitations in design specifications for these types of interfaces and could, in some circumstances, be due to a lack of familiarization with the experimental equipment. The introduction of new technologies to already complex systems such as ECDIS is one of the most challenging aspects in any work environment and needs to be supported by training and rigorous user-interface testing.

So far, the maritime digital service infrastructure provides standardized interfaces or reference services according to the SeaSWIM specification. However, standardization is a constantly ongoing and iterative process, where new input needs to be managed in a collaborative manner, gaining and re-gaining support from system suppliers and other stakeholders. Additionally, a continuous process of adapting, maintaining and further developing the principles and procedures of SeaSWIM in order to achieve a *common* digital maritime infrastructure is needed. Basically, the STM Validation Project laid the foundations for this, and needs to be further developed by joint efforts by interest groups and industry initiatives.

Indeed, the ongoing creation of an industry cluster has great potential to integrate the common maritime digital infrastructure in current operations. Already the obvious interest from such a broad industry group is a sign that SeaSWIM and the STM services have identified a significant need, although, it is important that the initiative is supported in parallel by new projects that continue the development of STM in innovative directions.

Considerable benefit is to be gained by moving towards a global implementation of STM in all ports, irrespective of any other coordinating mechanisms that may already be in place. There are clear advantages for all actors in the maritime transportation chain to embrace the concept.

STM in Ports engages all key actors in the port-call process. All need to have a common understanding of their role in the transportation chain and the impact that their activities may have on others in it. This helps to break down any initial reluctance to share planning data among competitors when they realize that the common benefits outweigh the possible individual gains of acting separately.

As one of the deliverables of the STM validation project, the International PortCDM Council (IPCDMC, www.ipcdmc.org) has been established to provide a sustainable international governance body for STM in Ports. IPCDMC is a major force in establishing S-211 as an international standard The governance body and the standard might pave the way for harmonized collaboration and data sharing of port-call operations for the maritime community on a global level by supporting regional and local implementations.

Improved Situational Awareness and Predictability means Substantial Savings

Some conclusions from practical end-to-end usage of the various test-bed services prove that certain services – such as the Nordic Pilot Route Service, the Baltic Navigational Warning Service and Enhanced Monitoring from shore centres – demonstrated improved situational awareness and operational safety. Specific tests for the Ship-to-Ship Route Exchange service may enhance the officer’s situational awareness and shows a tendency to improve navigational safety in traffic situations when used as a tool for supporting decision-making and situational awareness at a longer range, i.e. during strategic navigation.

However, there are several risks, notably over-reliance on or misinterpretation of the data and potential confusion/uncertainty when the “route” and “intention” are implicitly assumed to be same thing that could be involved when using the service.

The simulations highlighted the many benefits, challenges and risks associated with the implementation of the STM services from the point of view of experienced seafarers. These were generally eager and supportive of further development and implementation of STM services even in the earliest stages of development, provided that proper training was offered and that safety was prioritized ahead of costs in shipping.

The validation of STM in Ports identified considerable potential savings across various aspects of the transportation chain. Improved predictability of operations offers port and ship operators potential economic gains. The validation also showed that the optimization of assets and resources at the port level could be better achieved if port calls were managed in line with the principles underlying

STM in Ports. If all the actors involved inform each other at the earliest opportunity about their plans and similarly notify any subsequent disruptions, this would allow downstream port call actors to coordinate more effectively. Everyone would be kept informed in real-time or near real-time through a common, digital situational awareness picture prior to, during, and after a particular port call.

The enhanced situational awareness provided by data sharing is valuable and beneficial, providing positive effects for operations, including making better estimates for ETAs and ETDs, improving work procedures, reducing the time spent on information gathering, and a reduction in administrative workloads. Overall, these results would lead to the savings showed in the STM Validation Project.

8. Suggested Actions and Subsequent Steps

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Ongoing Initiatives

Four implementation projects have already commenced ahead of the completion of STM Validation:

- Real Time Ferries will use the on board knowledge of ferry delays to inform passengers, goods handlers and public transportation about the changes.
- EfficientFlow will implement STM in two ports and help ships plan encounters in narrow passages at an earlier stage to save fuel and increase safety.
- STM BALT SAFE will increase tanker safety in the Baltic Sea, taking into account the cross-traffic of ferries for the most part.
- STM in the Eastern Mediterranean, STEAM, will establish an STM shore centre in Cyprus and implement PortCDM in the Port of Limassol, exchanging information with ports in neighbouring countries.

Projects in the Adriatic Sea, addressing Sea Traffic Management, are in the planning phase.

Partners will continue collaboration with the SMART Navigation project in Korea and with SESAME Solution II in Singapore.

Recommendations for the Future

The overall project recommendation is that the concept and the infrastructure are ready for commercial implementation in the form of new and updated software, service and functions. However, continued support from public funding towards implementation would be advantageous in increasing the adoption rate. Some of the benefits for the entire industry and individual users will be larger as the number of ships using STM reaches a critical mass.

In the coming phases of STM, more and new kinds of operational services based on new message formats and information services/APIs are required. Further focus needs to be directed towards the refinement of operational services as well as components related to the architecture, such as information services and cyber security precautions and solutions. The ultimate goal is to get STM included in standard operation procedures and make it a natural part of everyday work.

The report also suggests continued work by project partners in international consortia and organizations, such as the International PortCDM Council, for the port side. For the infrastructure, there is the Maritime Connectivity Platform Consortium and the non-profit industry group for maritime digital infrastructure. A new organization has also been formed to develop and operate the European Maritime Simulator Network, for future research, training and testing of new services.

Sea Traffic Management is currently part of the MoS Detailed Implementation Plan under the third pillar – maritime safety, traffic management and human element.

Sea Traffic Management addresses all three pillars and is of special interest for pillar 1 - Environment, as it contributes with operational improvements that in short term can have a significant impact on emissions from shipping. Sea Traffic Management could therefore be reshaped into a horizontal framework, or programme, within the MoS, addressing all three MoS pillars.

Despite that some of the parts of STM are ready for deployment, there is a need for a large number of research and innovation projects that continue to develop, test, demonstrate and implement various parts of Sea Traffic Management. These different projects and initiatives for the continued phases of STM development need to be coordinated to continue to provide benefits within the framework of Motorways of the Sea.

Thus, there is an urgent need for a long-term program aimed at continued developing the Sea Traffic Management This work also includes continuing to promote the development of international standards and standardized interfaces with the goal of achieving interoperability.

The setup of this programme and its coordination mechanism could be inspired by SESAR (Air Traffic Management) and its Joint Undertaking. Alse the Shift2Rail programme could act as an inspiration to the European STM programme.

The establishment of an EU program for Sea Traffic Management and a coordination mechanism to support it would contribute to:

Process oriented benefits:

- Long-term planning horizon for public sector, the stakeholders and the industry.
- Faster return of investments for public and private sector.
- Efficient coordination and communication of Sea Traffic Management initiatives and projects, within EU and with other parts of the world.
- A governance structure that would gather industry, maritime stakeholders and governments around the same table and to agree on the challenges and the way forward.

Policy-oriented benefits:

- Improved environmental footprint for shipping.
- Improved safety of navigation.
- Improved efficiency of port call management and
- A coordinated approach when it comes to integration of maritime transport in the intermodal logistic chain.

The work on standards and on regulation must continue and intensify in IEC, IALA and IMO. Some examples are:

- IEC has approved the proposal for a work item turning the STM Voyage Information Service (VIS) into a standardized interface for transfer of S-100 products. The work commenced on May 22-23 2019 with a meeting in Stockholm. The working title for the VIS-inspired interface is SECOM – Secure Exchange and Communication. As mentioned earlier in this report, VIS is the key to interoperability for services referring to the route exchange standard. SECOM will bring this interoperability to all S-100 data formats.
- The IMO has asked the project to provide input papers for their MSC committee. The Secretary General Kitack Lim has said: “Let the IMO consider the global implementation of STM”.
- Ongoing work to transform the data formats used by the project into S-100 formats, the route format RTZ to S-421 and the port call message format PCMF to S-211.
- Promote exchange of routes and voyage plans by ships to facilitate STM services.

It is important to get many of the project partner countries to cooperate in various actions to speed up the development.

One possible way forward is a mandated capability of sharing voyage plans, according to defined standards. This would be a means of speeding up adoption on board ships and ensure long-term, sustainable usage. This would require regulatory changes. Examples of relevant resolutions and regulations for a mandated capability of sharing voyage plans include but are not limited to:

- IMO Assembly Resolution A.893 (21) on Guidelines for voyage planning.
- Revised Performance Standards for Electronic Chart Display and Information Systems (ECDIS) – Resolution MSC.232 (82).
- SOLAS regulation V/34.

This would require a careful review and further investigation.

The full benefits of STM in ports will be realized when all parts of the maritime transport chain become interconnected and collaborate in the four collaboration arenas – intra-port, port-to-port, ship-to-port, and port-to-hinterland. The last of these four – port-to-hinterland – is the aspect least validated in the project, and future projects investigating this potential are most welcome. This is where the true intermodal benefits come to life. The most important step for a port looking to implement Port Collaborative Decision Making, PortCDM, is to create a local community to bring all interested actors together and find a common way forward based on the STM Validation project findings.

The project has several recommendations to further enhance the maritime digital infrastructure established by the project:

Establishment of a governance structure for future development and business

- A long term public-private programme for STM should be established by EU to facilitate further policy development, develop financing mechanisms research and development, innovation and demonstration as well as deployment of systems and services
- This is well under way with the Maritime Connectivity Platform Consortium and the newly launched industrial consortium for operations and development.

Transform SeaSWIM to a business ecosystem

- This is of interest to the non-profit industrial consortium.

Focus on vulnerabilities and security-related issues

Defining of SLA for monitoring, reporting and performance optimization

- The consortia and their customers will help refine this.

Iterative refinement of reference service requirements

Refinement of STM identifiers after validation in test-beds

- Rules and relations of identifiers for voyages and port calls.

Collaboration between EU partners and third party countries

- Safeguard world-wide compliance.
- Promote EU business.
- Facilitate international policy-making within IMO, IHO and IALA.

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